

The RADIO AMATEUR'S HANDBOOK

A MANUAL OF AMATEUR
HIGH-FREQUENCY RADIO COMMUNICATION



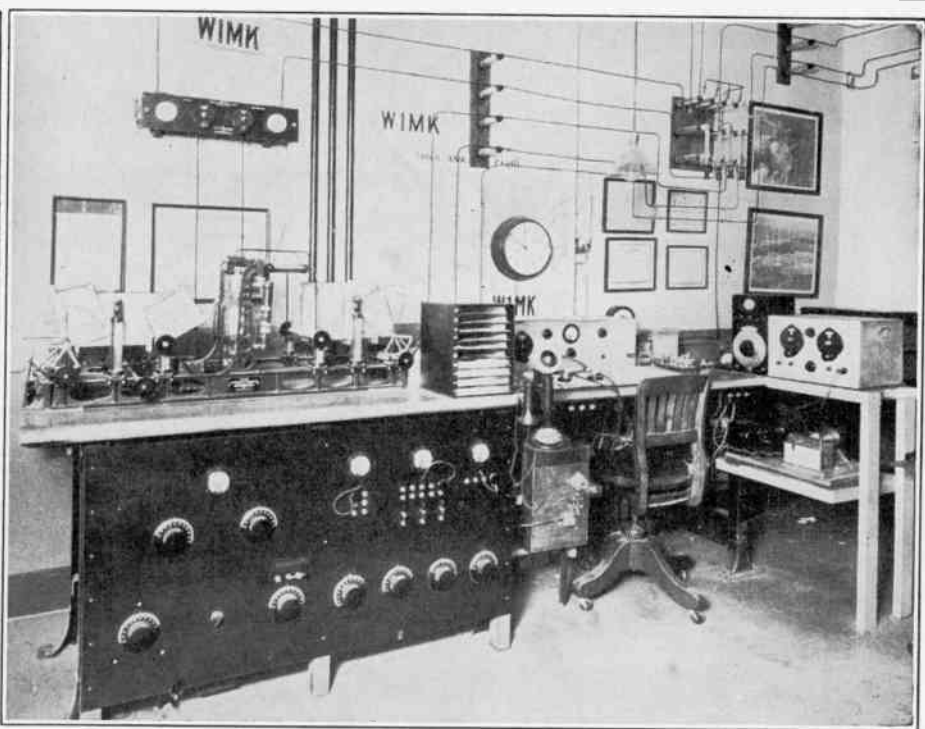
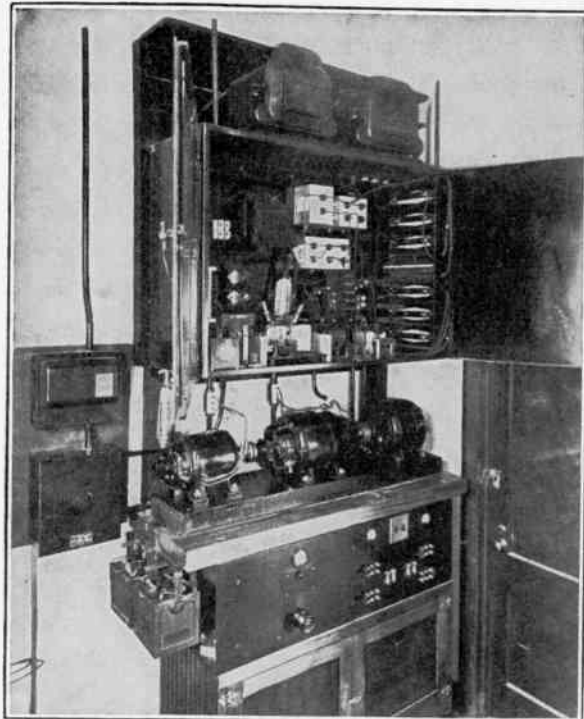
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AMERICAN RADIO
RELAY LEAGUE

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THE
RADIO AMATEUR'S
H A N D B O O K



WIMK, THE HEADQUARTERS STATION OF THE A.R.R.L. AT HARTFORD, CONN.

These views of power supplies and operating position show good station arrangement. Note the neatness and accessibility of every piece of apparatus. High voltage d.c. is obtained from a motor-generator and a mercury-arc rectifier and filter, with facilities also available for using mercury-vapor rectifiers. Fuses, relays, batteries, and charging equipment are all in the power-supply room. The single-signal receiver is in front of the operator, key and controls at his right hand, message file box and telephone at his left. At his right side are monitor, electron-coupled frequency meter, and an automatic tape transmitter for sending Official Broadcasts to A.R.R.L.

members. On the table is the 3500-4000-kc. band transmitter using two Type 04-A tubes in a self-excited T.P.T.G. circuit. The panel transmitter below works on the 7-mc. and 14-mc. bands. This is a controlled-temperature crystal-excited set terminating in a Type 61 tube. Two-wire voltage (Zeppelin) feed is used to separate antennas for the two transmitters, and a separate receiving antenna facilitates "break-in" work. WIMK is a very busy station but is always ready for a call from any "ham." See page twelve for the schedule of regular transmissions of addressed information to A.R.R.L. members

THE
RADIO AMATEUR'S
H A N D B O O K

*A Manual of Amateur High-Frequency
Radio Communication*

BY
THE HEADQUARTERS STAFF OF THE
AMERICAN RADIO RELAY LEAGUE

Twelfth Edition



THE AMERICAN RADIO RELAY LEAGUE, INC.
WEST HARTFORD, CONNECTICUT
1935

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FOREWORD

IN PRESENTING a twelfth edition of *The Radio Amateur's Handbook* the publishers again express the hope that it will be found as helpful as the previous editions and enjoy as whole-hearted a reception at the hands of the amateur fraternity.

The *Handbook* is intended both as a reference work for member-operators of the American Radio Relay League and other skilled amateurs and as a source of information to those wishing to participate in amateur radio activities but having little or no idea how to get started. The choice and sequence of material have been planned with particular thought to the needs of the beginning amateur but each subject has been developed to embrace the most modern amateur practice in that particular department of activity. Designed to be a practical rather than a theoretical work, theoretical discussions have been made as simple and fundamental as possible and the chief effort directed at practical means for securing results — which, after all, is the principal aim of the amateur in radio.

In 1925 Mr. Francis Edward Handy, for many years the League's communications manager, commenced work on a small manual of amateur operating procedure, at the direction of the A.R.R.L. Executive Committee. It was deemed desirable to include a certain amount of "technical" information, since an amateur's results are so greatly influenced by the disposition and adjustment of his apparatus. When Mr. Handy completed his manuscript he had written a considerable-sized book of great value. It was published in 1926 and enjoyed an instant success. Three successive editions were revised by Mr. Handy as reprinting became necessary.

Throughout the year 1928 the League conducted a technical development program at its headquarters laboratory for the purpose of developing new apparatus and methods which would overcome the handicaps of reduced space in the radio spectrum which were to become effective upon the radio amateur at the beginning of 1929, by virtue of the then newly-signed international radio treaty. The modified technique and equipment which resulted from this technical development program naturally called for a complete revision of the technical chapters of the *Handbook*. Indeed, the rapid technical progress during that and the succeeding years has demanded constant and comprehensive re-writing and revision of the technical material.

In the headquarters establishment of the League at West Hartford there are many tech-

nically skilled amateurs, each a specialist in his own field. It is only natural that the preparation of the technical chapters of the *Handbook* should have fallen into their hands and that the publication should have become the family affair which it now is.

To a total of sixteen printings the fame of the *Handbook* has echoed around the world. More than a quarter of a million copies have been distributed at this writing. Its success has been really inspiring. Quantity orders have come from many a foreign land; schools and technical classes have adopted it as a text; but most important of all, it has become the right-hand guide of practical amateurs in every country on the globe. But amateur radio moves with amazing rapidity and the best practices of yesterday are quickly superseded by the developments of to-day. The very success of the book as a publication brings a new responsibility to us, the publishers — the *Handbook* must be kept up to date.

Because the year 1934 has again seen further revolutionary changes in transmitting and receiving equipment and many revisions in licensing procedure it has been necessary again to undertake a comprehensive revision for this edition. Many of the chapters have been entirely re-written. All of them have been thoroughly modernized in the light of current amateur practice. The edition represents the collaboration of many members of the A.R.R.L. staff. The opening chapter is from the pen of Mr. A. L. Bullong, the assistant secretary of the League. Mr. Handy, our communications manager, has prepared the chapters on the A.R.R.L. Communications Department, on operating a station and on message handling. Mr. James J. Lamb, the technical editor of *QST* and Mr. George Grammer, the assistant technical editor, have collaborated in the preparation of the chapters on receivers and radiotelephony. Mr. Grammer has produced the re-written chapter on transmitters and the revised chapters on power supply, keying and frequency measurement. In the re-writing and revising of the remaining chapters, almost all members of the League's staff have had some hand.

We shall all feel happy if the present edition brings as much assistance and inspiration to amateurs and would-be amateurs as have its predecessors.

ROSS A. HULL

EDITOR

WEST HARTFORD, November, 1934

THE
RADIO AMATEUR'S
H A N D B O O K

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THE AMATEUR'S CODE

- I *The Amateur is Gentlemanly.* He never knowingly uses the air for his own amusement in such a way as to lessen the pleasure of others. He abides by the pledges given by the A.R.R.L. in his behalf to the public and the Government.
- II *The Amateur is Loyal.* He owes his amateur radio to the American Radio Relay League, and he offers it his unswerving loyalty.
- III *The Amateur is Progressive.* He keeps his station abreast of science. It is built well and efficiently. His operating practice is clean and regular.
- IV *The Amateur is Friendly.* Slow and patient sending when requested, friendly advice and counsel to the beginner, kindly assistance and coöperation for the broadcast listener; these are marks of the amateur spirit.
- V *The Amateur is Balanced.* Radio is his hobby. He never allows it to interfere with any of the duties he owes to his home, his job, his school, or his community.
- VI *The Amateur is Patriotic.* His knowledge and his station are always ready for the service of his country and his community.

The RADIO AMATEUR'S HANDBOOK

CHAPTER ONE

THE STORY OF AMATEUR RADIO

AMATEUR radio represents, to upwards of fifty thousand people, the most satisfying, most exciting of all hobbies. Forty thousand of these enthusiasts are located in the United States, for it is this country which gave birth to the movement and which, since the beginning, has represented its stronghold.

When radio broadcasting was first introduced to the public a few years ago it instantly caught the fancy of millions of people all over the world. Why? Because it fired their imagination — because it thrilled them to tune in on a program direct from some distant point, to hear speech and music that was at that moment being transmitted from a city hundreds and even thousands of miles away. To be sure there was also a certain amount of entertainment value, and it is true that as the years have passed this phase has become uppermost in the minds of many listeners; yet the thrill of “dx” is still a major factor in the minds of hundreds of thousands of people, as witness the present growing popularity of international short-wave reception of foreign programs.

That keen satisfaction of hearing a distant station is basic with the radio amateur but it has long since been superseded by an even greater lure, and that is the thrill of *talking* with these distant points! On one side of your radio amateur's table is his short-wave receiver; on the other side is his private (and usually home-made) short-wave transmitter, ready at the throw of a switch to be used in calling and “working” other amateurs in the United States, in Canada, Europe, Australia, every corner of the globe! Even a low-power transmitter using nothing more ambitious than one or two receiving-type tubes makes it possible to develop friendships in every State in the Union, in dozens of countries abroad. Of course, it is not to be expected that the first contacts will necessarily be with foreign amateurs. Experience in adjusting the simple transmitter, in using the right frequency band at the right time of day when foreign stations are on the air, and practice in operating are necessary before communication will be enjoyed with amateurs of other nationalities. But patience and experience are the sole prerequisites to foreign contacts; neither high power nor expensive equipment is required.

Nor does the personal enjoyment that comes from amateur radio constitute its only benefit. There is the enduring satisfaction that comes from doing things with the apparatus put together by our own skill. The process of designing and constructing radio equipment develops real engineering ability. Operating an amateur station with even the simplest equipment likewise develops operating proficiency and skill. Many an engineer, operator or executive in the commercial radio field got his practical background and much of his training from his amateur work. So, in addition to the advantages of amateur radio as a hobby, the value of systematic amateur work to a student of almost every branch of radio cannot well be overlooked. An increasing number of radio services, each expanding in itself, require additional personnel, technicians, operators, inspectors, engineers and executives and in every field a background of amateur experience is regarded as valuable.

▲ How did amateur radio start? What developments have brought it to its present status of a highly-organized and widespread movement?

It started shortly after Marconi had astounded the world with his first experiments proving that telegraph messages actually could be sent between distant points without wires. Marconi was probably the first amateur — indeed, the distinguished inventor so likes to style himself even today. But amateur radio as we think of it was born when the first private citizen saw in the new marvel a means for personal communication with others and set about learning enough of the new art to build a home-made station, hoping that at least one of his friends would do the same so he could have someone to talk to. Object: the fun and enjoyment of “wireless” communication with a few friends. Urge: the thrill of DX (one to five miles — maybe!). That was thirty-odd years ago.

Amateur radio's subsequent development may be divided into two periods, the first before and the second after the World War.

Pre-war amateur radio bore little resemblance to the art as we know it today, except in principle. The equipment, both transmitting and receiving, was of a type now long obsolete. The range of

even the highest-powered transmitters, under the most favorable conditions, would be scoffed at by the rankest beginner today. No United States amateur had ever heard the signals of a foreign amateur, nor had any foreigner ever reported hearing an American. The oceans were a wall of silence, impenetrable, isolating us from every signal abroad. Even trans-continental DX had to be accomplished in relays. "Short waves" meant 200 meters; the entire wavelength spectrum below 200 meters was a vast silence — no signal ever disturbed it. Years were to pass before its phenomenal possibilities were to be suspected.

Yet the period was notable for a number of accomplishments. It saw the number of amateurs in the United States increase to approximately 4,000 by 1917. It witnessed the first appearance of radio laws, licensing, wavelength specifications for the various services. ("Amateurs? — oh yes — well, stick 'em on 200 meters; it's no good for anything; they'll never get out of their own back yards with it.") It saw an increase in the range of amateur stations to such unheard-of distances as 500 and, in some cases, even 1,000 miles, with U. S. amateurs beginning to wonder, just before the war, if there were amateurs in other countries across the seas and if — daring thought! — it might some day be possible to span the Atlantic with 200-meter equipment. Because all long-distance messages had to be relayed, it saw relaying developed to a fine art — and what a priceless accomplishment that ability turned out to be later when our government suddenly needed dozens and hundreds of skilled operators for war service! Most important of all, the pre-war period witnessed the birth of the American Radio Relay League, the amateur organization whose fame was to travel to all parts of the world and whose name was to be virtually synonymous with subsequent amateur progress and short-wave development. Conceived and formed by the famous inventor and amateur, Hiram Percy Maxim, it was formally launched in early 1914 and was just beginning to exert its full force in amateur activities when this country declared war on Germany and by that act sounded the knell for amateur radio for the next two and one-half years. By presidential direction every amateur station was dismantled. Within a few months three-fourths of the amateurs of the country were serving with the armed forces of the United States as operators and instructors.

▲ Few amateurs today realize that the war not only marked the close of the first phase of amateur development but came very near marking its end for all time. The fate of amateur radio was in the balance in the days immediately following declaration of the Armistice, in 1918. The government, having had a taste of supreme authority over all communications in wartime, was more than half inclined to keep it; indeed, the war had

not been ended a month before Congress was considering legislation that would have made it impossible for the amateur radio of old ever to be resumed. President Maxim rushed to Washington, pleaded, argued; the bill was defeated. But there was still no amateur radio; the war ban continued in effect. Repeated representations to Washington met only with silence; it was to be nearly a year before licenses were again to be issued.

In the meantime, however, there was much to be done. Three-fourths of the former amateurs had gone to France; many of them would never come back. What of those who had returned? Would they be interested, now, in such things as amateur radio; could they be brought back to help rebuild the League? Mr. Maxim determined to find out and called a meeting of such members of the old Board of Directors as he could locate. Eleven men, several still in uniform, met in New York and took stock of the situation. It wasn't very encouraging: amateur radio still banned by law, former members of the League scattered no one knew where, no League, no membership, no funds. But those eleven men financed the publication of a notice to all the former amateurs that could be located, hired Kenneth B. Warner as the League's first paid secretary, floated a bond issue among old League members to obtain money for immediate running expenses, bought the magazine *QST* to be the League's official organ and dunned officialdom until the wartime ban was lifted and amateur radio resumed again. Even before the ban was lifted in October, 1919, old-timers all over the country were flocking back to the League, renewing friendships, planning for the future. When licensing was resumed there was a head-long rush to get back on the air. No doubt about it now — interest in amateur radio was as great as ever!

From the start, however, it took on new aspects. The pressure of war had stimulated technical development in radio; there were new types of equipment, principally the vacuum tube, which was being used for both receivers and transmitters. Amateurs immediately adapted the new apparatus to 200-meter work. Ranges promptly increased; soon it was possible to bridge the continent with but one intermediate relay. Shortly thereafter stations on one coast were hearing those on the other direct!

These developments had an inevitable result. Watching DX come to represent 1,000 miles, then 1,500 and then 2,000, amateurs wondered about that ole debbil ocean. Could we get across? We knew now that there were amateurs abroad. We knew, too, that their listening for our signals was still fruitless, but there was a justifiable suspicion that their unfamiliarity with 200-meter equipment had something to do with it. So in December, 1921, the A.R.R.L. sent abroad one of our most prominent amateurs, Paul Godley, with the

best amateur receiving equipment available. Tests were run, and thirty American amateur stations were heard in Europe! The news electrified the amateur world. In 1922 another trans-Atlantic test was carried out; this time 315 American calls were logged by European amateurs and, what was more, one French and two British stations were heard on this side.

Everything now was centered on one objective: two-way communication across the Atlantic by amateur radio! It *must* be possible — but somehow we couldn't quite make it. Further increases in power were out of the question; many amateurs already were using the legal maximum of one kilowatt. Better receivers? We already had the superheterodyne; it didn't seem possible to make any very great advance in that direction.

Well, how about trying another wavelength, then? We couldn't go up, but we could go down. What about those wavelengths below 200 meters? The engineering world said they were worthless — but then, they'd said that about 200 meters, too. There have been many wrong guesses in history. So in 1922 the technical editor of *QST* carried on some tests between Hartford and Boston on 130 meters. The results were encouraging. Early in 1923 the A.R.R.L. sponsored a series of organized tests on wavelengths down to 90 meters and it was noted that as the wavelength dropped the reported results were better. A growing excitement began to filter into the amateur ranks. It began to look as though we'd stumbled on something!

And indeed we had. For in November, 1923, after some months of careful preparation, two-way amateur communication across the Atlantic finally became an actuality when Schnell, 1MO, and Reinartz, 1XAM, worked for several hours with 8AB, Deloy, in France, all three stations using a wavelength of about 110 meters!

There was the possibility, of course, that it was a "freak" performance, but any suspicions in that direction were quickly dispelled when additional stations dropped down to 100 meters and found that they, too, could easily work two-way across the Atlantic. The exodus from the 200-meter region started.

By 1924 the entire radio world was agog and dozens of commercial companies were rushing stations into the 100-meter region. Chaos threatened until the first of a series of radio conferences partitioned off various bands of frequencies for all the different services clamoring for assignments. Although thought was still centered on 100 meters, League officials at the first of these conferences, in 1924, came to the conclusion that the surface had probably only been scratched, and wisely obtained amateur bands not only at 80 meters, but at 40 and 20 and 10 and even 5 meters.

Many amateurs promptly jumped down to the 40-meter band. A pretty low wavelength, to be

sure, but you never could tell about these short waves. What had worked once might work again. Forty was given a whirl and responded by enabling two-way communication with Australia, New Zealand and South Africa.

How about 20? It was given a try-out and immediately showed entirely unexpected possibilities in enabling an east-coast amateur to communicate with another on the west coast, direct, at high noon. The dream of amateur radio — daylight DX!

▲ From that time to the present represents a period of unparalleled accomplishment. The short waves proved a veritable gold mine. Country after country came on the air, until the confusion became so great that it was necessary to devise a system of international intermediates in order to distinguish the nationality of calls. The League began issuing what are known as WAC certificates to those stations proving that they had worked all the continents. More than a thousand such certificates have been issued. Representatives of the A.R.R.L. went to Paris several years ago and deliberated with the amateur representatives of twenty-two other nations. On April 17, 1925, this conference formed the International Amateur Radio Union — a union of national amateur societies. We have discovered that the amateur as a type is the same the world over.

Nor has experimental development been lost sight of in the enthusiasm incident to international amateur communication. The experimentally-minded amateur is constantly at work conducting tests in new frequency bands, devising improved apparatus for amateur receiving and transmitting, learning how to operate two and three and even four stations where previously there was room enough for only one.

As investigation of the short-wave territory proceeded, commercial engineers finally came to the conclusion that the lowest wavelength that could be used particularly effectively for long-distance communication was in the neighborhood of 13 meters. Yet in November, 1928, an amateur station on Cape Cod was pouring steady and strong signals into New Zealand day after day — on ten meters! Sponsored by the A.R.R.L., these experimental directive transmissions were also reported in England, Canada, and many parts of the United States.

In 1924 first amateur experiments on five meters showed that band to be practically worthless for distance transmission; signals at such wavelengths could be heard only to "horizon range." But the amateur turns even these apparent disadvantages to use. If not suitable for long-distance work, at least it was ideal for "short-haul" communication. Beginning in 1931, then, we have witnessed tremendous activity in five-meter work by thousands of amateurs all over the country, and a complete new line of transmitters

and receivers has been developed to meet the special conditions incident to communicating at these ultra-high frequencies. The pioneer work of the amateur in this band is showing the way for police, airplane and other special types of service whose requirements make the territory around five meters ideal.

Most of the technical developments in amateur radio have come from the amateur ranks. Many of these developments represent valuable contributions to the art. At a time when only a few broadcast engineers in the country knew what was meant by "100% modulation" the technical staff of the A.R.R.L. was publishing articles in *QST* urging amateur 'phones to embrace it and showing them how to do it. It is interesting to know that these articles were read as widely in professional circles as by amateurs with the result that dozens of broadcast stations besieged the League for information on how this method of modulation could be adapted to their own installations. When interest quickened in five-meter work, and experiments showed that the ordinary regenerative receiver was practically worthless for such wavelengths, it was the A.R.R.L. that developed practical super-regenerative receivers as the solution to the receiver problem. From the League's laboratory, too, came in 1932, the single-signal superheterodyne — the world's most advanced high-frequency radiotelegraph receiver. And in 1933 came another great contribution to transmitter practice in the form of the tri-tet crystal oscillator, simplifying the high-frequency crystal controlled transmitter by reducing the number of stages necessary and improving transmitter reliability, stability and efficiency.

▲ Amateur radio is one of the finest of hobbies, but this fact alone would hardly merit such whole-hearted support as was given it by the United States government at recent international conferences. There must be other reasons to justify such backing. There are. One of them is a thorough appreciation by the Army and Navy of the value of the amateur as a source of skilled radio personnel in time of war. The other is best described by the words "public service."

We have already seen 3,500 amateurs contributing their skill and ability to the American cause in the Great War. After the war it was only natural that cordial relations should prevail between the Army and Navy and the amateur. Several things occurred in the next few years to strengthen these relations. In 1924, when the U. S. dirigible *Shenandoah* made a tour of the country, amateurs provided continuous contact between the big ship and the ground. In 1925 when the United States battle fleet made a cruise to Australia and the Navy wished to test out short-wave apparatus for future communication purposes, it was the League's Traffic Manager

who was in complete charge of an experimental high-frequency set on the U.S.S. *Seattle*.

Definite friendly relations between the amateur and the armed forces of the Government were cemented in 1925. In this year both the Army and the Navy came to the League with proposals for amateur cooperation. The radio Naval Reserve and the Army-Amateur Net are the outgrowth of these proposals.

The public service record of the amateur is a brilliant one. These services can be roughly divided into two classes: emergencies and expeditions. It is regrettable that space limitations preclude detailed mention of amateur work in both these classes, for the stories constitute some of the high-lights of amateur accomplishment. As it is, only a general outline can be given.

Since 1913, amateur radio has been the principal, and in many cases the only, means of outside communication in nearly one hundred storm and flood emergencies in this country. The most noteworthy were the Florida Hurricane of 1926, the Mississippi and New England floods of 1927, and the California dam break and second Florida hurricane in 1928. During 1931 there were the New Zealand and Nicaraguan earthquakes, and in 1932 the floods at Caliente, California and in the upper Guadalupe valley of Texas. Outstanding in 1933 was the southern California earthquake. In all of these amateur radio played a major rôle in the rescue work, and amateurs earned world-wide commendation for their resourcefulness in effecting communication where all other means failed.

It is interesting to note that one of the principal functions of the Army-Amateur network is to furnish organized and coordinated amateur assistance in the event of storm and other emergencies in this country. In addition, Red Cross centers in various parts of the United States are now furnished with lists of amateur stations in the vicinity as a regular part of their emergency measures program.

Amateur cooperation with expeditions started in 1923, when a League member, Don Mix, of Bristol, Conn., accompanied MacMillan to the Arctic on the schooner *Bowdoin* in charge of an amateur set. Amateurs in Canada and the United States provided the home contact. The success of this venture was such that MacMillan has never since made a trip without carrying short-wave equipment and an amateur to operate it.

Other explorers noted this success and made inquiries to the League regarding similar arrangements for their journeys. In 1924 another expedition secured amateur cooperation; in 1925 three benefited by amateur assistance, and by 1928 the figure had risen to nine for that year alone. Each year since then has seen League headquarters in receipt of more and more requests for such service, until now a total of more than a hundred voyages and expeditions have been assisted. To-day practically no exploring trip starts from

this country to remote parts of the world without making arrangements to keep in contact through the medium of amateur radio.

Emergency relief, expeditionary contact, and countless instances of other forms of public service, rendered as they always have been and always will be, without hope or expectation of material reward, have made amateur radio one of the integral parts of our complex national life.

The American Radio Relay League

The American Radio Relay League is to-day not only the spokesman for amateur radio in this country but is the largest amateur organization in the world. It is strictly of, by and for amateurs, is non-commercial and has no stockholders. The members of the League are the owners of the A.R.R.L. and *QST*.

The League is organized to represent the amateur in legislative matters. It is pledged to promote interest in two-way amateur communication and experimentation. It is interested in the relaying of messages by amateur radio. It is concerned with the advancement of the radio art. It stands for the maintenance of fraternalism and a high standard of conduct. One of its principal purposes is to keep amateur activities so well conducted that the amateur will continue to justify his existence. As an example of this might be cited the action of the League in sponsoring the establishment of a number of Standard Frequency Stations throughout the United States; installations equipped with the most modern available type of precision measuring equipment, and transmitting "marker" signals on year-round schedules to enable amateurs everywhere to accurately calibrate their apparatus.

The operating territory of the League is divided into thirteen United States and six Canadian divisions. You can find out what division you are in by consulting *QST* or the *Handbook*. The affairs of the League are managed by a Board of Directors. One director is elected every two years by the membership of each United States division, and a Canadian General Manager is elected every two years by the Canadian membership. These directors then choose the president and vice-president, who are also directors, of course. No one commercially engaged in selling or manufacturing radio apparatus can be a member of the Board or an officer of the League.

The president, vice-president, secretary, treasurer and communications manager of the League are elected or appointed by the Board of Directors. These officers constitute an Executive Committee to act in handling matters that come up between meetings of the Board, their authority subject to certain restrictions.

The League owns and publishes the magazine *QST*. *QST* goes to all members of the League each month. It acts as a monthly bulletin of the League's organized activities. It serves as a

medium for the exchange of ideas. It fosters amateur spirit. Its technical articles are renowned. *QST* has grown to be the "amateur's bible" as well as one of the foremost radio magazines in the world. The profits *QST* makes are used in supporting League activities. Membership dues to the League include a subscription to *QST* for the same period.

The extensive field organization of the Communications Department coordinates practical station operation throughout North America.

Headquarters

From the humble beginnings recounted in the story of amateur radio, League headquarters has grown until now it occupies an entire floor in a new office building and employs more than two dozen people.

Members of the League are entitled to write to Headquarters for information of any kind, whether it concerns membership, legislation, or general questions on the construction or operation of amateur apparatus. If you don't find the information you want in *QST* or the *Handbook*, write to A.R.R.L. Headquarters, West Hartford, Connecticut, telling us your problem. All replies are directly by letter; no charge is made for the service.

If you come to Hartford, drop out to Headquarters at West Hartford. Visitors are always welcome.

W1MK

For many years it was the dream of the League's officers that some day Headquarters would be able to boast a real "he-station." In 1928 this dream became an actuality, and the League to-day owns and operates the station shown in the frontispiece, operating under the call W1MK.

The current operating schedules of W1MK may be obtained by writing the Communications Department at Headquarters or by consulting the current issue of *QST*. While much of the operating time is devoted to pre-arranged schedules, the station is always ready at other times for a call from any amateur.

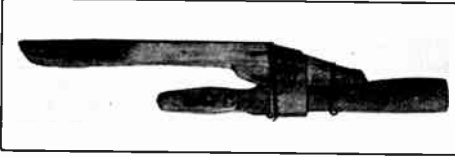
Traditions

As the League has come down through the years, certain traditions have become a part of amateur radio.

The Old Man with his humorous stories on "rotten radio" has become one of amateur radio's principal figures. Since 1915 his pictures of radio and radio amateurs as revealed by stories in *QST* are characteristic and inimitable. There is much speculation in amateur circles concerning the identity of T.O.M., but in eighteen years of writing he has not once given a clue to his real name or call.

The Wouff-Hong is amateur radio's most sacred

symbol and stands for the enforcement of law and order in amateur operation. It came into being originally in a story by T.O.M. For some time it was not known just what the Wouff-Hong looked like, but in 1919 The Old Man himself supplied the answer by sending in to League Headquarters



THE WOUFF-HONG

the one and only original Wouff-Hong, shown here. It is now framed and hangs on the wall of the Secretary's office at A.R.R.L. Headquarters.

Joining the League

The best way to get started in the amateur game is to join the League and start reading *QST*. Inquiries regarding membership should be addressed to the Secretary, or you can use the convenient application blank in the rear of this book. An interest in amateur radio is the only qualification necessary in becoming a member of

the A.R.R.L. Ownership of a station and knowledge of the code are *not* prerequisites. They can come later.

Learn to let the League help you. It is organized solely for that purpose, and its entire headquarter's personnel is trained to render the best assistance it can to you in solving your amateur problems. If, as a beginner, you should find it difficult to understand some of the matter contained in succeeding chapters of this book, do not hesitate to write the Information Service stating your trouble. Perhaps, in such a case, it would be profitable for you to send for a copy of a booklet published by the League especially for the beginner and entitled "How to Become a Radio Amateur." This is written in simple, straightforward language, and describes from start to finish the building of a single simple amateur installation. The price is 25 cents, postpaid.

Every amateur should read the League's magazine *QST* each month. It is filled with the latest amateur apparatus developments, "dope" on current expeditions which use short-wave radio for contact with this country, and the latest "ham" news from your particular section of the country. A sample copy will be sent you for 25c if you are unable to obtain one at your local newsstand.

CHAPTER TWO

GETTING STARTED

HAVING related, briefly, the origin and development of amateur radio in this country, we can now go on to the more practical business of describing in detail how to get in on the amateur radio of today. Subsequent chapters will treat of receiver and transmitter construction and adjustment, station operation, etc. This chapter deals with the first two *bête noir's* of every beginning amateur — learning the code and getting your licenses.

A high-frequency (short-wave) receiver alone will bring you hours of pleasure and will repay the little effort necessary to assemble it. Sooner or later, however, it is probable that you will build yourself either a radiotelephone or radiotelegraph transmitter. While many amateurs build 'phone transmitters, the majority both in this country and abroad operate radiotelegraph sets. There are several reasons for this. First, the code must be learned regardless of whether you operate a 'phone or telegraph set; the United States government won't issue any kind of amateur license without a code test. Secondly, radiotelegraph apparatus is far less expensive to build and less complicated to adjust than radiophone apparatus; less equipment and power are required and fewer tubes used. And lastly, code signals will usually cover four or five times the distance possible from the same or more complicated radiophone equipment, and are less susceptible to interference, fading and distortion.

There is nothing particularly difficult incident to taking your place in the ranks of licensed amateurs. The necessary steps are first, to learn the code, second, to build a receiver and a transmitter and third to get your amateur licenses and go on the air. Don't let any of these worry you. Thousands of men and women between the ages of 15 and 60 have mastered the code without difficulty by the exercise of a little patience and perseverance; these same thousands have found that only a moderate amount of study is necessary to prepare for the examination required by the government of all applicants for the combination station-operator license which every amateur must have before actually going on the air. We will treat of both of these subjects in detail later in this chapter.

Nor should you doubt your ability to build short-wave receivers and transmitters. The simpler types of receiver and transmitter described further on in this *Handbook* can be assembled and put into operation by anyone capable of using a screwdriver, a soldering iron and a little common sense. Of course, there are advanced

forms of amateur equipment that are intricate, complicated to build, and more difficult to understand and adjust, but it is not necessary to resort to them to secure results in amateur radio, and it would be best to avoid them until the rudiments of the game have been learned.

Our Amateur Band

▲ Most people, because they have never heard anything else, are prone to think of broadcasting as the most important radio service. To such people a few nights listening in on the high frequencies (wavelengths below the broadcast band) will be a revelation. A horde of signals from dozens of different types of services tell their story to whoever will listen. Some stations send slowly and leisurely. Even the beginner can read them. Others race along furiously so that whole sentences become meaningless buzzes. There are both telegraph and telephone signals. Press messages, weather reports, transoceanic commercial radiotelephone and telegraph messages, high frequency international broadcasting of voice and music, transmissions from government and experimental stations including picture transmission and television services, airplane dispatching, police broadcasts, and signals from private yachts and expeditions exploring the remote parts of the earth jam the short wave spectrum from one end to the other.

Sandwiched in among all these services are the amateurs, thousands of whose signals may be heard every night in the various bands set apart by International Treaty for amateur operation. These bands are in approximate harmonic relation to each other; their position in the short wave spectrum and their relative widths are shown in the sketch.

Many factors have to be considered in picking a certain frequency band for a certain job, especially the distance and the time of day when communication is desired. But in addition to daily changes, there are seasonal changes, and in addition a long-time change in atmospheric conditions which seems to coincide closely with the cycle of sun-spot or solar activity which is completed approximately each eleven years. The reliability of communication on a given frequency at a given time of day, the suitability of a given band for traffic or DX, the desires of the individual amateur in choosing his circle of friends with whom he expects to make contact on schedule, the amount of interference to be expected at certain hours, and the time of day available for operating — all influence the choice of an operat-

ing frequency. Many amateurs can use any one of the several available frequency bands at will. Let us now discuss briefly the properties peculiar to each of them.

The 1715-kc. band, which carried all our activity before experimenters opened the way to each of the higher frequency bands in turn, always served amateurs well for general contact between points all over the country. There was a short period, during the height of development of the higher frequencies, when activity in this band dwindled, but it is again greatly on the increase.

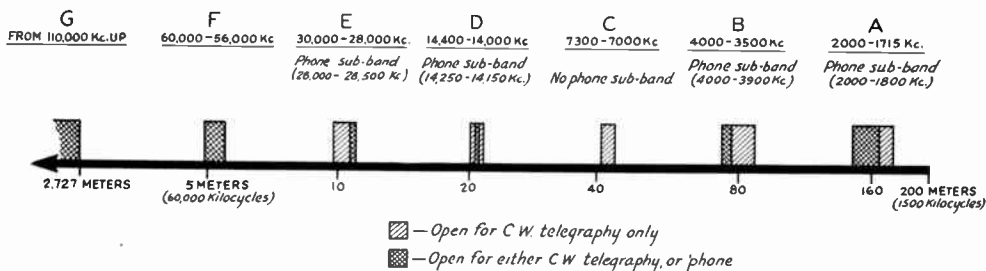
The band is popular especially for radiotelephone work. The very fact that it is less congested and occupied makes it an extremely attractive band for the amateur operator who would communicate effectively and avoid interference. Code practice transmissions are made in this band for beginning amateurs and many beginners may be heard in this region making their first two-way contact with each other. The band is one of our "widest" from the standpoint of the number of stations that may be comfortably accommodated. In the next year or so, it may be expected to take more of the present properties of the 3500-kc. region, and its use by amateurs continue to increase. The band is open to amateur television and picture transmission. If you are just getting on the air, plan to use this band. If you have been working on higher frequencies include this band in your plans for 1935—or you will be missing an important part of amateur radio.

The 3500-kc. band has, in recent years, been regarded as best for all consistent domestic communication. It is good for coast-to-coast work at night all the year except for a few summer

mote points, and 'phone signals heard in Europe. As the winter evening advances, the well-known "skip effect" (explained in detail in Chap. Four) of the higher frequencies has made itself known, the increased range of the "sky wave" brings in signals from the other coast and the increased range also brings in more stations, so that the band appears busier.

The 7000-kc. band has been the most popular band for general amateur DX work for some years. It is useful mainly at night for contacts with the opposite coast, or with foreign countries. Power output does not limit the range of a station to the same extent as when working on the lower frequency bands discussed above. However, the band is more handicapped by congestion in the early evenings and more subject to the vagaries of skip-effect and uncertain transmission conditions than are the lower frequency bands, but not limited in usefulness by these things to the same extent as the 14-mc. band. The 7000-kc. band is satisfactory for working distances of several hundred miles in daylight. It is generally considered the most desirable night band for general DX work in spite of difficulties due to interference. This band may be expected to take on better daylight DX characteristics during 1935 if predictions based on the sun-spot cycle are correct, and at the same time, while great possibilities will exist for evening work, it is likely to be more inconsistent and unreliable during the late evenings.

The 14,000-kc. or 14-mc. band is the very best frequency to use to cover great distances in daylight. In fact it is the *only* band generally useful for daylight DX contacts (QSO's) over coast-to-coast and greater distances. Communication over long distances will usually remain good during the



months. It has been recommended for all amateur message-handling over medium distances (1,000 miles for example). Much of the friendly human contact between amateurs takes place in the 3500-kc. band. It is the band from which we have made excursions to the higher frequencies on occasions when foreign contacts were desired. During the last year or so this band has exhibited some of its former DX properties, signals from amateur stations in this country being reported from South Africa, New Zealand and other re-

early evenings and surprising results can be obtained then, too. Using these higher frequencies there is often difficulty in talking with stations within three or four hundred miles, while greater distances than this (and very short distances within ten or twenty miles of a station) can be covered with ease. The reason that 14-mc. signals are less useful for general amateur DX late evenings is because the "skip" increases during darkness until the "sky wave" covers greater than earthly distances. The band, while one of the

very best for the amateur interested in working foreign stations without much difficulty from domestic interference, is sometimes subject to sudden fluctuations in transmitting conditions, and this characteristic will become more important perhaps as we return to the general conditions for radio communication that obtained back in 1923 and 1924, a condition now estimated to be due about 1935.

The 28,000-kc. (28-mc.) band, opened for amateur work by the Federal Radio Commission in early 1928 at the request of the A.R.R.L. is principally an experimental band at the present time. It combines both the long-distance characteristics of the 14-mc. band and some of the local advantages of the 56-mc. band, but its long-distance characteristics are generally too "spotty" for reliable communication. The result is that only a few amateurs to-day operate in this territory, though it is probable that more attention will be given to its short-distance properties as the 56-mc. band fills up.

The 56,000-kc. or 56-mc. band, likewise made available for amateur experimentation at the request of the League, has for many years been regarded as strictly a local and short-distance band for distances of ten to thirty miles. Because of the cheapness, compactness and ease of construction of the necessary apparatus it has proved ideal for this purpose and many hundreds of stations have operated "locally" there. During the latter part of 1934, however, experiments with directive antennas by the technical staff of the A.R.R.L. indicated the possibility of surprisingly consistent two-way work over distances of a hundred miles or more, with the result that tremendous impetus has been given to experimentation at these frequencies.

Above 110,000 kc. but little progress has as yet been made, since it was only during the summer of 1934 that the A.R.R.L. was able to secure a regulation permitting general amateur work on all the higher frequencies above 110-mc. These frequencies have in the past been generally considered useless for communication over any appreciable distance, just as were the frequencies around 56 mc. But the developments in that region have resulted in creating considerable interest in the still higher frequencies, and during 1935 it is expected that many experimenters will endeavor to exploit them to their utmost for communication purposes.

•••••	A
•••••	B
•••••	C
•••••	D
•••••	E
•••••	F
•••••	G
•••••	H
•••••	I
•••••	J
•••••	K
•••••	L
•••••	M
•••••	N
•••••	O
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•••••	Z
•••••	1
•••••	2
•••••	3
•••••	4
•••••	5
•••••	6
•••••	7
•••••	8
•••••	9
•••••	0
•••••	PERIOD
•••••	INTERROGATION
•••••	BREAK (DOUBLE DASH)
•••••	WAIT
•••••	END OF MESSAGE
•••••	END OF TRANSMISSION
•••••	RECEIVED (O.K.)
•••••	INVITATION TO TRANSMIT
•••••	(GO AHEAD)
•••••	EXCLAMATION
•••••	BAR INDICATING FRACTION
•••••	(OBLIQUE STROKE)
•••••	COMMA
•••••	COLON
•••••	SEMICOLON
•••••	QUOTES
•••••	PARENTHESIS

THE CONTINENTAL CODE

Memorizing the Code

▲ The first job you should tackle is the business of *memorizing* the code. This can be done while you are building your receiver. Thus, by the time the receiver is finished, you will know all the characters for the alphabet, the most-used punctuation marks, and the numerals, and will be ready to practice receiving in order to acquire speed. Speed practice, either by means of a buzzer, or by listening in on your receiver, can be indulged in in odd moments while the transmitter, in turn, is being constructed. The net result of such an organized program should be that by the time the transmitter is finished you will be able to receive the ten words a minute required by the government for your amateur operator license, and can immediately proceed to studying for the "theoretical" part of your license examination without loss of time.

Memorizing the code is no job at all if you simply make up your mind you are going to apply yourself to the job and get it over with as quickly as possible. The complete Continental alphabet, punctuation marks and numerals are shown in the table given here. The alphabet and all the numerals should be learned, but only the first eight of the punctuation marks shown need be memorized by the beginner. Start

by memorizing the alphabet, forgetting the numerals and punctuation marks for the present. Various good systems for learning the code have been devised. They are of undoubted value but the job is a very simple one and usually can be accomplished easily by taking the first five letters, memorizing them, then the next five, and so on. As you progress you should review all the letters learned up to that time, of course. When you have memorized the alphabet you can go to the numerals, which will come very quickly since you can see that they follow a definite system. The punctuation marks wind up the schedule — and be sure to learn at least the first eight — the more commonly-used ones.

One suggestion: Learn to think of the letters in terms of *sound* rather than their appearance as they are printed. Don't think of A as "dot-dash" but think of it as the sound "dit-dah." B, of course, is "dah-dit-dit-dit," C, "dah-dit-dah-dit" and so on.

Don't think about speed yet. Your first job is simply to memorize all the characters and make

sure you know them without hesitation. Good practice can be obtained, while building the receiver, if you try to spell out in code the names of the various parts you are working on at the time.

Acquiring Speed by Buzzer Practice

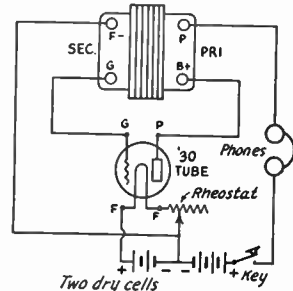
▲ When the code is thoroughly memorized, you can start to develop speed in receiving code transmission. The most enjoyable way to do this is to have two people learn the code together and send to each other by means of a buzzer-and-key outfit. One advantage of this system is that it develops sending ability, too, for the person doing the receiving will be quick to criticize uneven or indistinct sending. If possible, it is a good idea to get the aid of an experienced operator for the first few sessions, so that you will know what well-sent characters sound like.

The diagram shows the connections for a buzzer-practice set. When buying the key of this set it is a good idea to get one that will be suitable for use in the transmitter later; this will save you money.

Another good practice set for two people learning the code together is that using an old audio transformer, a type '30 tube, a pair of 'phones, key, two No. 6 dry cells, tube-socket, a 20-ohm filament rheostat, and a 22½-volt B battery. These are hooked up as shown in the diagram to form an audio oscillator. If nothing is heard in the 'phones when the key is depressed, reverse the leads going to the two binding posts at either transformer winding. Reversing both sets of leads will have no effect.

Either the buzzer set or this audio oscillator will give good results. The advantage of the

and sentences, always trying to have the material sent at just a little faster rate than you can copy easily; this speeds up your mind. Write down each letter you recognize. Do *not* try to write down the dots and dashes; write down the letters. Don't stop to compare the sounds of different letters, or think too long about a letter or word that has



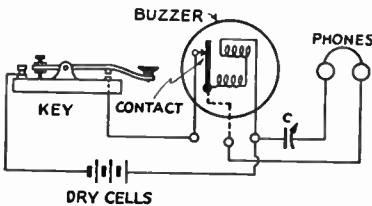
CONNECTING AN AUDIO OSCILLATOR (HARTLEY) FOR CODE PRACTICE WORK

been missed. Go right on to the next one or each "miss" will cause you to lose several characters you might otherwise have gotten. If you exercise a little patience you will soon be getting every character, and in a surprisingly short time will be receiving at a good rate of speed. When you think you can receive ten words a minute (50 letters a minute) have the sender transmit code groups rather than straight English text. This will prevent you from recognizing a word "on the way" and filling it in before you've really listened to the letters themselves.

Learning by Listening

▲ While it is very nice to be able to get the help of another person in sending to you while you are acquiring code-speed, it is not always possible to be so fortunate, and some other method of acquiring speed must be resorted to. Under such circumstances, the time-honored system is to "learn by listening" on your short-wave receiver. Nor should you make the mistake of assuming that this is a more difficult and less-preferred method: it is probable that the majority of amateurs acquire their code speed by this method. After building a receiver and getting it in operation, the first step in "learning by listening" will be to hunt for a station sending slowly. With even the simplest short-wave receivers a number of high-power stations can be heard in every part of the world. It is usually possible to pick a station going at about the desired speed for code practice. Listen to see if you cannot recognize some individual letters. Use paper and pencil and write down the letters as you hear them. Try to copy as many letters as you can.

Whenever you hear a letter that you know, write it down. Keep everlastingly at it. *Twenty minutes or half an hour is long enough for one*



CONNECTIONS OF A BUZZER CODE PRACTICE SET WITH A TELEPHONE HEAD SET

The intensity of the signal can be varied by changing the setting of the variable condenser. The 'phone and condenser are connected either across the coils of the buzzer or across the vibrator contacts. The condenser may be omitted and the tone may be changed by changing the number of dry cells.

audio oscillator over the buzzer set is that it gives a fine signal in the 'phones without making any noise in the room.

After the practice set has been built, and another operator's help secured, practice sending turn and turn about to each other. Send single letters at first, the listener learning to recognize each character quickly, without hesitation. Following this, start slow sending of complete words

session. This practice may be repeated several times a day. Don't become discouraged. Soon you will copy without missing so many letters. Then you will begin to get calls, which are repeated several times, and whole words like "and" and "the." After words will come sentences. You now know the code and your speed will improve slowly with practice. Learning by this method may seem harder to some folks than learning with the buzzer. It is the opinion of the writer, who learned in this way, that the practice in copying actual signals and having real difficulties with interference, static, and fading, is far superior to that obtained by routine buzzer practice. Of course the use of a buzzer is of value at first in getting familiar with the alphabet.

In "learning by listening" try to pick stations sending slightly faster than your limit. In writing, try to make the separation between words definite. Try to "read" the whole of short words before starting to write them down. Do the writing while listening to the first part of the next word. Practice and patience will soon make it easy to listen and write at the same time. Good operators usually copy several words "behind" the incoming signals.

A word of caution: the U. S. radio communication laws prescribe heavy penalties for divulging the contents of any radiogram to other than the addressee. You may copy anything you hear for practice but you must preserve its secrecy.

Volunteer Code Practice Stations

▲ Each fall and winter season the A.R.R.L. solicits volunteers, amateurs using code only, or often a combination of voice and code transmission, who will send transmissions especially calculated to assist beginners. These transmissions go on the air at specified hours on certain days of the week and may be picked up within a radius of several hundred miles under favorable conditions. Words and sentences are sent at different speeds and repeated by voice, or checked by mail for correctness if you write the stations making the transmissions and enclose a stamped addressed envelope for reply.

The schedules of the score or more volunteer code-practice stations are listed regularly in *QST* during the fall and winter. Information at other times may be secured by writing Headquarters. Some of the stations have been highly successful in reaching both coasts with code-practice transmissions from the central part of the country.

Interpreting What We Hear

▲ As soon as we finish our receiver and hook it up we shall begin to pick up different high-frequency stations, some of them perhaps in the bands of frequency assigned to amateurs, others perhaps commercial stations belonging to different services. The loudest signals will not necessarily be those from near-by stations. Depending on trans-

mitting conditions which vary with the frequency, the distance and the time of day, remote stations may or may not be louder than relatively near-by stations.

The first letters we identify probably will be the call signals identifying the stations called and the calling stations, if the stations are in the amateur bands. Station calls are assigned by the government, prefixed by a letter (W in the United States, VE in Canada, G in England, etc.) indi-



U. S. AMATEUR CALL AREAS

cating the country. In this country amateur calls will be made up of such combinations as W9GP, W8CMP, W3BZ, W1MK, etc., the number indicating the amateur call area (see map) and giving a general idea of the part of the country in which the station heard is located. The reader is referred to the chapter on "Operating a Station" for complete information on the procedure amateurs use in calling, handling messages, and the like. Many abbreviations are used which will be made clear by reference to the tables of Q Code, miscellaneous abbreviations, and "ham" abbreviations included in the Appendix. The table of international prefixes, also in the back of the book, will help to identify the country where amateur and commercial stations are located.

The commercial stations use a procedure differing in some respects from amateur procedure, and to some extent the procedure of army, naval and government stations is different from this, each service having a modified procedure meeting its own requirements. On the other hand, the International Radiotelegraph Convention has specified certain regulations, abbreviations and procedures which govern all services and insure basic uniformity of methods and wide understanding between stations of all nations, regardless of services.

"Tape" or "machine" transmission and reception is used to speed up traffic handling to the limit fixed by relays and atmospheric conditions. Most beginners are puzzled by certain abbreviations which are used. Many code groups are sent by different commercial organizations to shorten the messages and to reduce the expense of sending messages which often runs as high as 25 cents a

word. Unless one has a code book it is impossible to interpret such messages. Five- and ten-letter cypher groups are quite common and make excellent practice signals. Occasionally, a blur of code will be heard which results when tape is speeded up to 100 words per minute and photographic means are used to record the signals.

League O.B.S. System

▲ Official Broadcasting Stations of the A.R.R.L. send the latest Headquarters' information addressed to members on *amateur frequencies*. The messages are often interesting and many of them are sent slowly enough for code practice between 15 and 20 words a minute. Lists and schedules appear from time to time in the membership copies of *QST*.

The very latest *official and special information of general interest*, addressed to A.R.R.L. members, is broadcast twice nightly (except Wednesday and Saturday) simultaneously on two frequency bands from the Headquarters' amateur station, WIMK. The schedule for these transmissions is as follows:

Sun.	8:30 p.m. EST-13 w.p.m. — 3825 and 7150 kcs.
Sun.	Midnight EST-22 w.p.m. — 3825 and 7150 kcs.
Mon.	8:30 p.m. EST-22 w.p.m. — 3575 and 7150 kcs.
Mon.	10:30 p.m. EST-13 w.p.m. — 3575 and 7150 kcs.
Tues.	8:30 p.m. EST-13 w.p.m. — 3575 and 7150 kcs.
Thurs.	8:30 p.m. EST-13 w.p.m. — 3825 and 7150 kcs.
Thurs.	Midnight EST-22 w.p.m. — 3825 and 7150 kcs.
Fri.	8:30 p.m. EST-22 w.p.m. — 3825 and 7150 kcs.
Fri.	10:30 p.m. EST-13 w.p.m. — 3825 and 7150 kcs.

As you can see from this schedule, WIMK sends these bulletins simultaneously on two different frequency bands, so if you are unable to hear the station on the 3500-ke. band you may be able to pick it up on the 7000-ke. band, and *vice versa*.

These transmissions are sent at the indicated rates of speed and are frequently used by advanced beginners for *code practice* work.

Using a Key

▲ The correct way to grasp the key is important. The knob of the key should be about eighteen inches from the edge of the operating table and about on a line with the operator's right shoulder, allowing room for the elbow to rest on the table. A table about thirty inches in height is best. The spring tension of the key varies with different operators. A fairly heavy spring at the start is desirable. The back adjustment of the key should be changed until there is a vertical movement of about one-sixteenth inch at the knob. After an operator has mastered the use of the hand key the tension should be changed and can be reduced to the minimum spring tension that will cause the key to open immediately when the pressure is released. More spring tension than necessary causes the expenditure of unnecessary energy. The contacts should be spaced by the rear screw on the key only and not by allowing play in the side screws, which are provided merely for align-

ing the contact points. These side screws should be screwed up to a setting which prevents appreciable side play but not adjusted so tightly that binding is caused. The gap between the contacts should always be at least a thirty-second of an inch, since a too-finely spaced contact will cultivate a nervous style of sending which is highly undesirable. On the other hand too-wide spacing (much over one-sixteenth inch) may result in unduly heavy or "muddy" sending.

Do not hold the key tightly. Let the hand rest lightly on the key. The thumb should be against the left side of the key. The first and second fingers should be bent a little. They should hold the middle and right sides of the knob, respectively. The fingers are partly on top and partly over the side of the knob. The other two fingers should be free of the key. The photograph shows the correct way to hold a key.

A wrist motion should be used in sending. The whole arm should not be used. One should not send "nervously" but with a steady flexing of the wrist. The grasp on the key should be firm, not tight, or jerky sending will result. None of the muscles should be tense but they should all be under control. The arm should rest lightly on the operating table with the wrist held above the table. An up-and-down motion without any sideways action is best. The fingers should never leave the key knob.

Sending

▲ Good sending *seems* easier than receiving, but don't be deceived. A beginner shouldn't send fast. Keep your transmitting speed down to the receiving speed, and rather bend your efforts to sending *well*.

When sending do not try to speed things up too soon. A slow, even rate of sending is the mark of a good operator. Speed will come with time alone. Leave special types of keys alone until you have mastered the knack of properly handling the standard-type telegraph key. Because radio transmissions are seldom free from interference a "heavier" style of sending is best to develop for radio work. A rugged key of heavy construction will help in this.

When signals can be copied "solid" at a rate of ten words a minute it is time to start practicing with a key in earnest. While learning to receive, you have become fairly familiar with good sending. Try to imitate the machine or tape sending that you have heard. This gives a good example of proper spacing values.

When beginning to handle a key do not try to send more than six or seven words a minute. A dot results from a short depression of the key. A dash comes from the same motion but the contact is held three times as long as when making a dot. A common mistake of beginners is to make it several times too long. There is no great space between the parts of a letter. Particular care

should be exercised when sending letters such as *c* to make them "all at once" like this (— - — -) and *not* irregularly spaced like this (— - — -).

Key practice should not be extended over too long periods at first. The control of the muscles in the wrist and forearm should be developed gradually for best results.

Individuality in sending should be suppressed rather than cultivated. Speed needs to be held in check. "Copiability" is what we want. Repeats waste valuable time. When you find that you are sending too fast for the other fellow, slow down to his speed.

A word may be said about the "Vibroplex" and "double-action" keys. The "Vibroplex" makes dots automatically. The rate of making dots is regulated by changing the position of a weight on a swinging armature. Dots are made by pressing a lever to the right. Dashes are made by holding it to the left for the proper interval. A side motion is used in both types of keys.

These keys are useful mainly for operators who have lots of traffic to handle in a short time and for operators who have ruined their sending arm. Such keys are motion savers. However, a great deal of practice is necessary before readable code can be sent. The average novice who uses a "bug" tries to send too fast and ruins his sending altogether. The beginner should keep away from such keys. After he has become very good at handling a regulation telegraph key, he may practice on a "bug" to advantage.

Obtaining Government Licenses

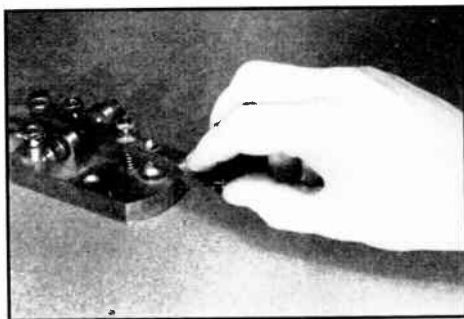
▲ When you are able to copy ten words per minute, have studied basic transmitter theory and familiarized yourself with the radio law and amateur regulations, you are ready to give serious thought to securing the government combination amateur operator-station license which is issued you, after examination, through the Federal Communications Commission, at Washington, D. C.

Because a discussion of license application procedure, license renewal and modification, exemptions, and detailed information on the nature and scope of the license examination involve more detailed treatment than it is possible to give within the limitations of this chapter, it has been made the subject of a special booklet published by the League, and at this point the beginning amateur should possess himself of a copy and settle down to a study of its pages in order to familiarize himself with the intricacies of the law and prepare himself for his test. The booklet, "*The Radio Amateur's License Manual*," may be obtained from A.R.R.L. headquarters for 25¢ post-paid. From the beginner's standpoint one of the most valuable features of this book is its list of nearly 200 representative examination questions with their correct answers. Aside from this, however, not only all beginning amateurs but those

already licensed should always have a copy of the latest edition of the *License Manual* at hand for the complete information it contains on licenses and regulations.

A few general remarks:

While no government licenses are necessary to operate receivers in the United States, you posi-



ILLUSTRATING THE CORRECT POSITION OF THE HAND AND FINGERS FOR THE OPERATION OF A TELEGRAPH KEY

tively must have the required amateur licenses before doing sending of any kind with a transmitter. This license requirement applies for any kind of transmitter on any wavelength. There is no basis for the assumption that low-power transmitters, or transmitters operating on 5 meters or below, need no license. They do, most emphatically, as do their operators. Attempts to engage in transmitting operation of any kind, without holding licenses, will inevitably lead to arrest, and fine or imprisonment.

Amateur licenses are free, but are issued only to citizens of the United States; this applies both to the station authorization and the operator's personal license, with the further provision in the station license that it will not be issued where the apparatus is to be located on premises controlled by an alien. But the requirement of citizenship is the only limitation, and amateur licenses are issued without regard to age or physical condition to anyone who successfully completes the required examination. There are licensed amateurs as young as nine and as old as eighty. Many permanently bed-ridden persons find their amateur radio a priceless boon and have successfully qualified for their "tickets"; even blindness is no bar — several stations heard regularly on the air are operated by people so afflicted.

Persons who would like to operate at amateur stations, but do not have their own station as yet, may obtain an amateur operator license without being obliged to take out a station license. But no one may take out the station license alone; all those wishing station licenses must also take out operator licenses.

Extracts from the basic Communications Act and the complete text of the amateur regulations

current at the time this Handbook went to press (November, 1934) will be found in the Appendix. Because the regulations are subject to occasional changes or additions, however, it is recommended that your study of them be from the *License Manual* already mentioned, since this latter publication is always revised, or a "change sheet" incorporated with it, whenever such alterations in our regulations take place.

Canadian Regulations

▲ Canadian amateurs wishing operators' licenses must pass an examination before a radio inspector in transmission and reception at a speed of ten words per minute or more. They must also pass a verbal examination in the operation of amateur apparatus of usual types, must have a working knowledge of procedure, and must have a little

operating ability prior to taking the examination. Nothing is likely to be asked which is not covered in this *Handbook* or the *License Manual*. The fee for examination as operator is 50 cents and is payable to the Radio Inspector who examines the candidate.

The form for application for station license may be obtained either from a local Radio Inspector's office or direct from the Department of Marine and Fisheries, Radio Branch, Ottawa. This consists of a blank form with spaces for details regarding the station equipment and the uses to which it is to be put. The applicant must also sign a declaration of secrecy which, as a matter of fact, is executed at the time of obtaining the operator's license. The annual fee for station licenses for amateur work in Canada is \$2.50.

CHAPTER THREE

ELECTRICAL FUNDAMENTALS

ALTHOUGH it is possible for the amateur unversed in electrical fundamentals to build and operate a station more or less successfully, better practical results and greater personal enjoyment of the game are in store for him who knows something of what it's all about. Amateur radio is really a part of the great field of electrical communication, both wire and radio, and hence has its foundations in the electrical fundamentals that have been in process of development for hundreds of years. To cover completely the basic principles involved is far beyond the scope of any one book, let alone a single chapter, so the aim here must be to present only those fundamentals that experience has shown to be of the greatest practical value to the amateur in the building and operating of his station. To the avid amateur whose appetite may be whetted for more, the books suggested in the Appendix are recommended for further study.

What Is Electricity?

▲ In the not distant past the nature of electricity was considered something beyond understanding but in recent years much of the mystery has been removed. We know now that what we call electricity is the evidence of activity of electrons.

"Electrons in motion constitute an electric current."

But what is the electron and what is the source of those that constitute electric current? The accepted theory is that the electron does not ordinarily exist in an isolated state but normally has a sort of family life, in combination with other electrons, in the *atom*. Atoms make up *molecules* which, in turn, make up the substances familiar to us, copper, iron, aluminum, etc. Atoms differ from each other in the number and arrangement of the electrons that constitute them.

The atom has a nucleus which is considered to be composed of both positive and negative electrons, but with the positive predominating so that the nature of the nucleus is positive. For purposes of identification the positive electrons are referred to as *protons* and the negative electrons simply as *electrons*. The electrons and protons of the nucleus are intimately and closely bound together. But exterior to the nucleus are negative electrons which are more or less free agents that can leave home with little urging. Ordinarily the atom is electrically neutral, the outer negative electrons balancing the positive nucleus. It is when something happens to disturb this balance and when the foot-loose electrons begin to leave home that electrical activity becomes evident.

Electron Flow — Electric Current

▲ It is considered likely that there is a continuous interchange of electrons between the atoms of a solid body, such as a piece of copper wire, but that the net effect under ordinary conditions is to make the average in any one direction zero. If, however, there is an electric field through the wire, as when the ends are connected to the terminals of a battery, there sets in a consistent drift of the negatively charged electrons, from

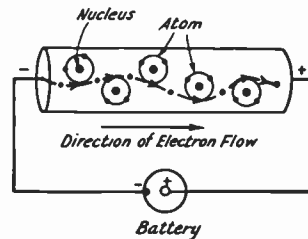


FIG. 301 — HOW CURRENT IS CONDUCTED IN A WIRE

Electrons are relayed from atom to atom, from the negative to the positive end of the conductor.

atom to atom, towards the end of the wire connected to the positive battery terminal, somewhat as shown in Fig. 301. This drift of electrons constitutes an electric current. The rate at which the current flows will be determined by the characteristics of the conductor, of course, and by the strength of the electric field.

Each electron, and they are all alike irrespective of the kind of atom from which they come, is unbelievably minute and a measure of electric current in terms of number of electrons would be impracticable. Therefore a larger unit is used, the *ampere*.

A current of 1 ampere represents nearly 10^{18} (ten million, million, million) electrons flowing past a point in 1 second; or a micro-ampere (millionth of an ampere) nearly 10 million electrons per micro-second (millionth of a second).

Conductors and Insulators

▲ The ease with which electrons are able to be transferred from one atom to another is a measure of the conductivity of the material. When the electrons are able to flow readily, we say that the material is a good *conductor*. If they are not able to chase off to another atom quite so readily, we say that the substance has more *resistance*. Should it be almost impossible for the electrons to break from their normal path

around their own nucleus, the material is what we term an *insulator*. Copper, silver and most other metals are relatively good conductors of electricity; while such substances as glass, mica, rubber, dry wood, porcelain and shellac are relatively good insulators.

The resistance of most substances varies with changes in temperature. Sometimes the variation is so great that a body ordinarily considered an insulator becomes a conductor at high temperatures. The resistance of metals usually increases with an increase in temperature while the resistance of liquids and of carbon is decreased with increasing temperature.

Conduction in Liquids and Gases

▲ Besides the case of conduction in the solid copper wire, in which there is electron drift from atom to atom but with the individual atoms remaining more or less stationary and each being but momentarily deficient in electron content, there are other forms of conduction important in radio communication. The general case of conduction in liquids is one.

For instance, take that of conduction in a solution of sodium chloride (common table salt) in water. In such a solution there is a number of *molecules* of salt that have separated into two parts, one of which has the nucleus of the sodium atom while the other has the nucleus of the chlorine atom. But the two parts are not truly atoms because the chlorine part has one excess electron and is *negative* in character while the sodium part is deficient by one electron and therefore is *positive* in character. No longer true atoms, they are now *ions* and the spontaneous process of *dissociation* in solution is one form of *ionization*. If plates connected to the terminals of a battery are now placed in the solution, the positive sodium ions travel to the negative plate where they acquire negative electrons; and the negative chlorine ions travel to the positive plate where they give up their excess electrons; and both again become neutral atoms. The energy supplied by the battery is used to move the ions through the liquid and to supply or remove electrons. Thus there is a flow of electric current through the liquid by *electrolytic conduction*. This kind of conduction plays a part in the operation of such radio equipment as electrolytic rectifiers.

Another type of conduction important in the operation of radio equipment is that which takes place in gases. This also involves ionization, although here the ionization is not spontaneous as in the electrolytic conduction just described but is produced by rapidly moving free electrons colliding with atoms, and hence, is called *ionization by collision*. Such conduction is illustrated by the ordinary neon lamp. The bulb contains a pair of plates and is filled with neon gas. In addition to the molecules of the gas, there will be a few free electrons. If a battery of sufficient voltage is con-

nected to the two plates, the initial free electrons will make a dive for the positively charged plate, their velocity being accelerated by the electric field. In their headlong dash they collide with neon atoms and knock off outer electrons of these atoms, converting the latter to positive ions. The additional free electrons produced by collision now join the procession, and ionize more atoms. As they are freed, the electrons travel towards the positive plate. In the meantime, the more sluggish positive ions have been traveling towards the negative plate, where they acquire electrons and again become neutral atoms. The net result is a flow of electrons, and hence of current, between the electrodes, from negative plate to positive plate. The light given off, it may be mentioned, is considered incidental to the recombination of ions and free electrons at the negative plate. This kind of *conduction by ionization* is utilized in the operation of the gaseous rectifiers used in radio power supplies.

Still another form of conduction very important in radio communication is pure *electronic conduction*. In the case of the copper wire we saw that the individual electrons did not make the complete trip from one end of the circuit to the other but that the flow was a sort of relay process. We also saw that the electrons could not leave the wire in random directions but, under the influence of the electric field, progressed only from the

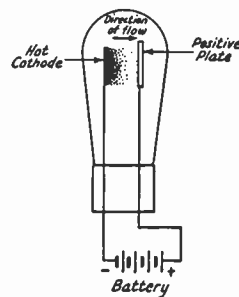


FIG. 302—ELECTRONIC CONDUCTION BY ELECTRON EMISSION IN THE VACUUM TUBE

Stimulated by heat, electrons fly off from the cathode or filament and are attracted to the positive plate.

negative towards the positive end. They were restrained from leaving the surfaces of the conductor. But they can be made to fly off from the conductor when properly stimulated to do so, as is illustrated by the familiar radio vacuum tube. Here we have electrons being freed from the *cathode*, a conductor that would nominally retain them, and actually traveling through vacuum to the plate that attracts them because it is connected to the positive terminal of a battery, as illustrated in Fig. 302. The reason that the electrons are freed from the cathode is that it has been heated to a temperature that activates them sufficiently to enable them to break away. This is known as *thermionic electron emission*, sometimes called simply *emission*. Once free, most of the emitted electrons make their way to the plate, although some return, repelled from traveling farther by the cloud of negative electrons immediately surrounding the cathode. This electron cloud about the emitting cathode constitutes

what is known as the *space charge*. A few electrons that reach the plate may have sufficient velocity to dislodge one or more electrons already on the plate. This dislodging of electrons from the plate by other fast moving electrons constitutes *secondary emission*. When it occurs there is actually simultaneous electron flow in two directions. The various phenomena connected with electronic conduction, briefly outlined here, are of such extreme importance in the operation of vacuum tubes that they cannot be emphasized too greatly.

Direction of Flow

▲ There is one point in connection with current flow which is likely to cause confusion in the reader's mind if particular attention is not paid to it. *The drift of electrons along a conductor (which constitutes a current flow) is always from the negative to the positive terminal.* On the other hand, the usual conception is that of electricity flowing from the positive to the negative terminal. The discrepancy results from the fact that the pioneer electrical experimenters, having no accurate understanding of the nature of electricity, assumed the direction to be from positive to negative. However, just so long as the facts are recognized clearly, no confusion need result.

Electromotive Force — Voltage

▲ Just as soon as electrons are removed from one body and become attached to a second one, there is created a firm desire on the part of the estranged electrons to return to their normal position. For instance, the excess electrons on the negatively charged pole of a battery, attempting to return to the positively charged pole, create an *electrical pressure* between the two terminals. This pressure is termed *electromotive force* and the unit of measurement, widely used in our radio work, is the *volt*. In the ordinary dry cell (when fresh) the electromotive force between the two terminals is of the order of 1.5 or 1.6 volts. Should we have two such cells, and should we connect the negatively charged terminal of one to the positively charged terminal of the second cell we would then have twice the voltage of one cell between the remaining two free terminals. In this example we have connected the cells in *series* and the combination of the two cells becomes what we know as a *battery*. In the common "B" battery, so widely used with radio receivers, a great many small cells are so connected in series to provide a relatively high electromotive force or voltage between the outer terminals.

Another method of connecting a battery of cells together is to join all the positive terminals and all the negative terminals. The cells are then said to be connected in *parallel*. The voltage between the two sets of terminals will then be just the same as that of a single cell but it will be possible to take a greater amount of current from the

battery than would have been possible from the single cell.

In practical work we use meters to measure voltage and current. The *voltmeter* is connected across the points between which the unknown voltage exists while the *ammeter* is connected in series with the conductor in which the current flows. With this arrangement, the ammeter becomes a part of the conductor itself. In both cases, the reading in volts or amperes will be indicated directly on the calibrated scale of the instrument.

How Electricity Is Produced

▲ The ordinary electric cell and the electric generator are the sources of current used in ordinary practice. The electric cell may take the form of a so-called dry cell, a wet cell or perhaps a storage cell. In any case, the current is derived by a chemical action within the cell. In the first two forms mentioned, the action of the fluid (there is a fluid even in a "dry" cell) tears down the structure of one of the elements or "poles" of the cell, producing an excess of electrons in one element and a deficiency in the other. Thus, when the elements are connected by a conductor, this unbalance of electrons results in a flow of electrons from one element to the other and the flow is what we know as an electric current. In the storage cell, the chemical change is reversible and the cell can be "recharged." The manner in which the electric generator produces a current is to be discussed at a later stage.

Direct and Alternating Current — Frequency

▲ Of course, all electric currents do not flow continuously in the same direction along a conductor. The currents produced by batteries and by some generators flow in this manner, and therefore are termed *direct currents*. Should the current, for some reason or other, increase and decrease at periodic intervals or should it stop and start frequently it is still a direct current as long as the flow is always in the same direction, though it would be a fluctuating or intermittent one.

The type of current most generally used for the supply of power in our homes does not flow in one direction only, but *reverses* its direction many times each second. The electron drift or flow in a conductor carrying such a current first increases to a maximum, falls to zero, then reverses its direction, again rises to a maximum and again falls to zero — to reverse its direction again and continue the process. In most of the power circuits, the current flows in one direction for 1/120th of a second, reverses, flows in the opposite direction for another 1/120th of a second and so on. In other words, the complete *cycle* of reversal occupies 1/60th of a second. The number of complete cycles of flow in one second is termed the *frequency* of the current. In the instance under discussion we would say that the frequency

is 60 cycles per second. All currents which reverse their direction in this manner are known as *alternating currents*. We are to find that they are not by any means limited to the circuits which supply power to our homes. Telephone and radio circuits, for instance, are virtually riddled with alternating currents having a wide variety of frequencies. The currents which are produced by the voice in a telephone line may have frequencies between about 100 and 5,000 cycles per second while the alternating currents which we are to handle in the circuits of a radio transmitter may have a frequency as high as 60 million cycles per second. Because of the high frequencies used in radio work the practice of speaking in terms of cycles per second is an awkward one. It is customary, instead, to use *kilocycles per second* or, simply, *kilocycles* (kc.) — the kilocycle being one thousand cycles. Yet another widely used term is the *megacycle* (mc.) — a million cycles.

Alternating current, unlike direct current, cannot be generated by batteries. For the supply of commercial power it is almost always produced by rotating machines driven by steam turbines. In radio work we make use of this current for the power supply of our radio apparatus but the very high frequency alternating currents in the radio transmitter are almost invariably produced by vacuum tubes connected in appropriate circuits.

Resistance and Resistors — Ohm's Law

Now that we have some conception of what an electric current really is and of the different forms

readily than others — they have less resistance. Most of the conductors in radio apparatus — such as wiring, coils, etc. — are required to have the greatest conductivity or the least resistance possible. They are of metal, usually copper. But many of the conductors are actually placed in the circuit to offer some definite amount of resistance. They are known under the general term of *resistors* and the amount of resistance they (or any conductor) offer is measured in *ohms*.

When a current flows in any electric circuit, the magnitude of the current is determined by the electromotive force in the circuit and the resistance of the circuit, the resistance being dependent on the material, cross-section and length of the conductor. The relations which determine just what current flows are known as *Ohm's Law*. It is an utterly simple law but one of such great value that it should be studied with particular care. With its formula, carrying terms for current, electromotive force and resistance, we are able to find the actual conditions in many circuits, providing two of the three quantities are known. When *I* is the current in amperes, *E* is the electromotive force in volts and *R* is the circuit resistance in ohms, the formulas of Ohm's Law are:

$$R = \frac{E}{I} \quad I = \frac{E}{R} \quad E = IR$$

The *resistance* of the circuit can therefore be found by *dividing the voltage by the current*; the *current* can be found by *dividing the voltage by the resistance*; the *electromotive force* or *e.m.f.* is equal to the *product of the resistance and the current*. At a later stage it will be shown just how valuable may be the practical application of this law to the ordinary problems of our radio work.

Series and Parallel Connections

▲ The resistors used in electrical circuits to introduce a known amount of resistance are made up in a variety of forms. One common type consists of wire, of some high resistance metal, wound on a porcelain former. To

obtain very high values of resistance the wire must be extremely fine. Because this introduces manufacturing difficulties, some of the high value resistors which are not required to carry heavy current are made up of some carbon compound or similar high resistance material. Resistors, like cells, may be connected in series, in parallel or in series-parallel. When two or more resistors are

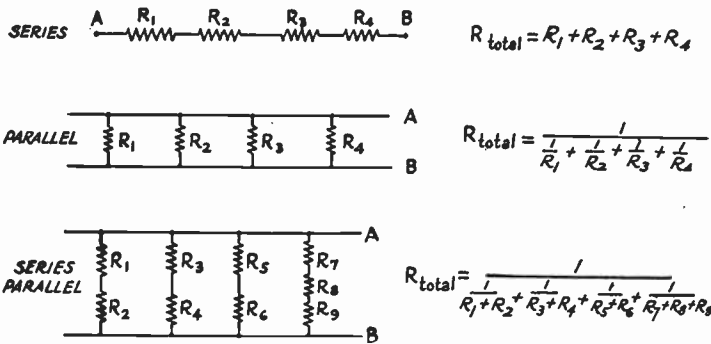


FIG. 303 — RESISTANCES CONNECTED IN SERIES, PARALLEL, AND SERIES-PARALLEL.

in which electricity is to be found, we may proceed to examine its effects in the apparatus which is to be used in radio work.

The most common equipment used in radio work is the conductor. We have already mentioned that any substance in which an electric current can flow is a conductor and we have also pointed out that some substances conduct more

connected in series, the total resistance of the group is higher than that of any of the units. Should two or more resistors be connected in parallel, the total resistance is decreased. Fig. 303 shows how the value of a bank of resistors in series, parallel or series-parallel may be computed.

Heating Effect and Power

▲ The heating effect of the electric current is due to molecular friction in the wire caused by the flow of electricity through it. This effect depends on the resistance of the wire; for a given time (seconds) and current (amperes) the heat generated will be proportional to the resistance through which the current flows. The power used in heating or the heat dissipated in the circuit (which may be considered sometimes as an undesired power loss) can be determined by substitution in the following equations.

Power (watts) = $E I$
 We already know that $E = I R$
 Therefore, $P = I R \times I = I^2 R$
 Also, $P = \frac{E^2}{R}$

It will be noted that if the current in a resistor and the resistance value are known, we can readily find the power. Or if the voltage across a resistance and the current through it are known or measured by a suitable voltmeter and ammeter, the product of volts and amperes will give the instantaneous power. Knowing the approximate value of a resistor (ohms) and the applied voltage across it, the power dissipated is given by the last formula.

Just as we can measure power dissipation in a resistance, we can determine the plate power input to a vacuum-tube transmitter, oscillator or amplifier, by the product of the measured plate voltage and plate current. Since the plate current is usually measured in *milliamperes* (thousandths of amperes), it is necessary to divide the product of plate volts and milliamperes by 1000 to give the result directly in watts.

Part C of the diagram, showing the variation of output of a generator with different resistance loads, suggests how a voltmeter and ammeter may be connected for measuring the power output of the generator or the power dissipated in the resistor. The power will be $E \times I$ in all cases, but this product will be zero in either A or B where either I or E is zero. As shown by the sketch the maximum power in the load (but not maximum efficiency) is obtained when the load resistance equals the internal resistance of the battery or generator.

Alternating Current Flow

▲ In all of these examples we have been assuming that direct currents are being considered. When we impress an alternating voltage on circuits such

as those discussed we will cause an alternating current to flow, but this current may not be of the same value as it would be with direct current. In many instances, such as that of a vacuum tube filament connected to a source of alternating current by short wires, the behavior of the circuit would follow Ohm's Law as it has been given and if alternating current meters were used to read

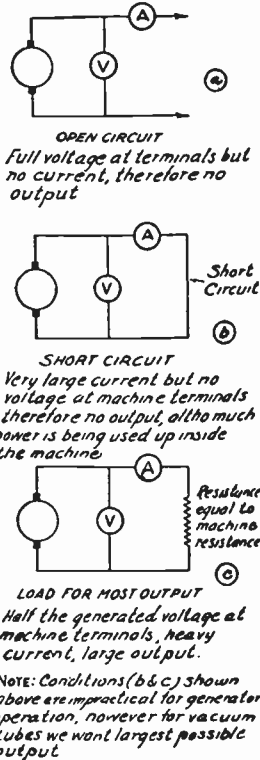


FIG. 304 — SHOWING THE VARIATION OF OUTPUT AS LOAD RESISTANCE IS CHANGED

the current and voltage we could compute the resistance of the circuit with sufficient accuracy for all ordinary practical purposes. Should there be a coil of wire in the circuit, however, or any electrical apparatus which is not a pure resistance, it would not necessarily be possible to apply our simple formula with satisfactory results. An explanation of the reason for this involves an understanding of the characteristics of other electrical apparatus, particularly of coils and condensers, which have very important parts to play in all radio circuits.

Electromagnetism

▲ When any electric current is passed through a conductor, magnetic effects are produced. *Moving electrons produce magnetic fields.* Little is known of the exact nature of the forces which

come into play but it is assumed that they are in the form of lines surrounding the wire; they are termed *lines of magnetic force*. It is known that these lines of force, in the form of concentric circles around the conductor, lie in planes at right angles to the axis of the conductor.

The magnetic field constituted by these lines of force exists only when current is flowing through the wire. When the current is started through the wire, we may think of the magnetic field as coming into being and sweeping outward from the axis of the wire. And on the cessation of the current flow, the field collapses toward the wire again and disappears. *Thus energy is alternately stored in the field and returned to the wire.* When a conductor is wound into the form of a coil of many turns, the magnetic field becomes stronger because there are more lines of force. The force is expressed in terms of *magneto-motive force (m.m.f.)* which depends on the number of turns of wire, the size of the coil and the amount of current flowing through it. The same magnetizing effect can be secured with a great many turns and a weak current or with fewer turns and a greater current. If ten amperes flow in one turn of wire, the magnetizing effect is 10 *ampere-turns*. Should one ampere flow in ten turns of wire, the magnetizing effect is also 10 ampere-turns.

The length of the magnetic circuit, the material of which it is made and the cross-sectional area, determine what *magnetic flux* (Φ) will be present. And just as the resistance of the wire determines what current will flow in the electric circuit, the *reluctance* (μ) of the magnetic circuit (depending on length, area and material) acts similarly in the magnetic circuit.

$$I = \frac{E}{R} \text{ in the electric circuit; so}$$

$$\Phi = \frac{m.m.f.}{\mu} \text{ in the magnetic circuit.}$$

The magnetic field about wires and coils may be traced with a compass needle or by sprinkling iron filings on a sheet of paper held about the coil through which current is passing. When there is an iron core the increased magnetic force and the concentration of the field about the iron are readily discernible.

Permeability is the ratio between the flux density produced in a material by a certain m.m.f. and the flux density that the same m.m.f. will produce in air. Iron and nickel have higher permeability than air. Iron has a permeability some 3000 times that of air, is of low cost, and is therefore very commonly used in magnetic circuits of electrical devices. The permeability of iron varies somewhat depending on the treatment it receives during manufacture. Soft iron has low *reluctivity*, another way of saying that its permeability is extremely high. The molecules of soft iron are readily turned end to end by bringing a current-

carrying wire or a permanent magnet near. When the influence is removed they just as quickly resume their former positions.

When current flows around a soft iron bar we have a *magnet*. When the circuit is broken so the current cannot flow, the molecules again assume their hit-or-miss positions. Little or no magnetic effect remains. When a steel bar is subjected to the same magneto-motive force in the same way, it has less magnetic effect. However, when the current is removed, the molecules tend to hold their end-to-end positions and we have produced a *permanent magnet*. Compass needles are made in this way. Permanent magnets lose their magnetism only when subjected to a reversed m.m.f., when heated very hot or when jarred violently.

Inductance

▲ The thought to be kept constantly in mind is that whenever a current passes through a coil it sets up a magnetic field around the coil; that the strength of the field varies as the current varies; and that the direction of the field is reversed if the direction of current flow is reversed. It is of interest now to find that the converse holds true—that if a magnetic field passes through a coil, an electro-motive force is *induced* in the coil; that if the applied field varies, the induced voltage varies; and that if the direction of the field is reversed, the direction of the current produced by the induced voltage is reversed. This phenomenon provides us with an explanation of many electrical effects. It serves in the present instance to give us some understanding of that valuable property of coils—*self-inductance*. Should we pass an alternating current through a coil of many turns of wire, the field around the coil will increase and decrease, first in one direction and then in the other direction. The varying field around the coil, however, will induce a varying voltage in the coil and the current produced by this induced voltage will always be in the opposite direction to that of the current originally passed through the wire. The result, therefore, is that because of its property of self-induction, the coil tends constantly to prevent any change in the current flowing through it and hence to limit the amount of alternating current flowing. The effect can be considered as electrical inertia. The formula for computing the inductance of radio-frequency coils is given in the Appendix; and data for iron-core coils in Chapter Ten.

The Reactance of Coils

▲ As we have said, a coil tends to limit the amount of current which an alternating voltage can send through it. A further very important fact is that a given coil with a fixed amount of inductance will impede the flow of a high frequency alternating current much more than a low frequency current. We know, then, that the characteristic of a coil in impeding an alternating

current flow depends both on the inductance of the coil and on the frequency of the current. This combined effect of frequency and inductance in coils is termed *reactance*, or *inductive reactance*.

The inductive reactance formula is:

$$X_1 = 2\pi fL$$

where: X_1 is the inductive reactance in ohms
 π is 3.1416
 f is the frequency in cycles per second
 L is the inductance in henries

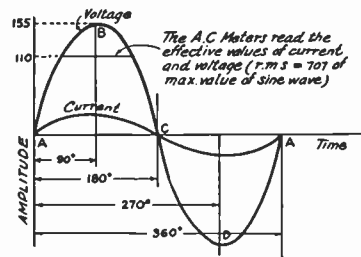
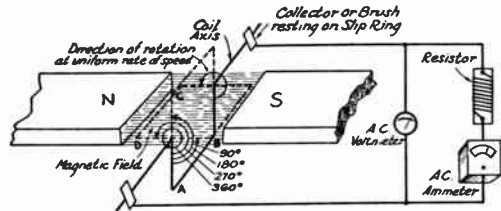
Transformers and Generators

▲ We have stated that if a magnetic field passes through a coil, an electromotive force is induced in the coil. Not only does this phenomenon provide us with an explanation of self-inductance in coils but it permits an understanding of how transformers and generators operate. Transformers are very widely used in radio work — their essential purpose being to convert an alternating current supply of one voltage to one of higher or lower voltage. In transmitters, for instance, there will be one or more transformers serving to step down the 110-volt supply voltage to 7.5, 10 or 11 volts for the filaments of the transmitting tubes. Then there will be another transformer to step up the 110-volt supply to 500, 1000 or perhaps several thousand volts for the plate supply of the transmitting tubes. These transformers will consist of windings on a square *core* of thin iron strips. The 110-volt supply will flow through a primary winding and the magnetic field created by this current flow, because it is common to all windings on the core, will induce voltages in all the windings. Should one of the secondary windings have twice the number of turns on the primary winding, the secondary voltage developed will be approximately twice that of the primary voltage. Should one of the secondary windings have one third of the primary turns, the voltage developed across the secondary will be one third the primary voltage. Direct current flowing in the primary of such a transformer would build up a magnetic field as the current started to flow but the field would be a fixed one. So long as the primary current remained steady there would be no voltages developed in the secondaries. This is the reason why transformers cannot be operated from a source of continuous direct current.

A somewhat similar arrangement is to be found in the alternating current generator — a simplified diagram of which is shown in Fig. 305. In one common form of alternator, the magnetic field is fixed and voltages are induced in the coil by its rotation in the field. The result is exactly similar to that which would be obtained if the coil was fixed and the field rotated around it. As the coil turns at a uniform rate from the vertical position, it is cut by an increasing number of magnetic lines of force and the induced voltage increases until it becomes a maximum when the

coil is horizontal. As the coil continues to rotate towards the vertical position the induced voltage decreases until it becomes zero when the coil is again in the vertical plane. When the coil continues its rotation from this position, the direction of the field with respect to the turns of the coil has now been reversed and the voltage between the ends of the coil has therefore been reversed also. As the coil continues its rotation, the voltage again climbs to a maximum and falls to zero when the coil reaches its original vertical position. In the actual generator, of course, the rotation of the coil (the armature) is very rapid. The speed of rotation in the elementary machine shown in the diagram would directly govern the frequency of the alternating voltage produced.

In the practical alternator, of course, the arrangement is much more complex and the electro-magnet which produces the field may have many pairs of poles. A similar machine is used to generate direct current. The chief difference in it is that a commutator is provided on its shaft to



SIMPLE ALTERNATOR CIRCUIT

Diagram shows instantaneous values of current and voltage with electrical degrees of coil rotation — there are 360 electrical degrees for every pair of poles so that one complete mechanical revolution may correspond to more than one electrical revolution.

FIG. 305

rectify the output of the armature. This process involves changing the direction of every alternate half-cycle — so causing all the pulses of voltage generated to be in the same direction.

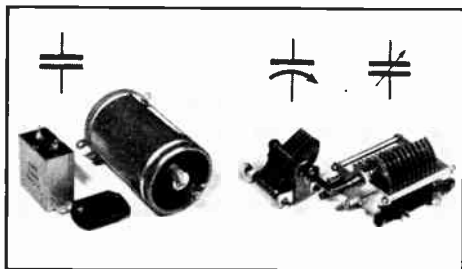
Condensers — Capacitance

▲ In radio circuits condensers play just as important a part as coils. Condensers and coils, in fact, are almost always used together. The condenser consists essentially of two or more metal plates separated by a thin layer of some

insulating medium from a second similar plate or set of plates. The insulating medium between the metal elements of the condenser is termed the *dielectric*. Unvarying direct current cannot flow through a condenser because of the insulation between the plates. But a steady voltage applied to the terminals of such a condenser will cause it to become charged. The effect, to return to a discussion of electrons, is simply that one element of the condenser is provided with an excess of electrons — thus becoming negatively charged — while the other plate suffers a deficiency of electrons and is therefore positively charged. Should the charging voltage be removed and the two elements of the condenser be joined with a conductor, a flow of electrons would take place from the negative to the positive plate. In other words, a current would flow.

The characteristic which permits a condenser to be charged in this manner is termed *capacity* or *capacitance*. The capacity of a condenser depends on the number of plates in each element, the area of the plates, the distance by which they are separated by the dielectric and the nature of the dielectric. Glass or mica as the dielectric in a condenser would give a greater capacity than air — other things being equal. The *dielectric constants* for different materials and the formula used for computing the capacity of condensers are to be found in the Appendix.

The unity of capacity is the *farad*. A condenser of one farad, however, would be so large that its construction would be impractical. A more com-



FORMS OF CONDENSERS

The variable condenser symbols are interchangeable. Both are widely used.

mon term in practical work is the *microfarad* (abbreviated $\mu\text{fd.}$) while another (used particularly for the small condensers in high-frequency apparatus) is the *micro-microfarad* (abbreviated $\mu\mu\text{fd.}$). The $\mu\text{fd.}$ is one millionth of a farad; the $\mu\mu\text{fd.}$ is one millionth of a microfarad.

A considerable variety of types of condensers is used in radio work. Perhaps the most commonly known type is the variable condenser — a unit comprising two sets of metal plates, one capable of being rotated and the other fixed and with the two groups of plates interleaving. In this case, the dielectric is almost invariably air. The fixed con-

denser is also widely used. One type consists of two sets of metal foil plates separated by thin sheets of mica, the whole unit being enclosed in molded bakelite. Yet another type — usually of high capacity — consists of two or more long strips of tin foil separated by thin waxed paper, the whole thing being rolled into compact form and enclosed in a metal can. Common units of this type have capacities of from one to four microfarads.

Alternating Current in a Condenser

▲ We can readily understand how very different will be the performance of any condenser when direct or alternating voltages are applied to it. The direct voltages will cause a sudden charging current, but that is all. The alternating voltages will result in the condenser becoming charged first in one direction and then the other — this rapidly changing charging current actually being the equivalent of an alternating current through the condenser. Many of the condensers in radio circuits are used just because of this effect. They serve to allow an alternating current to flow through some portion of the circuit but at the same time prevent the flow of any direct current.

Capacitive Reactance

▲ Of course, condensers do not permit alternating currents to flow through them with perfect ease. They impede an alternating current just as an inductance does. The term *capacitive reactance* is used to describe this effect in the case of condensers. Unlike inductances, condensers have a reactance which is *inversely* proportional to the condenser size and to the frequency of the applied voltage. The formula for capacitive reactance is

$$X_c = \frac{1}{2\pi f C_{td}}$$

where X_c is the capacitive reactance in ohms

π is 3.1416

f is the frequency in cycles per second

C_{td} is the condenser capacitance in farads.

Where the capacitance is in microfarads ($\mu\text{fd.}$), as it is in most practical cases, the formula becomes

$$X_c = \frac{10^6}{2\pi f C_{\mu\text{fd.}}}$$

10^6 being 1,000,000.

Condenser Connections

▲ Capacitances can be connected in series or in parallel like resistances or inductances. However, connecting condensers in parallel makes the total capacitance *greater* while in the case of resistance and inductance, the value is lessened by making a parallel connection.

The equivalent capacity of condensers con-

nected in parallel is the sum of the capacities of the several condensers so connected:

$$C = C_1 + C_2 + C_3$$

The equivalent capacity of condensers connected in series is expressed by the following formula which can be simplified as shown when but two condensers are considered:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}; \quad C = \frac{C_1 C_2}{C_1 + C_2}$$

It is sometimes necessary to connect filter condensers in series. This increases the break-down voltage of the combination although, of course, it decreases the capacity available. Condensers of identical capacitance are most effectively connected in series for this purpose. Voltage tends to divide across series condensers in inverse proportion to the capacity, so that the smaller of two series condensers will break down first if the condensers are of equal voltage rating. Before selecting filter condensers the operating conditions, voltage peaks and r.m.s. values should be carefully considered. For complete information on this matter the chapter on Power Supply should be consulted.

Distributed Inductance, Capacity and Resistance

▲ So far we have considered three very important properties of electrical circuits and apparatus: Resistance, inductance and capacity. Resistors, coils and condensers are all built to have as much as possible of one of these properties with as little as possible of the other two. These "lumped" properties can then be utilized in a circuit to produce the required effect on the current and voltage distribution. In every sort of coil and condenser, however, we find not just the one property for which the instrument is used but a combination of all the electrical properties we have mentioned. And for this reason most design work is somewhat of a compromise. Every coil and transformer winding has resistance and distributed capacity between the turns in addition to the inductance that makes it a useful device. Then, every condenser has some resistance. Resistors, as another example, quite often have appreciable inductance and distributed capacity.

Ohm's Law for Alternating Current

▲ We start to realize the importance of these characteristics just as soon as we endeavor to apply Ohm's Law to circuits in which alternating current flows. If inductances did not have any resistance we could assume that the current through the coil would be equal to the voltage divided by the reactance. But the coil will have resistance, and this resistance will act with the reactance in limiting the current flow. The combined effect of the resistance and reactance is termed *impedance* in the case of both coils and

condensers. The symbol for impedance is Z and it is computed from this formula:

$$Z = \sqrt{R^2 + X^2}$$

where R is the resistance of the coil and where X is the reactance of the coil. The terms Z , R and X are all expressed in ohms. Ohm's Law for alternating current circuits then becomes

$$I = \frac{E}{Z} \quad Z = \frac{E}{I} \quad E = IZ$$

In finding the current flow through a condenser in an alternating current circuit we can often assume that $I = \frac{E}{X_c}$ (X_c being the capacitive reactance of the condenser). The use of the term Z (impedance) is, in such cases, made unnecessary because the resistance of the usual good condenser is not high enough to warrant consideration. When there is a resistance in series with the condenser, however, it can be taken into account in exactly the same manner as was the resistance of the coil in the example just given. The impedance of the condenser-resistance combination is then computed and used as the Z term in the Ohm's Law formulas.

The Sine Wave

▲ In Fig. 305, illustrating the action of the alternator in generating an alternating voltage, a curve indicating the voltage developed by the alternator during one complete cycle was shown. This curve, as obtained with a theoretically perfect alternator, is known as a *sine* curve. All the formulas given for alternating current circuits have been derived with the assumption that any alternating voltage under consideration would follow such a curve. It is evident that both the voltage and current are swinging continuously between their positive maximum and negative maximum values, and the beginner must wonder how one can speak of so many amperes of alternating current when the value is changing continuously. The problem is simplified in practical work by considering that an alternating current has a value of one ampere when it produces heat at the same average rate as one ampere of continuous direct current flowing through a given resistor. This *effective* value of an alternating current, if it truly follows a sine curve or has a *sinusoidal wave form*, is equal to the maximum or peak value divided by 1.41, the square root of 2. Similarly, the effective value of an alternating voltage is its peak value divided by 1.41.

Another important value, involved where alternating current is rectified to direct current, is the *average*. This is equal to .636 of the maximum (or peak) value of either current or voltage. The three terms *maximum* (or *peak*), *effective* (or *r.m.s.*) and *average* are so important and are encountered so frequently in radio work that they should be fixed firmly in mind right at the start.

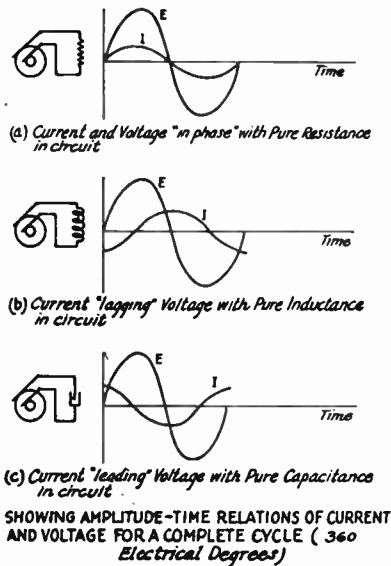


FIG. 306

They are related to each other as follows:

$$E_{\max} = E_{\text{eff}} \times 1.414 = E_{\text{ave}} \times 1.57$$

$$E_{\text{eff}} = E_{\max} \times .707 = E_{\text{ave}} \times 1.11$$

$$E_{\text{ave}} = E_{\max} \times .636 = E_{\text{eff}} \times .9$$

The relationships for current are the same as those given above for voltage. The usual alternating current ammeter or voltmeter gives a direct reading of the effective or r.m.s. (root mean square) value of current or voltage. A direct current ammeter in the plate circuit of a vacuum tube approximates the average value of rectified plate current. Maximum values can be measured by a peak vacuum-tube voltmeter such as is described in the chapter on Radiotelephony.

Phase Angle

▲ It has been mentioned that in a circuit containing inductance, the rise of current is delayed by the effect of electrical inertia presented by the inductance. Both increases and decreases of current are similarly delayed. It is also true that a current must flow into a condenser before its elements can be charged and so provide a voltage difference between its terminals. Because of these facts, we say that a current "lags" behind the voltage in a circuit which has a preponderance of inductance and that the current "leads" the voltage in a circuit where capacity predominates. Fig. 306 shows three possible conditions in an alternating current circuit. In the first, when the load is a pure resistance, both voltage and current rise to the maximum values simultaneously. In this case the voltage and current are said to be *in phase*. In the second instance, the existence of inductance in the circuit has caused the current

to lag behind the voltage. In the diagram, the current is lagging one quarter cycle behind the voltage. The current is therefore said to be 90 degrees *out of phase* with the voltage (360 degrees being the complete cycle). In the third example, with a capacitive load, the voltage is lagging one quarter cycle behind the current. The *phase difference* is again 90 degrees. These, of course, are theoretical examples in which it is assumed that the inductance and the condenser have no resistance. Actually, the angle of lag or lead depends on the ratio of reactance to resistance in the circuit.

Power Factor

▲ In a direct current circuit or in an alternating current circuit containing only resistance, the power can be computed readily by multiplying the voltage by the current. But it is obviously impossible to compute power in this fashion for an alternating current circuit in which the current may be maximum when the voltage is zero; or for any case in which the voltage and current are not exactly in phase. In computing the power in an a.c. circuit we must take into account any phase difference between current and voltage. This is made possible by the use of a figure representing the *power factor*.

The power factor is equal to the actual power in the circuit (watts) divided by the product of the current and voltage (volt amperes). In terms of a circuit property, it is equal to the resistance divided by the impedance in the circuit. In the case of a circuit containing resistance only, the ratio and, hence, the power factor, is 1 or 100% (unity). If there is reactance only in the circuit (zero resistance), then the power factor is zero. In circuits containing both resistance and reactance the power factor lies between these two values. As instances, a good condenser should have nearly zero power factor, as should a good choke coil. Resistors for use in a.c. circuits should, on the other hand, have a power factor approaching 100%.

Practical Problems

▲ It is surprising how many practical uses may be found for the fundamental information and formulas set forth in this chapter. A brief study of the equations and explanations with the few examples that will now follow will enable you to apply Ohm's Law and other electrical relations to determining practical things that arise in planning, building and operating even the simplest amateur station equipment. The problems which follow will serve as examples of some of the different things taken up in this chapter.

Plate Power Input

▲ A certain transmitter has an output stage in which a single 203-A tube is employed. A high-voltage voltmeter is connected across the plate

supply circuit and a milliammeter of suitable range used in the circuit so as to measure the current of this tube only. We have seen that $P = E \times I$. Therefore, assuming that the meters read 1125 volts and 125 milliamperes, the plate input

power will be $1125 \times \frac{125}{1000} = 140.6$ watts.

Resistance of a Grid Leak

▲ It is necessary to determine whether a resistor has a resistance which would make it suitable for a grid leak for a Type 10 transmitter, either used separately or in connection with other resistors of the same type. A 90-volt B-battery and a 0-50 ma. scale milliammeter are available. The battery is connected to the unknown resistor through the meter which is observed to read 10 milliamperes. The resistance is next calculated from Ohm's Law: $R = E/I$. $90 \div .010 = 9000$ ohms.

Measuring Grid Bias Voltage

▲ When the grid-leak resistance is known, the current through the grid leak measured by a milliammeter of suitable range enables us to calculate the voltage drop across the resistor, which is the same as the bias between grid and filament. For example, 9000-ohm resistor is used biasing a Type 10 tube in the r.f. amplifier stage of a small oscillator-amplifier transmitter. A milliammeter connected in series with the resistors reads 21 milliamperes. Calculating the voltage drop by Ohm's Law ($E = RI$) we have the bias as $9000 \times .021$, which equals 189 volts (a high value).

Resistance Value for Dropping Plate Voltage

▲ The transformer output goes to a tube rectifier through a filter which has a 70-henry choke in one lead. After keying in the negative lead the current passes through a 3-henry "keying" filter choke to the plates of two Type 10 tubes. There is some voltage drop in the rectifier tubes and in the resistance of the two choke-coil windings. In addition to this, a resistor may be added in series with the keying choke winding to drop the voltage further so our tube will operate normally with about 400 volts d.c. on its plate. The proper size of this resistor is quickly found by using Ohm's Law. If it is desired to produce a *drop in voltage* of about 100 volts, divide this value by the estimated plate current, let us say 100 ma. or .1 ampere. ($R = E/I$)

$$\frac{100}{.1} = 1000 \text{ ohms.}$$

Size Resistor to Handle a Given Current

▲ In purchasing resistors, be sure they are of ample size to dissipate the heat that will be produced by the current they will have to carry. The power that must be dissipated in heating is $W = I^2R$ (watts).

$1000 \times .1^2 = 10$ watts, which must be dissipated by the resistor for dropping the plate voltage to two Type 10 tubes. Examining manufacturers' lists, this size can be used, but a 20-watt resistor is recommended to give long life and keep the maximum temperatures low. It is best to allow 40 per cent or 50 per cent factor of safety, since resistors are usually rated for their maximum allowable dissipation mounted in free space. Actually, the heat radiation is limited by mounting resistors near other apparatus. Heat also should be kept away from filter condensers or any other apparatus whose life varies inversely with temperature.

Transformer Output Current to Resistance Load

▲ The transformer is rated at 100 watts (v.a.) which means that it will deliver

$$I = \frac{W}{E} = \frac{100}{1100} = 90.9 \text{ ma.}$$

Capacities

▲ A fixed condenser of 250 μfd . is connected in parallel with two variable air condensers having a maximum capacitance of 140 μfd . and .0005 μfd ., respectively. What is the total capacitance obtainable for any adjustment or setting of the condensers? First it is necessary to change the ratings to either microfarads or micro-microfarads to get the three units on the same basis. The answer will be either:

$$250 + 140 + 500 = 890 \mu\text{fd. (micro-microfarads)}$$

or

$$.00025 + .00014 + .0005 = .00089 \mu\text{fd. (micro-farads).}$$

Assume the three capacities to be connected in series. Let us determine the equivalent lumped capacity:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{250} + \frac{1}{140} + \frac{1}{500} =$$

$$.004 + .00715 + .002 = .01315$$

$$C = 76.04 \mu\text{fd. (micro-microfarads).}$$

Condenser Reactance

▲ A high-voltage power-supply transformer may, under certain conditions, require protection of the windings from voltages built up due to leakage of high-frequency currents back through r.f. chokes and the filter, or due to r.f. induced in power-supply leads located in the field of the high-power stage of a transmitter. The same circumstances can cause break-down of insulation in filament transformers. At any rate it will be assumed that we have a 7200-ke. transmitter and that it is desired to connect a small condenser across the high-voltage winding to by-pass current of this radio frequency. Remembering that *the higher the frequency is, the lower the reactance of a condenser*, we judge that a small condenser

will sufficiently by-pass the radio-frequency current, preventing the undesired r.f. voltage from building up across our transformer winding (or a choke coil, milliammeter or other piece of apparatus could be protected similarly).

Finding a .02- μ f. mica-insulated transmitting condenser available, rated to withstand 2000 volts, we decide to consider what may happen if we connect it across the transformer secondary.

First of all to see if it will be practical and accomplish the result we want, let's find (a) what the reactance of the condenser to the 7200-kc. (7,200,000-cycle) voltage which has strayed into the circuit will be; and (b) what the reactance will be to the 60-cycle source. In the formula the units are cycles and farads so we must remember to use the proper conversion factors.

$$\begin{aligned} \text{(a) } X_c &= 1 \div 2\pi fC \\ &= 1 \div 6.28 \times 7,200,000 \times .02 \times 10^{-6} \\ &= 1 \div 6.28 \times 7.2 \times .02 \\ &= 1/.904 \\ &= 1.105 \text{ ohms} \end{aligned}$$

reactance at this frequency. This is an extremely low value which will readily by-pass r.f. and prevent any harmful voltages building up across an inductance.

$$\begin{aligned} \text{(b) } X_c &= 1 \div 2\pi fC \\ &= 1 \div 6.28 \times 60 \times .02 \times 10^{-6} \\ &= 132,800 \text{ ohms} \end{aligned}$$

reactance at 60 cycles.

Current Through a Reactance

▲ The transformer is a small one and so we cannot be sure until we figure it out whether the secondary current taken by the protective condenser and the set combined will be likely to overheat the transformer or not. The plate transformer we happen to have has a ratio of 10:1 and delivers 1100 volts (effective value) when run normally. The 60-cycle current through the condenser will be:

$$\begin{aligned} I &= \frac{E}{X_c} = \frac{1100}{132,800} = .0083 \text{ amperes} \\ &= 8.3 \text{ ma.} \end{aligned}$$

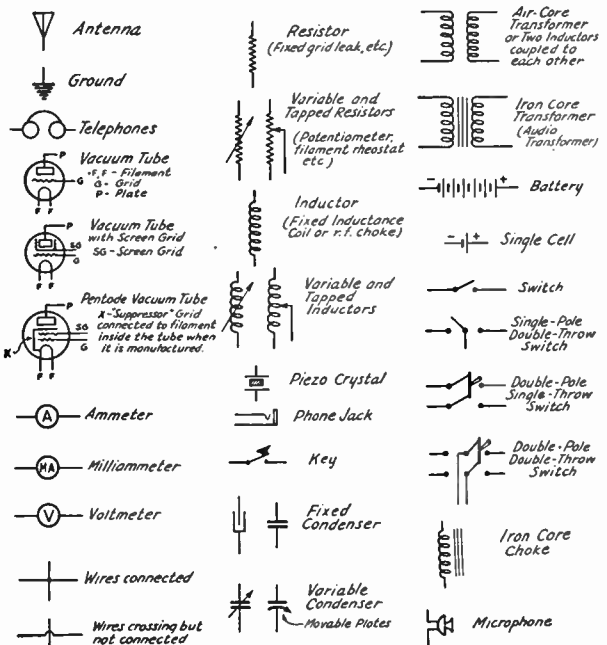
Reading Diagrams — Schematic Symbols

▲ Schematic diagrams show the different parts of a circuit in skeleton form. Pictures show the apparatus as it actually appears in the station or laboratory. A little study of the symbols used in schematic diagrams will be helpful in understanding the circuits that appear in *QST* and in most radio books. The diagrams are easy to understand once we have rubbed shoulders with some real apparatus and read about it. Schematic

diagrams are used in all electrical work because they save so much space and time when discussing the various circuits. Photographs of apparatus show the actual arrangement used but the wiring is not as clear as in the schematic diagrams. In building most apparatus a schematic diagram and a photograph will make everything clear. It is suggested that the beginner carefully compare a few pictures and schematic diagrams if not entirely familiar with the latter.

The symbols used in schematic diagrams throughout this book will be easily understood by reference to the Fig. below. Most of the diagrams shown are plainly labelled or worded so that it is only necessary to know the general scheme which differentiates coils, condensers, and resistors to read the diagram. Reference to the text will help in understanding fully what is intended, since diagrams and text have been prepared to complement each other. In general, coils are indicated by a few loops of wire, resistances by a jagged line, and variable elements in the circuit by arrowheads. If a device has an iron core it is usually shown by a few parallel lines opposite the loops indicating coils or windings.

SCHEMATIC SYMBOLS USED IN CIRCUIT DIAGRAMS



When you can draw and talk about circuits in terms of the various conventional symbols you are on what is familiar ground to every amateur and experimenter. Then you can meet the dyed-in-the-wool expert and understand what he talks about.

RADIO FUNDAMENTALS

IN OUR discussion of fundamental principles, we have seen how a flow of electrons through a wire constitutes an electric current, and how this current, under certain conditions, gives rise to electric and magnetic effects as changes in the current flow take place. In addition to the effect which resistance produces in direct and alternating current circuits, we have learned how an inductance or coil tends to prevent any change in the current flowing through it because of the existence, around the coil, of a magnetic field, which varies in strength with every variation in the current flow. We have also seen how this field around a coil can link with the turns of a second coil, so inducing voltages in it — voltages which vary in accordance with the changes in the original current flow. Further, we have seen how a condenser can be charged by an applied voltage and how the energy represented by this charge can cause a current to flow in any conductor which is connected across the condenser terminals. Lastly, we have learned that in an alternating current circuit, inductance causes the current to lag behind the voltage while capacity causes the current to lead the voltage.

Equipped with an understanding of these principles we are now ready to study inductance, capacitance and resistance as combined in the circuits of our radio transmitters, receivers and other equipment. Examination of the circuit diagram of almost any piece of radio equipment will reveal one or more combinations of coil and condenser (inductance and capacitance) and, hence, of inductive reactance and capacitive reactance. Let us now consider how they work together to form the *tuned circuit*.

The Tuned Circuit

▲ Let us assume that a condenser *C* and coil *L* are connected as shown in Fig. 401, and that the condenser is initially charged as indicated in A, one plate having a surplus of electrons and therefore being negative while the other plate, being correspondingly deficient in electrons, is positive. The instant that the condenser plates are con-

nected together through the coil *L* there will start a flow of current as shown by the arrow in B. The rate of flow of current will be retarded by the inductive reactance of the coil and the discharge of the condenser will not be instantaneous even though the velocity of flow is constant. As the current continues to flow from the condenser into the coil, the energy initially stored in the condenser as an electrostatic field will become stored in the electromagnetic field of the coil. When substantially all the energy in the circuit has become stored in this field the lines of force about the coil begin to collapse, and thus cause

a continued flow of current through the circuit, the flow being in the same direction as the initial current. This again charges the condenser *but in opposite polarity to the initial charge*. Then, when all the energy again has been stored in the condenser, the sequence is repeated in the opposite direction. The process is one of *oscillation*. During one complete cycle the energy is alternately stored in the condenser and in the coil twice, and there is one reversal in the direction of current flow. This represents a complete cycle of alternating current. The process would continue indefinitely were there only inductance and capacitance in the circuit but, as has been pointed out in Chapter Three, all circuits contain some resistance. Therefore during each cycle a part of the energy will be dissipated in the resistance as heat, each cycle will be of lesser amplitude than the preceding one and the process will finally stop because there is no longer energy

to sustain it. This *damping* caused by resistance is overcome in practical circuits by continuously supplying energy to replace that dissipated in resistance of one form or another, as will be shown later.

Oscillation Frequency and Resonance

▲ In such an oscillatory circuit, the larger the coil is made the greater will be its inductance and the longer will be the time required for the condenser to discharge through it. Likewise, the larger the

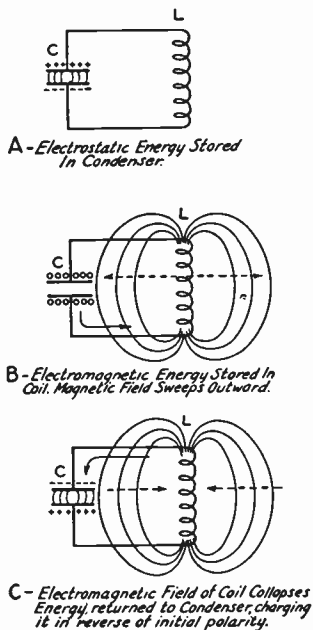


FIG. 401 — A HALF-CYCLE OF OSCILLATION IN A RESONANT CIRCUIT

condenser and the greater its capacitance, the longer it will take to charge or discharge it. Since the velocity of the current flow is substantially constant, it is clear that the circuit with the larger coil or condenser is going to take a longer period of time to go through a complete cycle of oscillation than will a circuit where the inductance and capacitance are small. Putting it differently, the number of cycles per second will

$$X_1 = X_c \text{ or } 2\pi fL = \frac{1}{2\pi fC}$$

The resonant frequency is, therefore,

$$f = \frac{1}{2\pi\sqrt{LC}} \times 10^6$$

where

f is the frequency in kilocycles per second

2π is 6.28

L is the inductance in microhenries (μh .)

C is the capacitance in micro-microfarads ($\mu\mu\text{fd}$.)

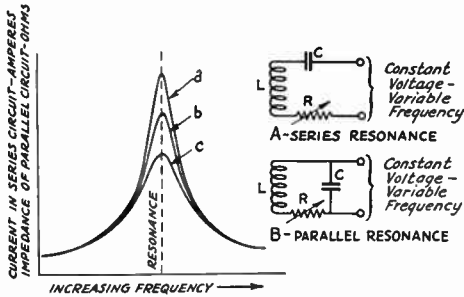


FIG. 402 — CHARACTERISTICS OF SERIES AND PARALLEL RESONANT CIRCUITS

be greater as the inductance and capacitance values become smaller. Hence the smaller the coil or condenser, or both, in the tuned circuit, the higher will be the frequency of oscillation.

The important practical aspect of all this is that in any circuit containing capacitance, inductance and not too much resistance, the introduction of a pulse of electrical energy will cause an alternating current oscillation of a frequency determined solely by the values of inductance and capacitance; and that for any combination of inductance and capacitance there is one particular frequency of applied voltage at which current will flow with the greatest ease. Recalling the explanations of inductive reactance and capacitive reactance given in Chapter Three, this becomes readily understandable. It has been shown that the inductive reactance of the coil and the capacitive reactance of the condenser are oppositely affected with frequency: Inductive reactance increases with frequency; capacitive reactance decreases as the frequency increases. In any combination of inductance and capacitance, therefore, there is one particular frequency for which the inductive and capacitive reactances are equal and, since these two reactances oppose each other, for which the net reactance becomes zero, leaving only the resistance of the circuit to impede the flow of current. The frequency at which this occurs is known as the *resonant frequency* of the circuit and the circuit is said to be *in resonance* at that frequency or *tuned* to that frequency.

In practical terms, since at resonance the inductive reactance must equal the capacitive reactance, then

Series and Parallel Resonance — Effect of Resistance

▲ In the simple tuned circuit just discussed the elements, inductance and capacitance, were considered with respect to each other but not in combination with other circuit elements as they are usually encountered in practical applications. In our radio transmitters, and in receivers as well, the tuned circuit is invariably associated with a source of electrical energy and also is usually coupled to still other circuits to which it transfers energy.

All practical tuned circuits can be treated as either one of two general types. One is the *series resonant* circuit in which the inductance, capacitance, resistance and source of voltage are in series with each other. With a constant-voltage alternating current applied as shown in A of Fig. 402 the current flowing through such a circuit will be maximum at resonant frequency. The magnitude of the current will be determined by the resistance in the circuit. The curves of Fig. 402 illustrate this, curve *a* being for minimum resistance and curves *b* and *c* being for greater resistances.

The second general case is the parallel resonant circuit illustrated in B of Fig. 402. This also contains inductance, capacitance and resistance in series, but the voltage is applied in parallel with the combination instead of in series with it as in A. Here we are not primarily interested in the current flowing *through* the circuit but in its characteristics as viewed from its terminals, especially in the *parallel impedance* it offers. The variation of parallel impedance of a parallel resonant circuit with frequency is illustrated by the same curves of Fig. 402 that show the variation in current with frequency for the series resonant circuit. The parallel impedance is maximum at resonance and increases with decreasing series resistance. Although both series and parallel resonant circuits are generally used in radio work, the parallel resonant circuit is most frequently found, as inspection of the diagrams of the equipment described in subsequent chapters will show.

High parallel impedance is generally desirable in the parallel resonant circuit and low series

impedance is to be sought in series resonant circuits. Hence low series resistance is desirable in both cases. At frequencies other than resonance frequency, the series resonant circuit has capacitive reactance for frequencies below resonance and inductive reactance for frequencies above resonance frequency, while the parallel resonant circuit offers inductive reactance at frequencies below resonance and capacitive reactance for frequencies above resonance.

It is to be noted that the curves become "flatter" for frequencies near resonance frequency as the resistance is increased, but are of the same shape for all resistances at frequencies further removed from resonance frequency. The relative sharpness of the resonance curve near resonance frequency is a measure of the sharpness of tuning or selectivity (ability to discriminate between voltages of different frequencies) in such circuits. This is an important consideration in tuned circuits used for radio work. Since the effective resistance is practically all in the coil, the condenser resistance being negligible, the efficiency of the coil is the important thing determining the "goodness" of a tuned circuit. A useful measure of coil efficiency, and hence of tuned circuit selectivity, is the ratio of the coil's reactance to its effective resistance. This ratio will be recognized as an approximation of the reciprocal of the circuit property of power factor discussed in Chapter Three, and is designated by Q .

$$Q = \frac{2\pi fL}{R}$$

A Q of 100 would be considered high for coils used at the lower amateur frequencies, while the Q of coils at still lower frequencies may run into the hundreds.

Coupled Circuits

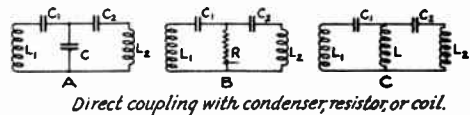
Resonant circuits are not found in an isolated state in very many instances but are usually associated with other resonant circuits or are coupled to other circuits. It is by such coupling that energy is transferred from one circuit to another. Such coupling may be direct, as shown in A, B and C of Fig. 403, utilizing as the common coupling element, capacitance (A), resistance (B) or inductance (C). These three types of coupling are known as direct capacitive, direct resistive or direct inductive, respectively. Current circulating in the L_1C_1 branch flows through the common element (C , R or L) and the voltage developed across this element causes current flow in the C_2L_2 branch. Other types of coupling are the indirect capacitive and magnetic or inductive shown below the others. The coupling most common in high-frequency circuits is of the latter type. In such an arrangement the coupling value may be changed by changing the number of active turns in either coil or by changing the relative position

of the coils (distance or angle between them). The arrangement then performs in a manner similar to the transformer described in the previous chapter.

All of the above coupling schemes may be classified as either tight or loose. Coupling cannot, however, be measured simply in "inches" separation of coils. The separation between the coils (distance and angle between axes) and the inductance in each determine the coefficient of coupling. Many turns in two coils very close together give us tight coupling and a big transfer of power. Few turns at right angles or far apart give us loose coupling with little actual energy transfer. "Tight" coupling is not necessarily the best coupling, it should be kept in mind. Too-tight coupling will give a double-humped resonance effect and should be avoided.

Radio Frequency Resistance — Skin Effect

The effective resistance of conductors at radio frequencies may be hundreds of times the "ohmic" resistance of the same conductors as it would be measured for direct current or low frequency alternating current. This is largely due to the skin effect, so called because the current tends to concentrate on the outside of the conductor, leaving the inner portion carrying little or no current. It is for this reason that hollow copper tubing is widely used in the coils and connections of high-frequency circuits. However, the current may not be distributed uniformly over the surface. With flat conductors the current tends to concentrate at the edges and with square conductors it tends to concentrate at the corners. Hence the popularity of round copper tubing in radio transmitters. In addition to the skin effect,



Direct coupling with condenser, resistor, or coil.



Indirect Capacitive Coupling Magnetic Coupling
FIG. 403 — COMMON TYPES OF COUPLED CIRCUITS

dielectric losses due to insulators and resistance losses in other conductors in the field of the conductor contribute to its effective resistance. The effective resistance is measured as the power in the circuit divided by the square of the maximum effective radio-frequency current.

Circuits with Distributed Constants — The Antenna

In addition to resonant circuits containing lumped capacitance and inductance, there are important tuned circuits in which no condensers and coils are to be found. Such circuits utilize the

distributed capacitance and inductance that are inevitable even in a circuit consisting of a single straight conductor. Our transmitting and receiving antennas are such circuits and depend on their distributed capacitance and inductance for tuning. A peculiarity of such a "linear" circuit is that when it is excited at its resonant frequency the current or voltage, as measured throughout its length, will have different values at different points. For instance, if the wire happens to be one in "free space" with both ends open circuited (in other words, a Hertz antenna), when it is excited at its resonant frequency *the current will be maximum at the center and zero at the ends*. On the other hand, *the voltage will be maximum at the ends and zero at the center*. The explanation of this is that the traveling waves on the wire are reflected when they reach an end. Succeeding waves traveling toward the same end of the wire (the *incident waves*) meet the returning waves (*reflected waves*) and the consequence of this meeting is that currents add up at the center and voltages cancel at the center; while voltages add up at the ends and currents cancel at the ends. A continuous succession of such incident and reflected waves therefore gives the effect of a *standing wave* in the circuit.

Frequency and Wavelength — Harmonic Operation

▲ Instead of specifying the properties of a linear circuit such as the antenna in terms of inductance

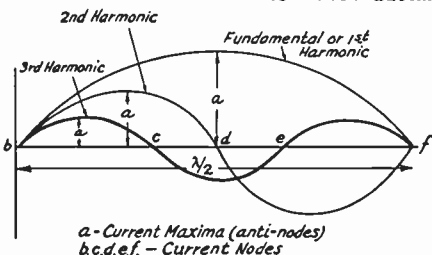


FIG. 404 — CURRENT DISTRIBUTION IN AN ANTENNA OPERATING AS A LINEAR OSCILLATORY CIRCUIT AT ITS FUNDAMENTAL, AND SECOND AND THIRD HARMONICS

and capacitance it is customary to do so simply in terms of length. This is possible because the length of such a circuit will be inversely proportional to its resonant frequency, since the velocity of the waves is practically identical for conductors of various materials, lengths and diameters. This velocity is given as three hundred million meters per second, corresponding to 186,000 miles per second. The *wavelength* is equal to the velocity divided by the frequency, and is usually expressed in meters and designated by the Greek letter λ . In practical terms,

$$\lambda = \frac{300,000}{f_{kc.}}$$

where $f_{kc.}$ is the frequency in kilocycles.

The length of an antenna is specified in terms of the wavelength corresponding to the lowest frequency at which it will be resonant. This is known as its *fundamental frequency* or *wavelength*. As will be shown in the chapter on Antennas, this length is (very nearly) a half-wavelength for an ungrounded (Hertz) antenna and a quarter-wavelength for a grounded (Marconi) antenna. Therefore it is common to describe antennas as *half-wave*, *quarter-wave*, etc., for a certain frequency ("half-wave 7000-kc. antenna," for instance).

Although a coil-condenser combination having lumped constants (capacitance and inductance) resonates at only one frequency, linear circuits such as antennas containing distributed constants resonate readily at frequencies which are integral multiples of the fundamental frequency (or wavelengths that are integral fractions of the fundamental wavelength). These frequencies are therefore in *harmonic* relationship to the fundamental frequency and, hence, are referred to as *harmonics*. In radio practice the fundamental itself is called the *first harmonic*, the frequency twice the fundamental is called the *second harmonic*, and so on. For example, a Hertz antenna having a fundamental of 1790 kc. (in the amateur 1750-kc. band) also will oscillate at the following harmonic frequencies: 3580 kc. (2nd), 5370 kc. (3rd), 7160 kc. (4th), 8950 kc. (5th), 10,740 kc. (6th), 12,530 kc. (7th) and 14,320 kc. (8th). Hence the one antenna can be used for four amateur bands, resonating at its first, second, fourth and eighth harmonics. A "free" antenna (Hertz) may be operated at the fundamental or any harmonic frequency, odd or even; a grounded (Marconi) type only at its fundamental or harmonics that are *odd* multiples of the fundamental frequency.

Fig. 404 illustrates the distribution of the standing waves on a Hertz antenna for its fundamental, second and third harmonics. There is one point of maximum current with fundamental operation, there are two when operation is at the second harmonic and three at the third harmonic; the number of current maxima corresponds to the order of the harmonic and the number of standing waves on the wire. As noted in the figure, the points of maximum current are called *anti-nodes* (also known as "loops") and the points of zero current are called *nodes*.

Because the velocity of the waves on the conductor (antenna) is essentially the same as that for the radio waves in space, wavelength is used interchangeably with frequency in describing not only antennas but also for tuned circuits, complete transmitters, receivers, etc. Thus the terms "high-frequency receiver" and "short-wave receiver," or "75-meter fundamental antenna" and "4000-kilocycle fundamental antenna" are synonymous. A chart showing the relationship between frequencies and wavelengths, including those of the amateur bands, is given in the Appen-

dix. The resonance equation of a tuned circuit, previously given for frequency, is expressed in terms of wavelength as follows:

$$\lambda = 1.885\sqrt{L_{\mu h}C_{\mu fd}},$$

where

λ is the wavelength in meters

$L_{\mu h}$ is the inductance in microhenries

$C_{\mu fd}$ is the capacitance in micro-microfarads.

Radiation By Antennas

▲ So far we have discussed the antenna with respect to its ability to perform as a resonant circuit. We now come to the practical use that is made of the energy that oscillates in the antenna. It will be remembered that in the preceding chapter it was shown that current flow in a conductor was accompanied by a magnetic field about the conductor; and that with an alternating current the energy was alternately stored in the field in the form of lines of magnetic force and returned to the wire. Now this is quite true when the alternating current is of low frequency, such as the 60-cycle kind commonly used. But when the frequency becomes higher than 15,000 cycles or so (radio frequency) all the energy stored in the field is not returned to the conductor but some escapes in the form of electro-magnetic waves. In other words, energy is radiated. This we know. Just how radiation occurs is not clearly understood at the present time. But we know enough for practical purposes about what happens in the antenna and about how the waves behave after leaving the antenna.

Some radiation will occur with any conductor that has high-frequency current flowing in it but the radiation is greatest when the antenna is resonant to the frequency of the current. If the antenna is essentially "in free space" (isolated from other wires, pipes, trees, etc., that might absorb energy from it), nearly all the energy put into it will be radiated as radio waves. As was seen in the paragraph on "Radio-Frequency Resistance," the radio-frequency resistance is equal to the actual power in the circuit divided by the square of the maximum current. Energy radiated by an antenna is equivalent to energy dissipated in a resistor. The value of this equivalent resistance is known as *radiation resistance*. Its average value for a Hertz (ungrounded) antenna operating at its fundamental frequency is approximately 70 ohms; and for a Marconi (grounded) antenna operating at its fundamental is about half this value, or 35 ohms. Since it is impossible to measure radio-frequency power directly with ordinary instruments, the approximate value of the power in an antenna can be computed by multiplying its assumed radiation resistance by the square of the maximum current (the current at the center of a fundamental Hertz antenna).

$$\text{Antenna power (watts)} = \text{Radiation resistance (ohms)} \times \text{Current Squared (Amperes}^2\text{)}$$

The antenna must, of course, be coupled to the transmitting equipment that generates the radio-frequency power. Practical methods of doing this are described in Chapter Twelve, together with details of the antenna systems most useful in amateur transmission.

The receiving antenna is the reciprocal of the transmitting antenna in operation. Whereas radio-frequency current in the transmitting antenna causes the radiation of electro-magnetic waves, the receiving antenna intercepts such waves and has a voltage induced in it. This voltage causes a flow of radio-frequency current of identical frequency to the radio receiver and through its tuned circuits. Generation of radio-frequency power by the transmitter and reception of radio-frequency waves will now be discussed further.

The Vacuum Tube — Rectification

▲ The most universally used device in radio communication is the vacuum tube. It works to change alternating to direct current in our power supplies, to amplify sound from a whisper to a roar, to generate the radio-frequency power used in transmission and to amplify and detect weak radio waves in our receiver. Vacuum tubes appear in many sizes and in a variety of structures. But all operate on the same principle. Most commonly, the vacuum tube has a glass bulb from which practically all air and other gas has been removed, and within which there are two or more elements, ranging from a filament (cathode) and plate on up to these two in combination with three, four and even more elements.

The simplest type of vacuum tube is that shown to illustrate electronic conduction in Chapter Three. It has but two elements, cathode and plate, and is therefore called a *diode*. As was explained, the hot cathode emits electrons which flow from cathode to plate within the tube when the plate is positive with respect to the cathode. The tube is a conductor in one direction only. If there should be a battery connected with its negative terminal to cathode and positive to plate, this flow of electrons would be continuous. But if a source of alternating current is connected between the cathode and plate, then electrons will flow only on the positive half-cycles of alternating voltage. There will be no electron flow, and hence no current flow, during the half cycle when the plate is negative. Thus the tube can be used as a *rectifier*, to change alternating current to pulsating direct current. This alternating current can be anything from the 60-cycle kind to the highest radio frequencies, making it possible to use the diode as a rectifier in power supplies furnishing direct current for our transmitters and receivers, as described in Chapter Ten, or even to

use it as a rectifier (detector) of radio-frequency current in receivers.

How Vacuum Tubes Amplify — Tube Characteristics

▲ If a third element, called the *control grid* or simply the *grid*, is inserted between the cathode and plate of the diode, the tube becomes a *triode* (three-element tube) and acquires utility for more things than rectification. This grid is usually in the form of an open spiral or mesh of fine wire. With the grid connected externally to the cathode and with a steady voltage from a d.c. supply applied between the cathode and plate (the positive of the plate or "B" supply is always connected to the plate), there will be a constant flow of electrons from cathode to plate, through the openings of the grid, much as in the diode. But if a source of variable voltage is connected between the grid and cathode there will be a variation in the flow of electrons from cathode to plate (a variation in plate current) as the voltage on the grid changes about a mean value. When the grid is made less negative with respect to the cathode there will be an increase in plate current; when the grid is made more negative with respect to the cathode there will be a decrease in plate current. This occurs because the electron flow to the plate is encouraged when the grid swings positive, while electrons leaving the cathode are repelled from traveling to the plate when the grid swings negative. The important thing about this is that when a resistance or impedance is connected in the plate circuit, the variation in plate

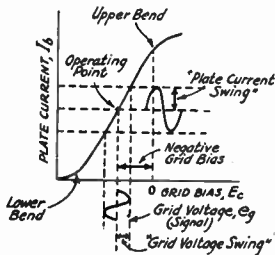


FIG. 405—OPERATING CHARACTERISTICS OF A VACUUM TUBE AMPLIFIER

current will cause a variation in voltage across this load that will be a magnified version of the variation in grid voltage. In other words there is *amplification* and the tube is an *amplifier*.

The measure of the amplification of which a tube is capable is known as its *amplification factor*, designated by μ ($\mu\mu$), an important *tube characteristic*. Another important characteristic involving plate current change caused by grid voltage change over a very small range is a tube's *mutual conductance*, designated by g_m and expressed either in milliamperes plate current change per volt grid voltage change (ma. per volt), or as the current to voltage ratio in *mhos* (inverse of ohms). Since the plate current changes

involved are often very small, the mutual conductance is also expressed in *micromhos*, the ratio of amperes plate current change to volts grid voltage change, multiplied by one million. Still another important characteristic used in describing the properties of a tube is the *plate resistance*, designated r_p . This is the ratio of a small plate voltage change to the plate current change it effects. It is expressed in *ohms*. These tube characteristics are inter-related and are different with tubes of different types, being dependent primarily on the tube structure (spacing between elements, spacing and size of wires in grid, etc.).

Amplifier Operation

▲ The operation of a vacuum tube amplifier is graphically represented in Fig. 405. The sloping line represents the variation in plate current obtained at a constant plate voltage with grid voltages from a value sufficiently negative to reduce the plate current to zero to a value slightly positive. It should be kept in mind that grid voltage is with reference to the cathode of filament. This is known as the *static grid-voltage plate-current characteristic*. Notable things about this curve are that it is essentially a straight line (is *linear*) over the middle section and that it bends towards the bottom (near *cut off*) and near the top (*saturation*). In other words, the variation in plate current is directly proportional to the variation in grid voltage over the region between the two bends. With a fixed grid voltage (*bias*) of proper value the plate current can be set at any value in the range of the curve.

With negative grid bias as shown in Fig. 405 this point (the *operating point*) comes in the middle of the linear region. If an alternating voltage (*signal*) is now applied to the grid in series with the grid bias, the grid voltage swings more and less negative about the mean bias voltage value and the plate current swings positive and negative about the mean plate current value. This is equivalent to an alternating current superimposed on the steady plate current. With this operating point it is evident that the plate current *wave shapes* are identical reproductions of the grid voltage wave shapes and will remain so as long as the grid voltage amplitude does not reach values sufficient to run into the lower- or upper-bend regions of the curve. If this occurs the output waves will be flattened or be *distorted*. If the operating point is set towards the bottom or towards the top of the curve there will also be distortion of the output wave shapes because part or all of the lower or upper half-cycles will be cut off. This kind of distortion may be undesirable or desirable, as will be shown later.

The major uses of vacuum tube amplifiers in radio work are to amplify at audio frequencies (approximately 100 to 10,000 cycles per second) and to amplify at radio frequencies (up to 60,000 kc. or higher). The audio-frequency amplifier is

generally used to amplify without discrimination at all frequencies in a considerable range (say from 100 to 3000 cycles for voice communication), and is therefore associated with non-resonant or untuned circuits. The radio-frequency amplifier, on the other hand, is generally used to amplify selectively at a single radio frequency, or over a small band of frequencies at most, and is therefore associated with resonant circuits tunable to the desired frequency.

The circuit arrangement of a typical audio-frequency amplifier using a triode is shown at A in Fig. 406. The alternating grid voltage is applied through the transformer T_1 to the grid circuit, in series with the grid bias furnished by a battery. The alternating current component in the plate circuit induces an alternating voltage in the secondary of the output transformer T_2 . This output might go on to another similar audio amplifier for further amplification. In lieu of the output transformer, a pair of 'phones could be connected in place of the primary in the plate circuit, in which case the alternating component in the plate current would be reproduced immediately as sound.

In B of Fig. 406 is shown the circuit arrangement of an amplifier for radio frequencies. In this case the tube is of the screen-grid type, the extra element being placed between the control grid and plate to prevent the feed-back and oscillation that will be discussed in the next section. Its operation, however, is similar to that shown in Fig. 405. The input and output circuits in this case are resonant circuits, tuned to the radio frequency that is to be amplified. The grid bias, instead of being furnished by a separate battery, is furnished by the voltage drop across the cathode resistor resulting from the steady plate current flowing through the plate circuit (which includes the "B" supply). Since this flow of current is from plate to cathode in the external circuit, the supply side of the cathode resistor will be negative with respect to the cathode and thus apply negative bias to the grid. Methods of obtaining grid bias are explained further in Chapter Five.

Generating Radio Frequency Power — Oscillators

▲ Because of its ability to amplify, the vacuum tube can oscillate or generate alternating current power. To make it do this, it is only necessary to couple the plate (output) circuit to the grid (input) circuit so that the alternating voltage supplied to the grid of the tube is opposite in phase to the voltage on the plate. Typical circuits for this condition are shown in Fig. 407. In A the feed-back coupling between the grid and plate circuits is inductive (by means of coils), while in B the coupling is capacitive (through a condenser). In the circuit of A the frequency of oscillation will be very nearly the resonant frequency of the tuned circuit L_1C_1 , while in B the frequency of

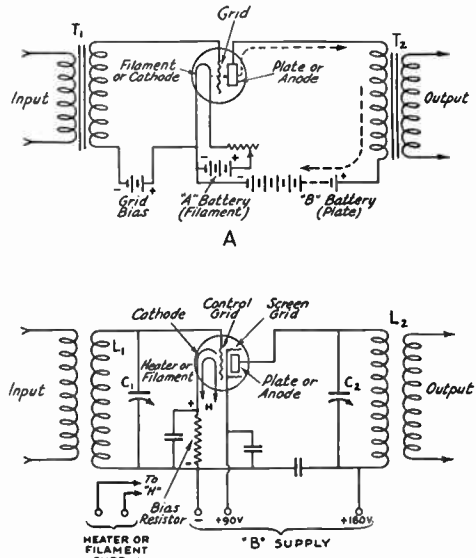


FIG. 406 — CIRCUITS OF TYPICAL VACUUM TUBE AMPLIFIERS

oscillation will be determined jointly by L_1C_1 and L_2C_2 . To insure the proper phase relationship between plate and grid voltage, with the inductive feed-back of A the grid and plate should be connected to the opposite ends of the plate and grid coils when these coils are wound in the same direction; while in the arrangement of B the plate circuit should be tuned to a slightly higher resonant frequency than the grid circuit. (Plate circuit reactance inductive with respect to the grid circuit.) At the high radio frequencies used in amateur work the inherent plate-grid capacitance of the usual triode tube is sufficient for feed-back in the tuned-grid tuned-plate type circuit of B and the feed-back condenser shown connected between grid and plate is not necessary.

There are many other arrangements of oscillator circuits but all utilize either the inductive or capacitive feed-back typified in the two shown here. Several of these other types are treated in Chapter Seven. A special type of oscillator of exceptional frequency stability that is becoming increasingly popular is the piezo-electric or crystal-controlled type. Most commonly it resembles the tuned-grid tuned-plate circuit of B with the exception that the tuned grid circuit is replaced by a plate of quartz crystal mounted between metal electrodes. This crystal acts like a tuned circuit, its electrical equivalent being that shown at B of Fig. 408. As shown, it consists of a very high inductance (L) in series with a very small capacitance (C) and resistance (R). The shunt capacitance C_1 is that of the electrodes between which the crystal is mounted, with the quartz as the dielectric. Its exceptional stability is attributable to its high ratio of inductive

reactance to resistance; in other words, to its high Q . This property also makes the crystal useful as a very selective tuned circuit or filter for radio reception, as it is used in the Single-Signal receivers outlined in Chapter Five. Power type oscillators and amplifiers are used in combination in radio transmitters, both for radioteleg-

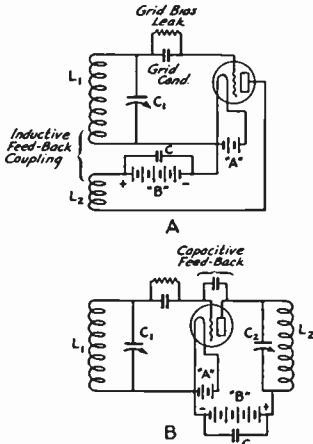


FIG. 407 — TWO GENERAL TYPES OF OSCILLATOR CIRCUITS

raphy and radiotelephony, and later chapters will describe practical aspects of these applications.

Modulation

▲ In addition to generating radio-frequency energy in the transmitter and radiating it from the antenna, it is necessary to do something to utilize this energy for communication of intelligence. This is accomplished by *modulating* the transmitter's output either to form the dots and dashes of the telegraph code (by keying) or by varying the amplitude of the radio-frequency current to conform with the variations in intensity of the voice. Radio-frequency currents modulated by these two methods are represented in Fig. 409, a wave modulated for telegraphy by keying the transmitter's output into dot and dash form being shown in A, and one modulated with a sine-wave of audio-frequency current being shown in B. The outline of the modulation is referred to as the *envelope* and it is to this that the useful output of the receiver must conform. Detailed descriptions of modulation methods for both telegraphy and telephony are given in later chapters.

Detection of Radio Signals

▲ After the modulated radio-frequency current has made its way into the receiver and perhaps through one or more radio-frequency amplifiers, it must be *demodulated* or *detected* to bring out the

useful modulation envelope just described. To do this it is necessary to rectify the radio-frequency current. This might be done with the simple diode, as mentioned previously. However, the triode is more commonly used in amateur receivers because it gives much greater output in proportion to its radio-frequency input (is more *sensitive*) than the diode. Triode detectors are of two types, one giving what is known as *plate detection* and the other what is known as *grid detection*.

The circuit arrangement of a typical *plate detector* is shown in A of Fig. 410 and its operating characteristics are illustrated in A of Fig. 411. The circuit L_1C_1 is tuned to resonance with the radio frequency and the voltage developed across it is applied between the grid and cathode, in series with the grid bias battery. A telephone headset (or the primary of a transformer feeding an audio amplifier) is connected in the plate circuit, a small fixed condenser C being connected across the plate load circuit to by-pass radio frequency. As shown in A of Fig. 411, the negative grid bias voltage is such that the operating point is in the lower-bend region of the curve, near cut-off. Hence only the positive half-cycles of the signal voltage are completely effective in causing plate current change. With a modulated signal as shown there will be a variation in plate current conforming to the average value of the positive

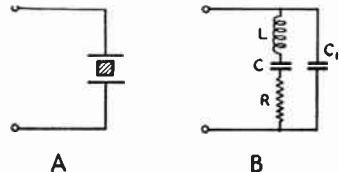


FIG. 408 — EQUIVALENT CIRCUIT OF PIEZO-ELECTRIC QUARTZ CRYSTAL

half-cycles of radio frequency. This variation corresponds to the envelope, representing an audio-frequency current superimposed on the steady plate current of the tube, and constitutes the useful audio output of the detector. When this pulsating current flows through the 'phones their diaphragms vibrate in accordance with it to give a reproduction of the modulation put on the signal at the transmitter. This type of detection is called *plate detection* because the rectification takes place in the plate circuit after radio-frequency amplification from grid to plate.

The circuit arrangement of a triode used as a *grid detector* (also called *grid leak detector*) is shown in B of Fig. 410. Here again we have an input circuit tuned to the frequency of the radio wave and connected so that the r.f. voltage developed across it is applied between the grid and cathode. However, there is no fixed negative grid bias, as in the case of the plate detector, but instead a small fixed condenser (*grid condenser*) and resistor of

high value (*grid leak*) in parallel are connected between tuned circuit and grid. The plate circuit connections are the same as for the plate detector.

As shown in B of Fig. 411, the operating point is near the upper bend of the curve because the grid bias is near zero when there is no signal on the grid. A modulated radio-frequency voltage applied to the grid swings it alternately positive and negative about the operating point. The grid attracts electrons from the cathode, the consequent grid current increasing more during the positive half cycles than it decreases during the negative half cycles of grid swing. Hence there is a rectified grid current flow at modulation frequency whose average value develops a voltage across the grid leak. This audio-frequency variation in voltage across the grid leak causes corresponding variations in plate current which are reproduced in the 'phones. In contrast to plate detection, with grid detection the rectification takes place in the grid circuit and there is audio-frequency amplification to the plate circuit. Grid detection is generally used in amateur receivers of limited r.f. amplification because grid detectors are capable of greater sensitivity for small signals than plate detectors using similar tubes. Plate detection is more commonly used where detector sensitivity is of minor importance.

Regenerative Detectors

▲ With both the grid and plate detectors just described it will be noted that a condenser is connected across the plate load circuit to by-pass radio-frequency components in the output. This radio-frequency can be fed back into the grid circuit, as shown in C of Fig. 410, and re-amplified a number of times. This *regeneration* gives a tremendous increase in detector sensitivity and is used in most amateur receivers. If the regeneration is sufficiently great the circuit will break into oscillation, which would be expected since the circuit arrangement is almost identical with that of the oscillator shown in Fig. 407-A. Therefore a control is necessary so that the detector can be

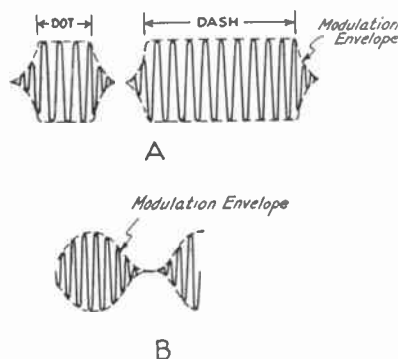


FIG. 409 — RADIO WAVES MODULATED FOR C. W. TELEGRAPHY AND TELEPHONY

operated either regenerating to give tremendous amplification without oscillation, or to oscillate and regenerate simultaneously. Methods of controlling regeneration are given in Chapter Five.

Heterodyne or Beat-Note Reception

▲ In discussing the detection of signals it has been pointed out that the detector output is a replica of the modulation applied at the transmitter. In the case of radiotelephony this modulation is at

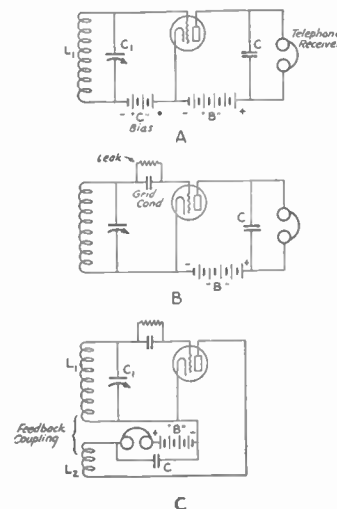


FIG. 410 — DETECTOR CIRCUITS OF THREE TYPES
A — Plate detection; B — Grid detection; C — Regenerative grid detection.

audio frequency and the methods of detection that have been described will reproduce it satisfactorily. But in the case of c.w. radiotelegraphy the variations in detector plate current, while they correspond with the dots and dashes of the code, will not cause an audio-frequency tone in the 'phones unless they are actually modulated with a tone of audible frequency. The most satisfactory method of giving this tone to c.w. signals is by *heterodyne* action, a form of modulation. The idea is illustrated in Fig. 412. When two alternating voltages of different frequencies are simultaneously applied to a detector, there appear in the detector output circuit current variations of both the original frequencies, of their sum frequency and of their difference frequency. This difference frequency is the *beat note*, and if the difference between the two original frequencies is an audio frequency, the beat note will be of audio frequency. One of the original frequencies is, of course, that of the radio signal. The other is that of a local oscillator. This local oscillator may be separate from the detector or a separate heterodyne. In most cases, however, the detector itself also serves as the local oscillator to give the beat

note. When so used, such a detector is known as an *autodyne*. A regenerative detector circuit like

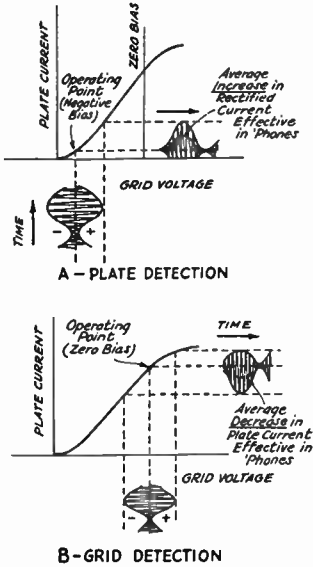


FIG. 41 — OPERATING CHARACTERISTICS OF, A — PLATE DETECTOR; B — GRID DETECTOR

that shown in Fig. 410-C, with the regeneration adjusted so that the detector oscillates, is commonly used for amateur c.w. reception.

Superheterodyne Reception

▲ As was mentioned in the section on series and parallel resonance, the selectivity of tuned circuits is relatively poor at even the lower amateur frequencies. At the higher amateur frequencies it becomes worse. Therefore it is impracticable to obtain really high selectivity in tuned amplifiers resonant to frequencies in the amateur bands. On the other hand, both higher selectivity and greater amplifications per stage can be obtained in radio-frequency amplifiers operating at intermediate frequencies of 500-ke. or so. Such amplifiers can be utilized for amateur reception by converting the amateur frequency signals to the lower *intermediate frequency*. This also is possible by the heterodyne method.

Both the incoming signal and the local oscillator signal are introduced in a detector, with the local oscillator frequency either intermediate frequency higher or lower than the signal frequency. Since the difference between the two frequencies is quite great in this case, it is advisable to use a separate oscillator rather than to use the detector as an autodyne. The output of the detector is coupled to the i.f. amplifier stages by a radio-frequency transformer tuned to the intermediate frequency, thus selecting the difference frequency component in the detector output and eliminating the other components.

After amplification in the intermediate-frequency (i.f.) stages, the signal is detected in normal fashion by the *second detector*. If the incoming signal is modulated at audio frequency, the intermediate-frequency signal will be identically modulated and the audio-frequency output of the second detector will be normal. For c.w. reception it will be necessary to use a second heterodyne oscillator at the second detector or to operate this detector as an autodyne, as with the detector in the usual amateur receiver. A receiver operating in this fashion is a *superheterodyne*. Several types of modern superheterodyne receivers especially designed for high-frequency work are shown in Chapter Five.

Generation of Harmonic Frequencies

▲ Distortion in vacuum tube amplifiers causes harmonics and we often purposely adjust vacuum tube circuits to give us maximum distortion when we desire output at a frequency that is a harmonic of the exciting frequency. High input voltage amplitude or grid swing and high negative bias are favorable for the production of harmonics. Because of curvature in the plate-current plate-voltage characteristic curves and because there is a different plate-voltage plate-current (static characteristic) for each value of impressed grid voltage, the current wave-form in the plate circuit becomes distorted, resulting in the generation of harmonic frequencies. A low plate-load (external) resistance or impedance will emphasize such distortion. Even with a high grid bias, large inputs to the grid circuit will also cause the grid to become positive during part of the input cycle, causing grid current to flow, thus decreasing the grid-filament resistance of the tube. This results in an uneven load and produces further distortion and harmonics. The way in which distortion in the output wave-form introduces a harmonic impulse or component is indicated in Fig. 413.

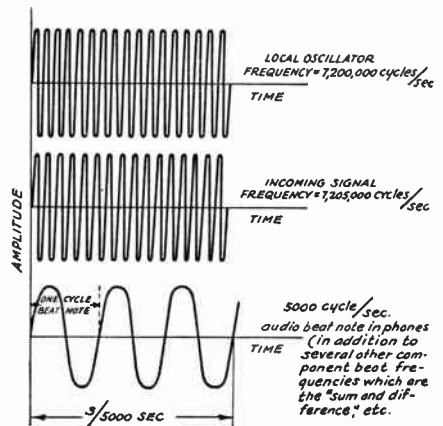


FIG. 412 — ILLUSTRATING HETERODYNE ACTION

Harmonics cannot be generated at frequencies below the fundamental but always occur at higher frequencies. When we pick up a radio signal with the receiver tuned to half the frequency of the transmitting station it is because our oscillating detector generates a harmonic in the receiver. In this case the harmonic is beating with the fundamental frequency of the transmitter.

By properly biasing tubes and tuning the output circuit to a desired harmonic frequency, a vacuum tube may be operated as a frequency doubler or frequency tripler, etc.

How Radio Waves Travel in Space — Fading and Skip Distance

▲ No discussion of amateur radio or of high-frequency phenomena can be complete without something about the commonly accepted theory advanced in explanation of the things that have been observed in connection with high-frequency

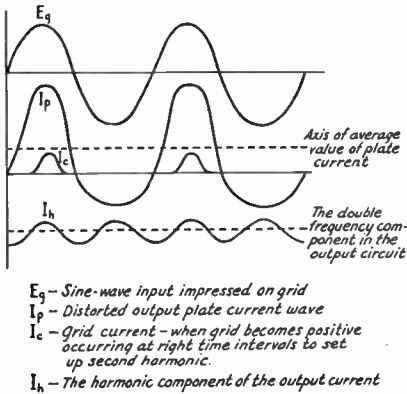


FIG. 43 — HOW DISTORTION CAUSES HARMONICS IN VACUUM TUBE OPERATION

transmission. It appears that just as light waves can be reflected and refracted so it is with radio waves. The behavior of radio waves is harder to understand because these waves are not visible or audible except by artificial means of detection. The frequency spectrum used for radio communication is a wide one and the determination of what happens is further complicated by the continuous variations taking place in the medium traversed by the radio waves. The bending or refraction of radio waves in the upper atmosphere is attributed to the presence of free electrons resulting from ionization of the earth's upper atmosphere, principally by radiation from the sun. The ionization passes through a daily and seasonal variation depending on sunlight and changes in the sun's radiation.

Changing reflecting and refracting properties of the Kennelly-Heaviside layer, so named for the two men who independently and almost simultaneously proposed the existence of an ionized region in the upper atmosphere, are presumed

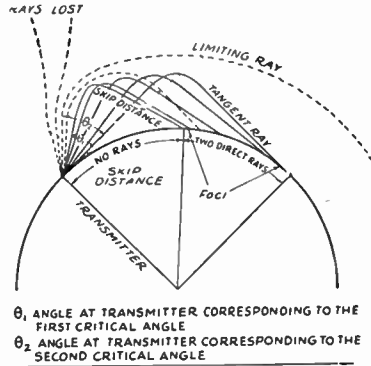


FIG. 44 — HOW RADIO WAVES TRAVEL FROM TRANSMITTER TO RECEIVER

The vertical and near-vertical rays penetrate the ionized layer and wander away. When one reaches the "limiting angle" the ray just does get bent enough to be kept from wandering away, but it continues to graze the layer and is after all worthless. Below this angle we have progressive reflection (or refraction) and the ray returns to earth. As the angle of departure from the transmitter is chosen flatter the energy strikes so far away as to miss the earth, possibly going out to the ionized layer again, and perhaps even being reflected down a second time if it has energy enough left.

to account for the rapid variation in the intensity of received signals that is called fading.

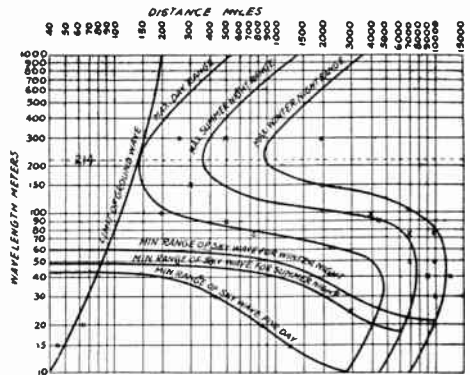


FIG. 45 — APPROXIMATE AVERAGE TRANSMISSION PERFORMANCE OF DIFFERENT WAVELENGTHS AT DIFFERENT DISTANCES

The received signal is assumed to have a field-strength of 10 microvolts per meter at the receiving point. The transmitter is assumed to have 5000 watts in the antenna. The chart is explained as follows. To the left of the line marked "limit of ground wave" it should be possible to receive at all times. After that, one must pick a pair of curves of the same sort (that is for the same time) and if the distance is between the curves one should hear the signal. Thus, a 30-meter wave should be reliable at all times to 70 miles for the conditions mentioned. From there to 400 miles its daylight performance will probably be uncertain while from 400 on it will gradually die down until at 4600 it will again be below 10 microvolts per meter. There are, of course, numerous exceptions where one does hear it when it should be absent. The curves are mainly from data by A. H. Taylor.

Fig. 414 explains what is commonly referred to as the *skip distance*, that distance which signals skip over. The signal decreases in intensity as we leave the transmitter due to spreading out and to energy absorption. It finally drops below a useful value, remaining out until we reach a great distance from the transmitter, after which it unexpectedly gets strong again, gradually dropping in intensity at still greater distances. The skip distance at night is much greater than in the daytime. It gradually increases up to about midnight. The skip distance also is known to be greater in winter than in summer which seems reasonable because the ionization should be less then, due to shorter periods of sunlight. It can be seen readily from the charts that the skip distance is very definitely influenced by the transmitted frequency.

Fading is usually less violent over long distances because the waves can arrive by many routes, thus averaging conditions and giving a fair signal in spite of fading along some paths. Right at the edge of the skip distance interference effects may occur with very severe fading, while beyond this point the rays of high-angle radiation die out, giving a better chance for a steady signal. In general high-frequency com-

munication results go to prove that the skip distance for any given time decreases with decreasing frequency. While skip-distance effects are important on our high frequencies they are not as noticeable on the broadcast band and less important still on low frequencies.

There is nothing absolute about any of the rules that different investigators have devised for determining whether a signal from a certain transmitter can be heard at a given point. However, some charts and rules are useful when studying the subject of transmission phenomena, even though they are approximate. Such a chart is shown in Fig. 415 with an explanation of what it means. It shows roughly what may be expected of different frequencies or the corresponding wavelengths in radio communication.

Amateur experience seems to indicate that the power of a transmitter is one of the less important considerations in high-frequency work. Extreme distances are covered day and night with less than ten watts in the antenna using 14,000- and 7000-kc. frequencies, and the signal strength of high and low power stations is much the same. The conditions in the upper atmosphere are undoubtedly the most important factor in determining the results.

HIGH-FREQUENCY RECEIVERS

WHATEVER one's principal interest in amateur radio, be it operating a complete station or experimenting with a variety of circuits, the basic piece of apparatus is a good receiver. The building of the complete station is always a process of evolution. Most amateurs start out with a simple receiver, listening in on it until they become proficient in the art of tuning in high-frequency signals, and at the same time learning the code in preparation for obtaining a transmitting license. The amateur has the choice of building his own receiver or of purchasing one of the several amateur-band manufactured receivers now available at reasonable prices. Many amateurs prefer to build their own, not just for reasons of economy, but more for the experience and to acquire the intimate knowledge of operation that they obtain. Constructional details of representative high-performance types and descriptions of modern circuit features are contained in this chapter.

The first receiver need not be an elaborate one; in fact it is better to pick out a simple and inexpensive set for the initial attempt. It will be relatively easy to get such a set working and, even though it is built with the full knowledge that it will not be the permanent receiver of the finished station, the investment in the equipment for it will not be wasted. Most of the parts used in simple receivers can be used equally well in more intricate sets later on. In this chapter several receivers are described, both in regenerative and superheterodyne types. All of them are thoroughly practical outfits, capable of giving excellent service if carefully built and correctly operated.

Receiver Characteristics

▲ The three important general characteristics of a receiver are its selectivity, its sensitivity and its fidelity. These three are interdependent, with selectivity the controlling factor. The *selectivity* is the receiver's ability to discriminate between signals of different frequencies. The *sensitivity* is the minimum r.f. voltage input required to give useful output. The *fidelity* is the proportionate response through the audio-frequency range required for a given type of communication.

Sensitivity is fundamentally limited by the

noise output, which in turn is directly related to the selectivity, being less as the selectivity is greater. Only signals that are detectable above the noise background are useful; therefore, reducing the noise output by increasing the selectivity improves the effective sensitivity in proportion. Sensitivity is thus not solely dependent on the amplification in the receiver but on the combination of amplification and selectivity. The fidelity requirement in amateur receivers is essentially different from broadcast receiver requirements, although this is not generally realized, and is set by the minimum required for intelligibility. For c.w. telegraph reception of hand-keyed signals (say up to 30 words per minute) adequate fidelity for intelligible reception can be obtained with selectivity such that the receiver's equivalent band width (the "measuring stick" for selectivity) is but 20 cycles or less; for 'phone reception with usable intelligibility the equivalent band-width must be proportionately greater, of course, although still considerably less than for broadcast reception. It is therefore evident that the most important receiver characteristic is the effective selectivity; for the higher the selectivity, the

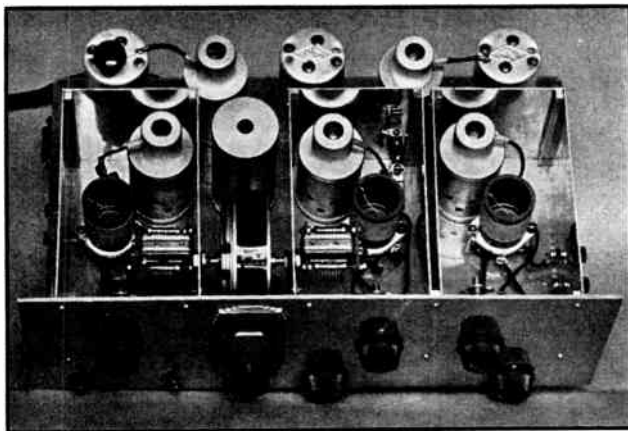


FIG. 501 — A SIX-TUBE SINGLE-SIGNAL SUPERHETERODYNE RECEIVER

A complete description of the receiver is contained in the text.

greater can be the amplification and the higher the effective sensitivity, to the limits imposed by the requirement of intelligible output.

Types of Receivers

▲ Two types of receivers meeting the requirements of general amateur work are the simple

regenerative receiver (autodyne) and the superheterodyne. Special types for ultra-high frequency work are treated in Chapter Nine. In the regenerative receiver there is r.f. feedback in the detector circuit with the amount of this regeneration controllable to give either high amplification and selectivity without oscillation, or to give these together with oscillation to provide the heterodyne for beat-note c.w. reception, as has been explained in Chapter Four. The simplest form of receiver would be just one tube in a regenerative detector circuit, although the output available from such an arrangement is so small as to be generally unsatisfactory. A single stage of audio amplification following the detector gives more satisfactory results. A still further improvement is a stage of tuned radio-frequency amplification preceding the detector. This increases sensitivity and gives somewhat greater selectivity, provides helpful isolation of the regenerative detector from the antenna circuit and allows sensitivity control ahead of the detector circuit.

Whereas the regenerative receiver's r.f. circuits handle the signal at incoming frequency, in the superheterodyne type receiver the incoming signal is converted to a lower radio frequency and then amplified in intermediate circuits prior to conversion to audio frequency in the second detector. As explained in Chapter Four, this method allows greater r.f. amplification and the attainment of higher selectivity, since both of these are more readily obtained in the intermediate-frequency (i.f.) amplifier. This applies particularly to the single-signal type superheterodyne, originally developed in the A.R.R.L. laboratory and described in this chapter, which obtains extremely high selectivity in the i.f. circuits either by means of a variable band-width quartz crystal filter or by controllable regeneration in an i.f. stage.

The simple regenerative type receiver is less complicated than the superheterodyne, of course, and is accordingly less expensive. Until one has gained experience it is advisable to work with the simpler receiver, progressing later to the superheterodyne type.

Receiver Operating Controls

▲ The most prominent operating control of any type receiver is the tuning dial or, in the case of separately tuned circuits, several such dials. In the simplest receiver the dial drives a single variable condenser while in more elaborate receivers it drives two or more "ganged" condensers. In some tuning systems, as described in the fol-

lowing paragraphs, there may be auxiliary panel controls for "band-setting" parallel or series condensers. In addition to the tuning control, regenerative type receivers have a control to govern the feed-back of the detector. This regeneration control also serves to some extent as an r.f. gain or sensitivity control, although a separate third control for this purpose is advantageous in the regenerative receiver equipped with an r.f. amplifier and is a practical necessity in the superhet. Also, there may be an audio volume control to vary the audio-frequency input to an amplifier stage following the detector. Superhet receivers of more advanced types also have controls for varying band-width (selectivity), for adjustment of the c.w. beat-note pitch, for switching the power circuit and so on.

Tuning Arrangements and Band Spreading

▲ Since the amateur frequency-bands comprise narrow slices of territory widely separated, it is not possible to cover them all effectively with one coil and condenser combination in the tuner. Many schemes have been evolved to provide interchangeable coils. The use of a tube-base or a special form of larger size plugging into a tube socket is almost universal in amateur built receivers. Coils of this type are pictured later on with the constructional details of the receivers in which they are used. Larger coils with a horizontal row of plugs fitting into a similarly-arranged row of sockets are also used in some cases. The important requirements are that the coils should be readily interchangeable; the contacts should be positive; the coils should be mechanically strong so they will not be deformed in handling; and they should be small in diameter in order to avoid the existence of an extensive magnetic field around them.

Several manufactured receivers intended for amateur use employ permanent built-in coils with a switching arrangement but this type of tuning arrangement is less suited to amateur construction.

Tuning condensers used in high-frequency receivers are much smaller than those employed for the broadcast band and lower frequencies. A 350- or 250- μfd . condenser will, at high frequencies, cover so wide a frequency range that tuning becomes extremely difficult. Many amateurs remove plates from standard-sized condensers to reduce the maximum capacity, or else use midjet condensers, which can be obtained in a variety of capacities. If the receiver is to cover all frequencies between 20,000 and 3000 kc., common prac-

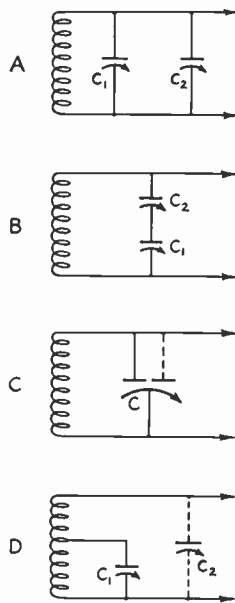


FIG. 502 — THE ESSENTIALS OF FOUR POPULAR BAND-SPREADING SYSTEMS

tice is to use a tuning condenser rated at 150 $\mu\text{mfd.}$ with three plug-in coils, but even this arrangement crowds the amateur bands in very small proportions of the dial scale. Most amateurs prefer to spread the bands over a large part of the dial.

The amateur bands are not entirely in harmonic relation, and therefore a condenser which spreads one band satisfactorily may not give the same spread on others. In order to make each band cover a large number of dial divisions, the ratio of maximum to minimum capacity must be different for each band.

Several widely used band-spreading schemes are shown in Fig. 502. At A is the parallel-condenser method. C_1 is the tuning condenser, usually with a maximum capacity of about 25 $\mu\text{mfd.}$ C_2 is a "band-setting" condenser; its maximum capacity should be at least 100 $\mu\text{mfd.}$ and may be larger. The setting of C_2 will determine the minimum capacity of the circuit, and the maximum capacity will be the maximum capacity of C_1 plus the setting of C_2 . A different maximum-to-minimum capacity ratio can be chosen to give good band-spreading on each band.

The series-condenser method is shown at B. As explained in Chapter Three, the total capacity of two condensers in series is less than that of either. C_1 again is the tuning condenser. It should have 100 $\mu\text{mfd.}$ or more maximum capacity. C_2 is the band-setting condenser and is preferably small, perhaps 25 $\mu\text{mfd.}$ The maximum-minimum capacity ratio in the circuit will be determined by the setting of C_2 . The minimum capacity changes very little for any setting of C_2 , but the maximum capacity can be varied over quite a range, depending upon the ratios of the capacities of the two condensers.

At C is another arrangement which makes use of a "split-stator" tuning condenser — one with two separate stationary-plate sections and a single rotor. One of the stator sections is made small enough to give good band spreading on the 14- and 7-megacycle bands, and the second stator section, when connected in parallel with the small stator, will give good spread on 3500- and 1750-ke. The dotted connection for the two lower-frequency bands shown in C can be made by using a jumper in the low-frequency coil forms, the change being automatically made when the coils are plugged in.

The tapped-coil system at D is used in several commercial amateur-band receivers and has also been adopted by a number of amateurs in home-built sets. Condenser C_1 may be fairly large — 100 $\mu\text{mfd.}$ or so — but will give good spread on any band if the right size of coil is chosen and the tap to which the stator plates of the condenser are connected is made at the right place. Trimmer condenser C_2 is not strictly necessary but will be found helpful in getting the spread just right, and its use will help eliminate some of the cut-

and-try in winding the coils. It should have a maximum capacity of 25 to 100 $\mu\text{mfd.}$

Regeneration Control

▲ In the regenerative receiver almost any one of a number of arrangements of the tickler coil and

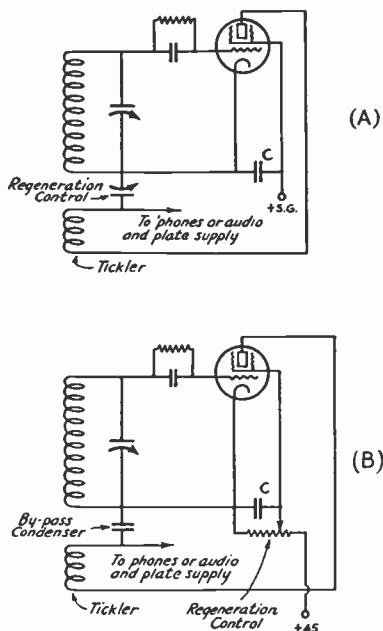


FIG. 503 — CONDENSER AND RESISTOR CONTROL OF REGENERATION

feed-back control in the detector circuit can be depended upon to give similarly loud signals, but some of them have the advantage of being more convenient and of permitting adjustment of regeneration without detuning the signal. It is also a great advantage if the regeneration control is absolutely quiet in action; if it permits a gradual adjustment up to and past the point of oscillation; and if it permits the tube to oscillate gently all across the frequency band on which the receiver is working without the necessity for touching anything but the tuning control.

Fig. 503 shows two ways in which regeneration may be controlled with a screen-grid detector. At A the regeneration control is a variable condenser having a maximum capacity of 100 or 150 $\mu\text{mfd.}$ It acts as a variable by-pass between the low-potential end of the tickler coil and the cathode of the tube. If the by-pass capacity is too small the tube will not oscillate, while increasing the capacity will cause oscillations to start at a certain critical value of capacity. This method of regeneration control is very smooth in operation, causes relatively little detuning of the received signal and, since the voltage on the screen-grid of the tube is fixed, permits the detector to be

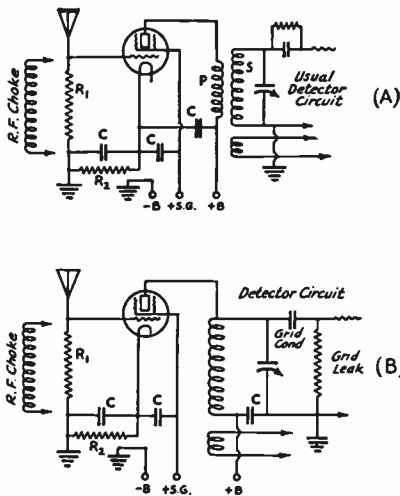


FIG. 504 — UNTUNED R. F. AMPLIFIER DIAGRAMS

A, transformer coupling, *B*, impedance coupling to detector. A resistor, R_1 , having a resistance of 10,000 to 20,000 ohms is connected between the grid of the screen-grid amplifier tube and ground. An r.f. choke, consisting of perhaps 100 turns of small wire wound on a form about the size of a pencil, can be substituted for the resistor if interference is experienced from local broadcast stations. Resistor R_2 gives the tube the correct operating bias, as explained in a later section of the text. If the tube filament is directly heated a battery of the proper voltage should be substituted for the resistor, and the ground connection should be brought to the filament of the tube.

worked at its most sensitive point. The sensitivity of a screen-grid detector depends a great deal upon maintaining the screen-grid voltage in the vicinity of 30 volts.

At *B* regeneration is controlled by varying the mutual conductance of the detector tube through varying its screen-grid voltage. The regeneration control is usually a voltage-divider — or so-called “potentiometer” — with a total resistance of 50,000 ohms or more. This circuit causes more detuning of the signal than *A*, and the resistor is likely to cause some noise unless by-passed by a large capacity (about $1 \mu\text{fd.}$) at *C*. In *A*, condenser *C* may be $.5 \mu\text{fd.}$ or larger. With circuit *B* it is necessary to adjust the number of turns on the tickler coil to make the tube just start oscillating with about 30 volts on the screen-grid if maximum sensitivity is desired.

Both the methods shown in Fig. 503 may be applied to three-electrode detectors, although these tubes have been largely superseded as detectors by the more sensitive screen-grid tubes. To use method *B* the regeneration-control resistor should be placed in series with the plate of the tube and it need not be used as a voltage-divider but simply as a series variable resistor. It can also be used as a series resistor when controlling a screen-grid tube. Another type of regeneration control, more suitable for lower radio frequencies,

uses a variable resistance across the feed-back portion of the r.f. circuit, as shown in the six-tube superhet described later.

In all methods it is essential that the tickler be mounted or wound at the filament end and not the grid end of the tuning coil. In the interests of smooth control it will be found advisable to use just as few turns on the tickler as will allow the tube to oscillate easily all over the tuning range. If the tube starts oscillating with a sudden thump instead of a smooth rushing noise, a different value of grid leak resistance should be tried.

Radio-Frequency Amplifiers — Gain Control

▲ A regenerative detector followed by a stage or two of audio-frequency amplification, when used for c.w. telegraphic work, will bring in amateur signals from all over the world on the higher frequencies. For such work, the sensitivity of this type of receiver usually proves to be ample. At times, however, a radio-frequency amplifier ahead of the detector is very desirable. The increase in sensitivity and selectivity provided by it can be put to good use in the reception of amateur radiotelephone signals. A further advantage of such an amplifier is that it isolates the detector from the antenna, reducing the radiation from the detector in an oscillating condition and making it impossible for the antenna, swaying in a wind, to cause the received signal to waver. A radio-frequency amplifier is also of considerable service in the elimination of “dead-spots” — points on the tuning dial at which the antenna, coming into resonance, might otherwise stop the detector from oscillating.

The three-element tube is almost useless as a radio-frequency amplifier in the short-wave receiver. The modern screen-grid tube, however, is most effective providing the circuit in which it is used is a suitable one. One arrangement for the radio-frequency amplifier is that in which the grid circuit for the first tube comprises a resistor or choke connected directly between the antenna and ground. This so-called “untuned” radio-frequency amplifier isolates the detector from the antenna and gives some amplification, but it does not improve the selectivity of the receiver. Rather, it makes the receiver susceptible to interference from any near-by powerful amateur or broadcast transmitters. Careful proportioning of the choke in the grid circuit makes it possible to avoid interference from broadcast stations, but not from other amateurs. If local interference is not likely to be troublesome an untuned r.f. stage will be found helpful. It is not hard to install because no shielding will be necessary.

Fig. 504 shows two methods of connecting an untuned r.f. amplifier to a regenerative receiver. That at *A* uses transformer coupling between the r.f. stage and detector, while at *B* impedance coupling is shown. Transformer coupling is pref-

erable because the number of turns on the two coils can be proportioned to give the greatest amplification (usually the primary, *P*, should have about $\frac{2}{3}$ as many turns as the secondary, *S*), and because the plate voltage for the r.f. tube is kept away from the detector circuit. It requires coil forms with enough pins to take care of primary, secondary and tickler, however. With impedance coupling, as at *B*, the detector coil must be isolated from ground by means of the by-pass condenser *C*. The grid leak must be connected between grid and filament instead of across the grid condenser, since the latter blocks the positive plate voltage from getting to the grid of the detector. Because of leakage across the grid condenser this circuit may be noisy unless a good mica condenser with extremely high insulation resistance is used.

A radio-frequency amplifier whose grid circuit is also tuned to the frequency of the received signal is considerably more effective than the untuned arrangement, providing both increased selectivity and greater gain. The circuit of a tuned r.f. stage is shown in Fig. 505. Examples of modern practice in such tuned amplifier stages are also shown in the receivers described later in this chapter. When the r.f. amplifier uses a screen-grid tube of the variable- μ type (such as the 58, 78, 6D6, etc.) its gain can be made adjustable by means of a variable cathode resistor, additional to the usual fixed cathode resistor, as is also shown in Fig. 505. As the value of the resistance in series with the cathode is increased the voltage drop across it rises, making the bias applied to the grid increasingly negative with respect to the cathode and thereby reducing the amplification of the stage. Since the space current of the tube falls as the grid becomes more negative, thereby tending to lessen the rate of increase in negative bias with increasing resistance, it is advisable to provide a bleeder resistor from the cathode side of the gain control to a more positive point of the high-voltage supply such as the screen-grid voltage tap. Suitable resistance values for a single r.f. amplifier tube would be 300 to 500 ohms for the fixed cathode resistor, 10,000 ohms for the variable gain control resistor and 50,000 ohms for the bleeder. If the gain of several stages is to be controlled by the one variable resistor, its value can be proportionately less and the bleeder may be omitted.

Rather complete shielding is always required when the input circuit to the r.f. amplifier tube is tuned. For this reason the tuned r.f. type receiver is somewhat more costly and more difficult to build. In one form such a receiver has two separate tuning dials — one for the input circuit to the r.f. tube and one for the input circuit to the detector. The obvious inconvenience of tuning these two controls has led to the development of receivers in which the two tuning condensers are "ganged." The construction of a receiver of this

type is a work requiring a little more skill, and had best be attempted after experience has been gained with the simpler types.

Radio Frequency Shielding

▲ The purpose of shielding is to confine the magnetic and electrostatic fields about coils and condensers so that those fields cannot act on other apparatus, and to prevent external fields from acting upon them in turn. Chapter Three has explained the nature of these fields. They can be confined by enclosing the apparatus about which the field exists in a metal box. The effectiveness of the shield depends upon the metal of which it is made and upon the completeness of contact at the joints. At radio frequencies the best shield is one made of a low-resistance non-magnetic metal, such as copper or aluminum, because the losses in it will be low. The magnetic fields about the apparatus enclosed in the shield cause currents to flow in it, and since the flow of current is always accompanied by some loss of energy the shield in effect causes an increase in the resistance of the tuned circuit. The lower the resistance of the shielding material the lower will be the energy loss. At low frequencies, such as those in the audio range, copper and aluminum are ineffective for shielding and iron must be used.

The increase in resistance caused by shielding also depends upon the proximity of the apparatus inside the shield to the walls. Coils in particular should be spaced from the walls in all directions by at least a distance equal to the coil diameter. For this reason small coils are much to be preferred to large ones if the set is to be kept reasonably small. The losses in the shielding due to electrostatic fields are negligible in comparison to those caused by magnetic fields, so condensers can be mounted right on the walls of the shield if desired.

To be effective a shield must be grounded. Although an actual ground connection always will

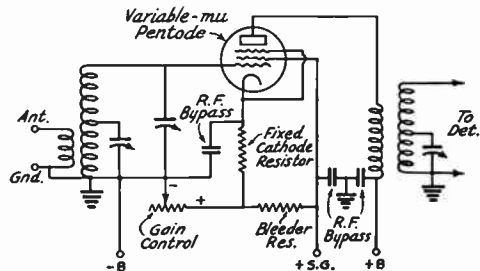


FIG. 505 — A TYPICAL RADIO-FREQUENCY AMPLIFIER CIRCUIT WITH BIAS GAIN CONTROL

It is suited to any of the variable- μ r.f. amplifier tubes such as the 58, 78, 6D6, 35, etc. With non-pentode types the suppressor-grid connection shown would be omitted. The value of the fixed cathode resistor will depend upon the tube type; values of the gain-control and bleeder resistors are discussed in the text.

be best, it is sometimes sufficient to connect the shielding to a point in the receiver at zero r.f. potential, such as the negative side of the plate supply. Another point is that shields must be complete for each amplifier stage or group of apparatus shielded. Do not attempt to use a single sheet of metal to form a common wall for two shields

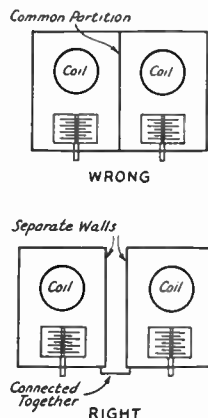


FIG. 506 — SHIELDING ALWAYS SHOULD BE COMPLETE ABOUT EACH PIECE OR GROUP OF APPARATUS SHIELDED

Do not attempt to use a common partition between shielded stages, especially when one of them contains a regenerative detector or oscillating circuit.

method will give good results, and the choice is usually dictated by mechanical considerations.

Although, as we pointed out in the previous section, shielding is not necessary if no tuned r.f. amplifiers are used, it is often helpful. A metal cabinet about a simple receiver will prevent direct pick-up of signals by the coils and wiring of the set, and it will also keep out "induction hums" from unshielded house wiring.

Amplifier Biasing

▲ Practically all amplifiers, both audio and radio frequency, must be operated with a minimum negative voltage between the grid and cathode of the amplifier tube. This *bias* voltage may be obtained from a battery or from a suitable voltage drop through a resistor in the circuit. Fig. 507 shows these two methods in an elementary fashion.

In general, the battery-bias method will be used with tubes having directly-heated cathodes (*filament-type* tubes). In such cases one side of the filament is connected to ground. In order to connect the bias battery in series with the lower end of the transformer secondary or whatever may be in the grid circuit of the amplifier tube, it is

necessary to insulate point X in Fig. 507-A from ground. Condenser *C* is used to provide a low-impedance path to the filament should the bias battery develop appreciable internal resistance. It should be about .01 μ fd. in r.f. circuits and 1 to 2 μ fd. in audio circuits.

The second method, known as *cathode resistor biasing*, is shown at B. This method does away with the extra bias battery, and is particularly adapted to tubes with indirectly-heated cathodes (*heater-type* tubes). With this method point X is grounded and the cathode is isolated from ground and negative "B" through the biasing resistor *R*. By-pass condenser *C* will have the same values as in A. When plate current flows through the tube there will be a voltage drop through *R* which makes the cathode more positive than the grid — in other words, puts negative bias on the grid. The right value for *R* can be calculated by Ohm's Law, knowing the bias voltage required and the total space current through the tube. The space current is the sum of the plate current and all currents that may be taken by auxiliary grids in the tube. For example, a certain pentode tube requires a bias of 10 volts with 150 volts on the plate and screen-grid; at this plate voltage the plate current will be 15 ma. and the screen-grid current 5. The bias resistance required will be:

$$R = \frac{10 \text{ volts}}{.02 \text{ amp.}} = 500 \text{ ohms.}$$

Cathode-resistor biasing can be used with tubes having directly-heated filaments provided a separate source of filament-heating is used with each stage so biased. This is often done in a.c.-operated receivers having an audio power output stage, the power tubes being heated by a separate filament winding on the power transformer.

Audio-Frequency Power Amplifiers — Volume Control

▲ A power audio stage can be added to the receiver intended for headphone output where it is desired to operate a loud speaker. Alternatively, a power stage of sufficient power sensitivity can be substituted for the usual low-output amplifier following the detector. Several power amplifier combinations capable of a watt or more output are shown in Figs. 508 and 509, including triodes

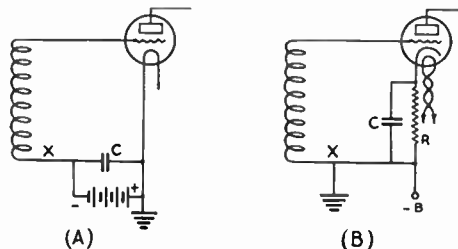


FIG. 507 — BATTERY AND CATHODE-RESISTOR BIASING

as single-ended and push-pull amplifiers, and pentodes of two types. The latter have the greater power sensitivity (require less grid excitation for equal output) and are suited to connection to the detector output of the usual receiver. The circuit shown in Fig. 509 is popularly used in amateur receivers. If the receiver does not have a gain or sensitivity control in its r.f. circuits, an audio-frequency volume level control is advisable. This volume control is arranged as shown in Fig. 509, being a variable voltage divider resistor or potentiometer connected across the secondary of the input transformer so that the audio voltage ap-

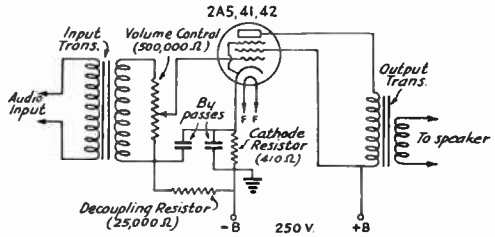


FIG. 509 — A TYPICAL PENTODE POWER AMPLIFIER CIRCUIT WITH VOLUME CONTROL

This circuit can be used with any of the indirectly heated cathode pentodes. The use of a decoupling circuit to prevent "degenerative" effects or loss of amplification at the lower audio frequencies, also is illustrated.

plied to the grid-cathode circuit of the tube can be varied from maximum to zero.

Fixed Condensers and Resistors

▲ In addition to the principal receiver circuit elements — coils, variable condensers, gain- or volume-control resistors, tubes, etc. — there are also certain fixed condensers and resistors that are important. In both audio- and radio-frequency circuits there will be found fixed condensers connected across resistors, from plate to filament and even across portions of the circuit that appear in the diagram to be directly connected. These are *by-pass* condensers, provided to give a direct path for audio- or radio-frequency currents and to prevent these currents from flowing through other paths where they might cause undesirable degenerative or regenerative effects. In other cases fixed condensers are used to serve as paths for audio- or radio-frequency currents while preventing the flow of direct current, in which case they are known as *coupling* or *blocking* condensers. Since the reactance of a condenser is inversely proportional to its capacity and to the frequency, radio-frequency coupling and by-pass condensers are of relatively large capacity while those for audio frequencies are of relatively large capacity. Small mica or non-inductive paper-dielectric condensers of from 100 $\mu\text{fd.}$ to 0.01 $\mu\text{fd.}$ capacity are commonly used for r.f. circuits, while capacities of from 0.01 to several $\mu\text{fd.}$ are used in a.f. circuits. The particular size used, while not especially critical as to value, will be determined by the impedance across which the condenser is connected, being smaller in capacity as the parallel impedance is greater. In the case of r.f. by-passes in circuits intended to transmit audio frequencies, as in the plate circuit of a detector, the capacity must be kept small enough so that the condenser will not by-pass audio frequencies also. Typical values are 0.001 $\mu\text{fd.}$ and smaller. Audio-frequency by-pass condensers, on the other hand, usually have values ranging from $\frac{1}{4}$ $\mu\text{fd.}$ for paper condensers to 8 or 10 $\mu\text{fd.}$ for electrolytic types.

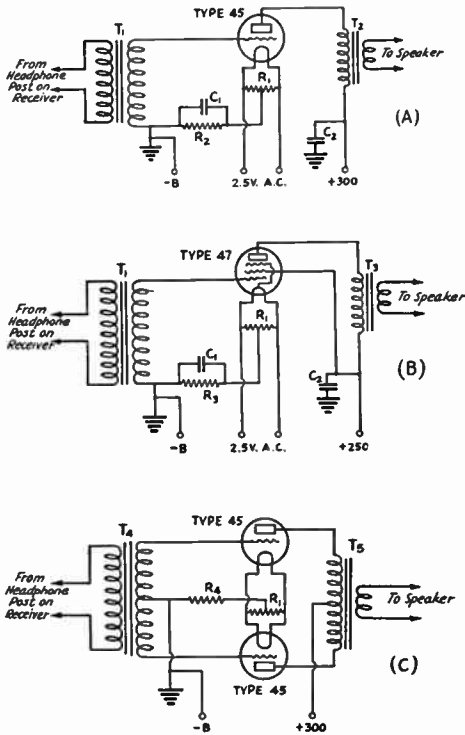


FIG. 508 — AUDIO POWER AMPLIFIERS FOR LOUD-SPEAKER OPERATION

A — using a single Type 45 tube, B — a single 47 pentode, C — two 45's in push-pull. Transformer T_1 is an ordinary audio transformer having a turns ratio of 2:1 or 3:1. T_2 is an output transformer designed to couple a 45 tube to the loud-speaker being used. T_3 is for coupling a 47 to the speaker. T_4 is a push-pull input transformer and T_5 a push-pull output transformer for a pair of 45's. It is necessary to know the impedance of the loud-speaker in order to purchase the right type of output transformer in all three cases. R_1 is a 20-ohm resistor, tapped at the center. R_2 is 1500 ohms, rated to carry approximately 50 ma. R_3 is 450 ohms, also to carry about 50 ma. R_4 is 750 ohms, rated at 75 ma. or more. Both C_1 and C_2 should be 1 to 2 $\mu\text{fd.}$ C_2 , which must be rated to stand the full plate supply voltage, may not be needed if the plate voltage for the amplifier comes directly from a filter condenser in the power pack.

The latter should be used only as by-passes in circuits carrying audio frequency superimposed on d.c., as in cathode circuits. A fair value for most audio applications in amateur receivers is 1 μ d., although larger values may be used where better response to lower audio frequencies is desired.

Fixed resistors are also used, in a wide variety of sizes, to provide bias voltage, to drop plate voltage, to serve as coupling loads in audio circuits and to decouple in both radio- and audio-frequency grid- and plate-return circuits. Values for resistors to provide bias voltages and to drop plate voltages depend on the current flowing through them and are determined from Ohm's law, as shown previously. Plate- and grid-coupling condenser and resistor values depend primarily on the tube combination with which they are used, values shown in receivers described in this chapter being typical. Decoupling resistor and condenser combinations, used principally in grid return circuits, are connected as shown in Fig. 509. They are not critical as to value, 25,000 ohms or higher being satisfactory for the resistor and usual by-pass capacity serving for the condenser in most instances. Usually such circuits are necessary only in high-gain amplifiers of two or more stages.

Receiving Tubes

▲ Modern receiving tubes are grouped into three classes, depending upon the type of service for which they are intended. One group is for dry-cell operation and is characterized by tubes with 2-volt directly-heated filaments which take very small currents. The second group has filaments or heaters designed for use with a 6-volt storage battery. Most of the tubes in this group have indirectly-heated cathodes. The third, or "a.c." group, has filaments which take rather heavy currents at 2.5 volts a.c. In this group the tubes used as r.f. amplifiers and detectors have indirectly-heated cathodes while the power audio amplifiers have both directly- and indirectly-heated cathodes.

In each group will be found general-purpose three-element tubes which are useful as detectors, audio amplifiers and oscillators; screen-grid amplifiers (usually two types of these, one with the "variable-mu" feature, the other without); and various kinds of power ampli-

fiers — triodes, pentodes and special tubes for superhet converters and Class-B amplifiers (see Chapter Eight also for information on the latter).

From the above it is obvious that the first question to be decided is that of filament supply. If a.c. is available it is undoubtedly best to use the heater-type tubes, not only because no batteries will be required but because, type for type, these tubes are better than the others. On the other hand, an all-d.c. set will have no "hum troubles."

Fig. 510 shows the socket connections for the tubes listed in the table. The symbol for each type of tube also is shown.

Receiver Construction

▲ The receiver descriptions which follow are intended to illustrate the points just discussed. The various arrangements need not be followed slavishly by the constructor, providing principles of good design are not violated. For instance, any of the various band-spreading schemes already detailed may be substituted for the one in the particular set in which you are interested. If you prefer to use coils wound on forms other than those specified by all means do so, but at the same time remember that some modification of the coil sizes given will be necessary if the forms differ in diameter. Audio systems may be interchanged, likewise. A little common sense applied to most of the problems you may encounter will solve nearly all difficulties.

Tools

▲ While it is possible to put a set together with the aid of only the proverbial jackknife, a few good tools of the proper sort will be found invaluable in saving time and helping to make a good job mechanically. The following list is typical of the tools which most amateurs consider adequate:

- Soldering iron (preferably electric)
- Large and small side-cutting pliers
- Large and small screwdrivers
- Hand drill stock with a few drills of different sizes (Nos. 11, 18 and 28 will be most useful)
- File (not too large)
- Knife (Boy-Scout kind)
- Hammer
- Vise (the small 4" size will do)
- Steel rule (6" or 12")

With these tools it is possible

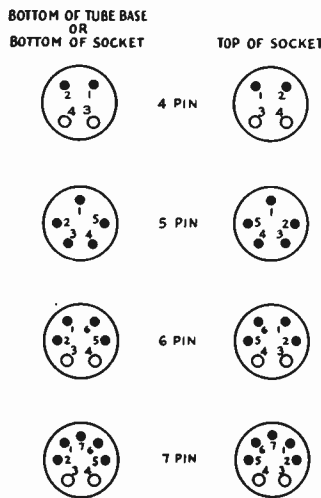


FIG. 510 — TUBE SOCKET CONNECTIONS FOR RECEIVING TUBES

The diagrams in the left-hand column are for the sockets as viewed from the bottom, those in the right-hand column as viewed from the top. The pin numbering is according to the system adopted by tube manufacturers (R.M.A. standard). The accompanying table indicates by number the tube element connected to each socket pin, also to the cap on top of the tube when there is one.

to construct practically any of the apparatus ordinarily built at home. Others will be found useful at times, however. A small tap-holder, a die-holder and three or four taps and dies covering the 6-32, 8-32 and 10-32 sizes can be obtained from a hardware store at reasonable cost. With the dies you can thread brass rod and run over threads that become "bunged-up" on machine screws. With the taps you can thread the holes you drill so that they will take machine screws to hold the apparatus you wish to mount. A hacksaw, reamer, center-punch, scribe, tweezers, square and some other inexpensive tools are also desirable but not entirely necessary.

In building equipment for experimental purposes and for temporary use it is just as desirable to use system in laying out the apparatus and in wiring up as when the more permanent panel job is built. Some square "breadboards," a bunch of General Radio plugs and jacks, Fahnestock clips, some scrap bakelite pieces for building terminal boards, angles for supports and an assortment of different sized brass machine screws, wood screws, nuts, and washers will make it easy to build up and try out new circuits. It is a good idea to keep some hook-up wire on hand, and various sized spools of magnet wire will prove useful in doing temporary wiring if you are an experimenter.

A table of drill sizes giving the proper numbered drill to use for passing a screw through a panel or for tapping to take a certain size of machine screw is included in the Appendix. Only the sizes most used in radio constructional work are given.

Soldering and Wiring

▲ In wiring different pieces of apparatus a neatly soldered job will repay the builder in good appearance and reliable operation. Good connections may be made without solder, but a well-soldered joint has low contact resistance.

Making good soldered joints is a quite simple matter. A few points should be kept in mind for best results. A hot well-tinned soldering iron, clean, bright surfaces, and a *small* amount of rosin-core solder will do the trick. Tinning the parts to be soldered before completing a joint will be helpful.

Soldering flux keeps the clean surface from becoming oxidized when heat is applied. Acid fluxes or soldering pastes are especially to be avoided. They are good for mending tin pans and gutter pipes but cause corrosion of electrical connections. The melted "paste" can cause a set to operate poorly or to become inoperative by adding leakage paths across coils and condensers. Use lump or powdered rosin that can be obtained for a dime from any drug store, or buy "rosin-core" solder.

"Tinning" the soldering iron is done by filing the point bright and clean and rubbing it in hot solder with a little flux until the point is covered

with clean solder. Scrape connections with a knife or file before soldering, to save time and make a joint good electrically and mechanically. The soldering iron must be re-tinned occasionally if it becomes overheated. It should always be used

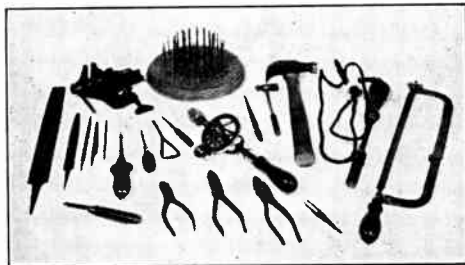


FIG. 511 — GOOD TOOLS CONTRIBUTE TO GOOD CONSTRUCTION

All those illustrated, although convenient, are not entirely necessary. Those suggested in the text are recommended as the basis for the constructor's equipment.

when very hot but not allowed to become red hot. A hot iron makes soldering easy.

Simple Regenerative Receivers

▲ A simple receiver of sturdy construction, representative of modern regenerative types, is illustrated in Figs. 512-516, inclusive. It consists essentially of a regenerative detector and one audio stage, and is intended for headset reception. It is also adapted to either 2.5- or 6-volt a.c. or d.c. filament supply with heater-type tubes, or to 2-volt low-current filament supply with slight modifications.

The circuit diagram of the receiver is shown in Fig. 514 as intended for heater-type tubes and in Fig. 517 as modified for 2-volt filament-type tubes. Additional views demonstrating the constructional details are given in Figs. 513 and 515. The actual layout used is not particularly important except that, as always, it is desirable to have short leads in the r.f. circuit. Metal chassis construction is strongly recommended, since the shielding thus afforded is helpful in reducing capacity effects and in cutting out hum pickup from the induction fields which permeate most homes having a.c. wiring. For these same reasons a metal cabinet is advantageous, and since it is possible to purchase metal boxes for less than the cost of the aluminum that would go into making one of the same dimensions, the set was made to fit such a box, in this case a National Type C-SRR. The aluminum base or chassis on which all the parts, including the tuning condensers and the regeneration control, are mounted measures $7\frac{1}{2}$ by $7\frac{1}{2}$ inches. Quarter-inch square brass rods, drilled and tapped for 6-32 screws, are fastened along two edges of the base to furnish a convenient means of securing it in place in the cabinet.

STANDARD RECEIVING TUBES

Type No.	Description	Filament or Heater		Plate Volts E_b	Neg. Grid Volts E_c	Screen Volts E_d	Screen Ma. I_d	Plate Ma. I_b	Plate Resistance r_p	Mutual Conductance Micromhos	Amp. Factor μ	Load Resistance Ohms	Power Output Watts (Audio)	Base Connections [†]				
		Volts E_f	Amps. I_f											1	5	6	7	Cap
30	Triode Det., Amp.	2.0	0.06	180	13.5			3.1	10,300	900	9.3			G				
32	S.G. R.F. Amp., Det.	2.0	0.06	180	3.0	67.5	0.4	1.7	1,200,000	650	780			S				G
34	Var.- μ S.G. Pentode	2.0	0.06	180	3.0	67.5	1.0	2.8	1,000,000	620	620			S				G
1A6	Pentagrid Converter ²	2.0	0.06	180	3.0	67.5	2.4	1.3	500,000					G ₂	G ₃	G ₁		G ₄
1C6	Pentagrid Converter ²	2.0	0.12	180	3.0	67.5	2.0	1.5	750,000					G ₂	G ₃	G ₁		G ₄
19	Twin Amp. (Class B)	2.0	0.26	135	0			10-35				10,000	2.1	G	P	G		
31	Triode Power Amp.	2.0	0.13	180	30.0			12.3	3,600	1050	3.8	5,700	0.375	G				
33	Pentode Power Amp.	2.0	0.26	135	13.5	135	3.0	14.5	50,000	1450	70	7,000	0.7	G	S			
49	Dual-Grid Power Amp. ³	2.0	0.12	180	0			4-35				12,000	3.5	G ₁	G ₂			
27	Triode Det., Amp.	2.5*	1.75	250	21.0			5.2	9,250	975	9.0			G	C			
56	Triode Det., Amp.	2.5*	1.0	250	13.5			5.0	9,500	1450	13.8			G	C			
24-A	S.G. R.F. Amp.	2.5*	1.75	250	3.0	90	1.7	4.0	600,000	1050	630			S	C			G
35	Var- μ S.G. R.F. Amp.	2.5*	1.75	250	3.0	90	2.5	6.5	400,000	1050	420			S	C			G
57	Pentode R.F. Amp.	2.5*	1.0	250	3.0	100	0.5	2.0	over 1.5 meg.	1225	1500			S	C	K		G
58	Var.- μ Pentode R.F. Amp.	2.5*	1.0	250	3.0	100	2.0	8.2	80,000	1600	1280			S	C	K		G
2A7	Pentagrid Converter ²	2.5*	0.8	250	3.0	100	2.2	3.5	360,000					G ₃	C	G ₁	G ₂	G ₄
2A6	Duplex-Diode, High- μ Triode ⁴	2.5*	0.8	250	1.35			0.4						D	C	D		G
2B7	Duplex-Diode, Pentode ⁵	2.5*	0.8	250	3.0	125	2.3	9.0	65,000	1125	730			S	C	D	D	G
55	Duplex-Diode, Triode ⁴	2.5*	1.0	250	20.0			8.0	7,500	1100	8.3	20,000	0.35	D	C	D		G
2A3	Triode Power Amp.	2.5	2.5	250	45.0			60.0	800	5250	4.2	2,500	3.5	G				
2A5	Pentode Power Amp.	2.5*	1.75	250	16.5	250	6.5	34.0	100,000	2200	220	7,000	3.0	S	C	G		
45	Triode Power Amp.	2.5	1.5	275	56.0			36.0	1,700	2050	3.5	4,600	2.0	G				
46	Dual-Grid Power Amp. ⁶	2.5	1.75	250	33.0			22.0	2,380	2350	5.6	6,400	1.25	G ₁	G ₂			
47	Pentode Power Amp.	2.5	1.75	250	16.5	250	6.0	31.0	60,000	2500	150	7,000	2.7	G	S			
53	Twin Amp. (Class B)	2.5*	2.0	300	0			35-110				10,000	10.0	G	P	G		C
59	Triple-Grid Power Amp. ⁷	2.5*	2.0	250	28.0			26.0	2,400	2600	6.0	5,000	1.25	G ₂	C	G ₃	G ₁	
2B6	Special Power Amp. ¹¹	2.5*	2.25	250	24.0			40.0	5,150	3500	18.0	5,000	4.0	P ₁	C ₂	C ₁ , G ₂	G ₁	

Plate and screen ratings in this table are maximum.

* Indirectly-heated cathode.

¹ See tube-base layout diagram, Fig. 508. Pins 3 and 4 are always heater or filament connections; Pin 2 is always a plate. C, cathode; D, diode plate; G, control grid; G₁, G₂, G₃, G₄, grids in multi-grid multi-purpose tubes numbered in order from cathode; K, suppressor grid; P, plate; S, screen grid.² Ratings refer to screen-grid section only.¹¹ Also known as Triple Twin. Consists of two triodes, each of 5 pins.

Type No.	Description	Filament or Heater		Plate Volts E_b	Neg. Grid Volts E_c	Screen Volts E_d	Screen Ma. I_d	Plate Ma. I_b	Plate Resistance r_p	Mutual Conductance Micromhos	Amp. Factor μ	Load Resistance Ohms	Power Output Watts (Audio)	Base Connections ¹				
		Volts E_f	Amps. I_f											1	5	6	7	Cap
37	Triode Det., Amp.	6.3*	0.3	250	18.0			7.5	8,400	1100	9.2			G	C			
76	Triode Det., Amp.	6.3*	0.3	250	13.5			5.0	9,500	1450	13.8			G	C			
36	S.G. R.F. Amp.	6.3*	0.3	250	3.0	90	1.7	3.2	550,000	1080	505			S	C			G
39-44	Var.- μ Pentode R.F. Amp.	6.3*	0.3	250	3.0	90	1.4	5.8	1,000,000	1050	1050			S	C			G
77	Pentode R.F. Amp.	6.3*	0.	250	3.0	100	0.6	2.3	1,500,000	1250	1500			S	C	K		G
78	Var.- μ Pentode R.F. Amp.	6.3*	0.3	250	3.0	125	3.0	10.5	600,000	1650	990			S	C	K		G
6C6	Pentode R.F. Amp.	6.3*	0.3	250	3.0	100	0.5	2.0	over 1.5 meg.	1225	1000			S	C	K		G
6D6	Var.- μ Pentode R.F. Amp.	6.3*	0.3	250	3.0	100	2.0	8.2	80,000	1600	1280			S	C	K		G
75	Duplex-Diode, High- μ Triode ⁴	6.3*	0.3	250	1.35			0.4						D	C	D		G
85	Duplex-Diode, Triode ⁴	6.3*	0.3	250	20.0			8.0	7,500	1100	8.3	20,000	0.35	D	C	D		G
6B7	Duplex-Diode, Pentode ⁵	6.3*	0.3	250	3.0	125	2.3	9.0	650,000	1125	730			S	C	D	D	G
6F7	Triode, Pentode ⁵	6.3*	0.3	250	10.0	100	0.6	2.8						S	C	G	P	G
6A7	Pentagrid Converter ²	6.3*	0.3	250	3.0	100	2.2	3.5	360,000					G ₃	C	G ₁	G ₂	G ₄
6A4	Pentode Power Amp. ³	6.3	0.3	180	12.0	180	3.9	22.0	45,500	2200	100	8,000	1.4	G	S			
38	Pentode Power Amp.	6.3*	0.3	250	25.0	250	3.8	22.0	100,000	1200	120	10,000	2.5	S	C			G
41	Pentode Power Amp.	6.3*	0.4	250	18.0	250	5.5	32.0	68,000	2200	150	7,600	3.4	S	C	G		
42	Pentode Power Amp.	6.3*	0.7	250	16.5	250	6.5	34.0	100,000	2200	220	7,000	3.0	S	C	G		
79	Twin Amp. (Class B)	6.3*	0.6	250	0			10-60				14,000	8.0	G	P	C		G
89	Triple-Grid Power Amp. ¹⁰	6.3*	0.4	250	31.0			32.0	2,600	1800	4.7	5,500	0.9	G ₂	C	G ₃		G ₁
864	Triode Amp.	1.1	0.25	135	9.0			3.5	12,700	645	8.2			G				
20	Triode Power Amp.	3.3	0.13	135	22.5			6.5	6,300	525	3.3	6,500	0.11	G				
22	S.G. R.F. Amp.	3.3	0.13	135	1.5	67.5	1.3	3.7	325,000	500	160			S				G
01-A	Triode Amp., Det.	5.0	0.25	135	9.0			3.0	10,000	800	8.0			G				
40	Triode Amp.	5.0	0.25	180	3.0			0.2	150,000	200	30			G				
112-A	Triode Amp., Det.	5.0	0.25	180	13.5			7.7	4,700	1800	8.5			G				
71-A	Triode Power Amp.	5.0	0.25	180	43.0			20.0	1,750	1700	3.0	4,800	0.79	G				
43	Pentode Power Amp.	24.0*	0.3	135	20.0	135	7.0	34.0	35,000	2300	80	4,000	2.0	S	C	G		
48	Tetrode Power Amp.	30.0*	0.4	125	22.5	100	9.0	50.0	10,000	2800	28	2,000	2.5	S	C	G		

¹ Ratings are for two tubes in Class B. ⁴ Triode ratings only. ⁵ Pentode ratings as screen-grid r.f. amplifier. ⁶ Class-A ratings. See Chapter Eight for Class-B ratings. ⁷ Class-A triode ratings. ⁸ Class-B ratings approximately the same as those of 46; Class-A pentode ratings approximately the same as those of 2A5. ⁹ Pentode unit as mixer. ¹⁰ Class-A triode ratings. As pentode, maximum output is 3.4 watts; two 89's in Class B at 180 volts, 3.5 watts output. ³ Also known as Type LA.

The two tuning condensers are mounted along the front edge of the base with their shafts projecting beyond the edge so the dials can be fastened to them when the set is put in the box. Behind the tuning condensers is the socket for the plug-in coils, an isolantite socket mounted on metal pillars so the socket prongs clear the base. The grid condenser and leak are just behind the right-hand tuning condenser, the far end of the condenser being supported from the base by a small piece of bakelite drilled and tapped to serve as a mounting.

To the rear of the grid condenser is the detector tube socket, and in the rear right-hand corner the binding posts for the phones. The audio tube socket is next, and occupying the rear left-hand corner is the audio coupler. The antenna and ground terminals are along the left edge of the base mounted on a bakelite strip.

The coil socket is mounted so that the leads to the tuning condensers are short and convenient.



FIG. 512 — THIS TWO-TUBE RECEIVER HAS A CONTINUOUS FREQUENCY RANGE OF 1450 TO 41,000 KILOCYCLES AND GIVES COMPLETE BAND-SPREAD ON FIVE AMATEUR BANDS

It can be used with either 2.5- or 6.3-volt tubes without change in the wiring. The right-hand dial gives general coverage and that at the left gives band-spread around any frequency for which the general-coverage dial may be set.

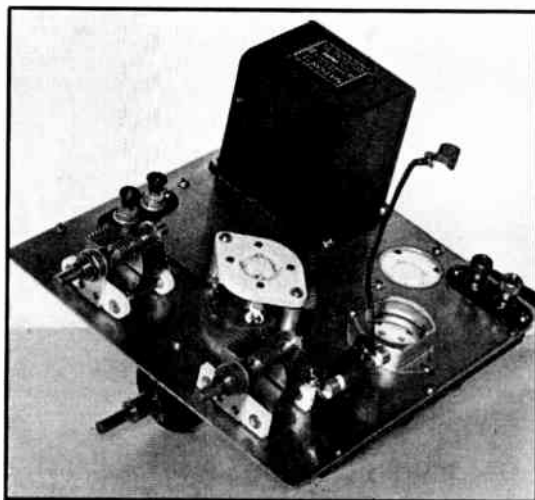


FIG. 513 — THE "CHASSIS" OF THE TWO-TUBE RECEIVER

All parts are mounted on the square sheet-aluminum base. The location of the components is described in the text.

The rear right-hand socket terminal (No. 4) is connected to the cathode of the detector tube; the wire from the coil socket drops down through a hole in the base and runs underneath to the tube socket. A wire from this same prong also runs through another hole in the base to the antenna post. The connection to the ground terminal is similarly made to the rear left-hand terminal (No. 2) on the coil socket. The feedback coil — the part of the coil included between the cathode tap and ground — is thus made to serve as the antenna coupling coil as well. Experiment has shown that this method provides just about the right amount of coupling, keeping antenna effects to a minimum while providing plenty of signal strength.

Parts mounted below the base include the regeneration control, the plate by-pass condensers and plate choke, and the screen and audio cathode by-pass condensers. This last is a double condenser having two sections of 0.5 μ fd. each. Increasing each to 1 μ fd. will reduce regeneration-control resistor noise and aid in amplification of the lower audio frequencies. The audio cathode resistor and the screen dropping resistor also are mounted underneath the base. The regeneration control resistor is mounted on a bracket made from half-inch brass strip, from which it must be insulated. An extension shaft gives the necessary length so that this resistor can be controlled from the panel.

Fitting the set to the box requires a little care, but presents no particular problems. The back and bottom of the box should be removed, after which the receiver can be pushed in from the

rear. A space of about two inches between the bottom and the base will be sufficient; lines should be ruled along the inner sides of the box as guides so the chassis will be square with the box. Then the points at which the shafts of the tuning condensers and regeneration control go through the front should be marked and holes drilled to correspond. These may be made fairly large, and small inaccuracies will not matter. The next step is to drill small holes along the sides of the box for the screws which fit into the brass-rod mounting strips. Drilling and tapping of these rods for the side screws should be left until after the holes in the sides of the box have been drilled, so that their exact location can be easily spotted when the set is in its final position. The dials should not be fastened in place until all the other mechanical work has been finished; if dials similar to those shown (National Type B Midget) are used, the drilling template should be lined up with the condenser shafts after the receiver is securely mounted in the box. This will avoid the embarrassment of having condenser shafts and dials refuse to line up. The only precaution to be observed in connection with the regeneration-control shaft is to see that it does not touch the box as it comes through.

Coil Construction

▲ Fig. 516 shows how the connections are made on the coil forms, while the specifications are given under Fig. 514. In all cases the grid and ground ends of the coils come through the forms directly over their respective pins, and the tap specifications are given in turns and fractions of turns from the ground end. The length of the winding should be exactly 1½ inches on all coils, and on all but the 1.75-mc. coil the turns should be separated to give an even spacing throughout. The 1.75-mc. coil is close-wound with the wire specified. Different brands of wire vary a bit in insulation thickness, so if the completed close-wound 1½-inch coil has a turn or two more or less than indicated in the coil table it is quite in line with what would be expected. A small variation in the total number of turns on this coil is unimportant so long as the taps are counted off from the ground end as specified. The turn spacing on the 3.5-mc. coil is adjusted by putting another winding of the same size wire between the turns of the actual coil, the auxiliary winding being removed after the coil terminals are soldered in place. Spacing on the higher-frequency coils is adjusted by hand. Taps are made by drilling a hole through the

form at the proper point, cutting off the wire and running it down to the proper pin. A new piece of wire with its end fastened in the same pin continues the winding. When finished, the windings should be given a coat of clear Duco or coil dope possessing good adhesive properties.

With the coils specified, the band-spread is between 80 and 100 dial divisions on the band-spread condenser on all except the 3500-kc. coil. In this case the tap has been adjusted to spread the 400-kc. c.w. portion over the whole dial. Good spread on the 'phone portion is obtained by resetting the main tuning condenser, C₂, so that the high-frequency end of the band is covered on C₁.

Any desired degree of spread can be obtained by changing the position of the tap. Moving the tap toward the ground end will increase the spread — decrease the frequency coverage — on C₁, while moving the tap toward the grid end will make C₁ cover a wider frequency range. Unfor-

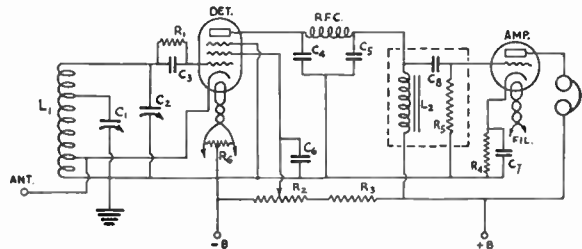


FIG. 514 — CIRCUIT DIAGRAM OF THE TWO-TUBE RECEIVER

For 2.5-volt a.c. filament operation, the 57 and 58 are recommended as detectors and the 56 as the audio amplifier. For storage battery operation suitable detectors are the 77, 78, 6C6, and 6D6; audio amplifier, 76 or 37. These tubes also can be operated from a 6.3-volt transformer.

- C₁, C₂ — 100-μfd. midget variable (Hammarlund MC-100-S).
- C₃, C₄, C₅ — 100-μfd. fixed mica condenser (Aerovox Type 1460).
- C₆, C₇ — .5-μfd. or larger.
- R₁ — 5 megohms.
- R₂ — 50,000-ohm potentiometer (Frost) small size.
- R₃ — 25,000 ohms, 10 watts (Ohmite).
- R₄ — 2000 ohms, 1 watt.
- R₅ — 75 ohms, center-tapped (Ohmite).
- RFC — Universal wound short-wave choke (Hammarlund).
- L₂, C₃, R₅ — Screen-grid coupler (National Type 2-101). Suitable values are: L₂, 500 henrys; C₃, .01 μfd.; R₅, 0.5 megohm.

Frequency Range	Coil Data		Band-Spread
	Total turns, L ₁	Cathode Tap	
1450 to 3400 kc. (1.75)	54½	3¼	29¾
3050 to 7100 kc. (3.5)	27½	1¼	11¾
6100 to 14,200 kc. (7)	13½	¾	4¼
10,600 to 24,000 kc. (14)	7½	½	1¼
18,000 to 41,000 kc. (28)	3½	½	½

All coils are wound with No. 24 d.s.c. wire on 1½-inch diameter forms, the length of the coil being 1½ inches in all cases. The figure in parenthesis after each frequency range indicates the amateur band for which that coil is used. The taps are counted off from the lower or ground terminal. Assuming that the tuning dials have 100 divisions and that the 0 end of the scale represents maximum condenser capacity, the setting of C₂ to give amateur band coverage on C₁ will be approximately as follows, using appropriate coils: 1.75 mc., 44; 3.5 mc., 38; 7 mc., 28; 14 mc., 54; 28 mc., 78. See text on coil construction.

tunately the position of the tap for a predetermined amount of band-spread cannot be readily calculated, and the work must be done experimentally.

Electrically, there are only two pitfalls to avoid. The first is to make sure that the part of the coil included between the cathode tap and ground end is as close to specifications as possible. It does not take much "tickler" in this circuit to provide all the needed feedback, and too much feedback not only reduces the sensitivity but also may lead to howls.

The second thing to avoid is the use of a makeshift audio coupler between the detector and amplifier. While audio transformers can be pressed into service as coupling impedances, a good many of them show a pronounced tendency to produce fringe howl. Trouble of this sort can be sidestepped by acquiring a coupler made especially for the job of coupling a screen-grid detector to an audio amplifier. There are several of them on the market.

The receiver can be used with either 2.5- or 6.3-volt tubes of the types enumerated under the circuit diagram, and is suitable for either a.c. or storage-battery operation of the filaments of 6.3-volt tubes. Plate voltage can come either from a "B" pack or batteries, with voltages from 90 to 250 volts being satisfactory. Somewhat greater signal strength will be obtained at the higher "B" voltages.

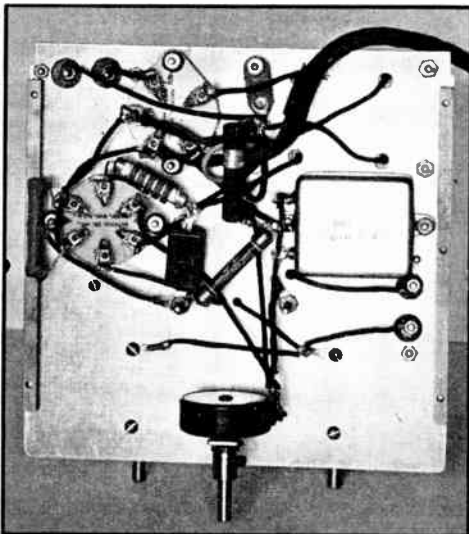


FIG. 515 — THIS UNDERNEATH VIEW SHOWS THE REGENERATION CONTROL RESISTOR AND THE VARIOUS BY-PASS CONDENSERS AND RESISTORS

The positive "B" terminal is on a small piece of fibre which insulates it from the base. Each filament lead in the six-wire cable consists of two wires soldered together to lower the voltage drop. All ground connections from the tuning condensers and coil are bonded together.

The set should first be tested with the antenna disconnected to make sure that it goes into oscillation smoothly, and, incidentally, to make sure that the plate power-supply, if an eliminator, is free from tunable hums. If the receiver is quiet and stable throughout the entire range, the antenna may be connected. If hum and body capacity now appear at some part of the range, different

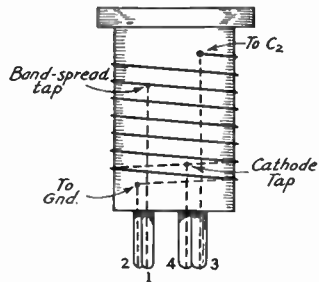
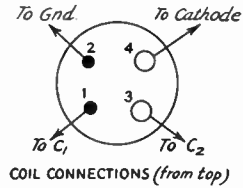


FIG. 516 — COIL SOCKET CONNECTIONS AND THE METHOD OF BRINGING OUT COIL TERMINALS

antenna lengths should be tried. It should not be difficult to find a length which will permit stable operation in the amateur bands.

A circuit diagram of the receiver arranged for operation with battery-type 2.0-volt tubes is shown in Fig. 517. The differences between this and the circuit of Fig. 514 are principally in the filament circuits, the directly-heated filaments of the 2.0-volt tubes requiring somewhat different treatment. The mechanical construction and operating features remain unchanged from the other model, however.

When batteries are used for "B" supply with the heater-type tube model, a switch should be installed in the negative "B" lead so the batteries can be disconnected from the voltage divider when the receiver is not in use and thus avoid unnecessary drain on the batteries. In the 2.0-volt tube model the filament switch is all that is necessary, since the voltage divider is omitted from the receiver.

A Three-Tube Regenerative Receiver

▲ The progressive amateur is rarely content to operate a receiver not fitted with at least one stage of radio-frequency amplification. The increase in sensitivity and the general improvement in performance made possible by a stage of

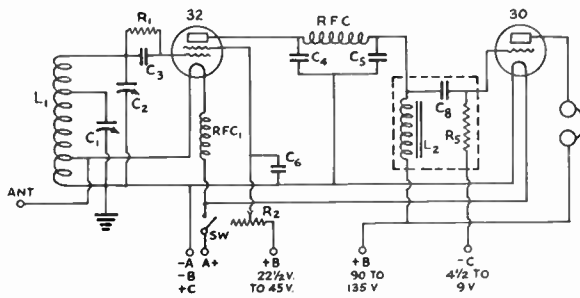


FIG. 517 — THE TWO-TUBE RECEIVER DIAGRAM ADAPTED FOR TWO-VOLT TUBES

Components have the same values as indicated in Fig. 511. The filament supply may be from an Air-Cell Battery or from two dry cells connected in series; in the latter case a 10-ohm rheostat should be connected in series with the "A" battery so the voltage applied to the filaments can be regulated to the proper value. The detector filament choke, RFC₁, is wound with No. 30 s.s.c. wire on a half-inch form to a length of two inches.

r.f. amplification is usually well worth the additional apparatus and the added construction.

The three-tube receiver illustrated, and diagrammed in Fig. 519, has a tuned r.f. stage with controllable sensitivity. The circuit arrangement differs a little from those previously described, but the operating principles are the same. The band-spreading system will be recognized as the first of those outlined early in this chapter. It is used in this set because it is one of the easiest systems to get working when the tuning of two stages is to be ganged, and because the relatively large capacity in the tuned circuits makes the detector oscillate more stably and thus prevents the signals from wavering should the "B" supply voltage change slightly.

The panel is of 1/8-inch aluminum and measures 7 by 14 inches. The sub-base is made of a single piece of 3/32-inch aluminum with the corners cut out and edges bent down in a vise so that the top surface is 13 1/2 by 7 1/2 inches and the vertical sides are two inches high. The two shield boxes are made of 1/16-inch aluminum, each measuring 4 3/4 inches high, 4 1/4 inches wide and 7 inches deep. The panel constitutes the front of both boxes. The pieces making up the sides of the boxes are fastened together by being screwed to vertical pieces of 1/4-inch square brass rod which have been drilled and tapped to take small machine screws at appropriate points. Similar rods also are used to fasten the boxes to the panel.

It is important, in building up the chassis, to make certain that good contact is made between all metal parts. Loose panels in the shield boxes will re-

sult not only in poor shielding but will undoubtedly be the source of many noises.

The tuning condensers are Hammarlund midgets, mounted as shown in Fig. 520. To gang the two condensers the spring contacts which wipe on the shaft should be removed so that a flexible coupling can be slipped over the shaft. The connection to the rotor plates of the condenser so altered should be made through the front bearing when this is done, because the rear bearing may be

noisy. The condensers and dial are connected together by means of pieces of quarter-inch shafting and small flexible couplings.

The detector circuit is designed to permit the use of 5-prong coil forms. Only three terminals are needed for the oscillating circuit, the other two being available for the coupling coil from the r.f. stage. As in the two-tube receiver, the tickler in this circuit comprises the portion of L₄ between cathode and ground, and is smaller than the tickler of more usual regenerative circuits.

A small audio transformer is used to couple the detector to the audio amplifier. A coupler such as the one used in the two-tube receiver can be substituted, provided changes are made in the mechanical arrangement of the set so it can be fitted in.

The wiring diagram, Fig. 519, is for operation from an a.c. power pack which will deliver 2.5 or 6.3 volts a.c. for the filaments and 200 volts d.c. for the plates. Voltages for the screen grids

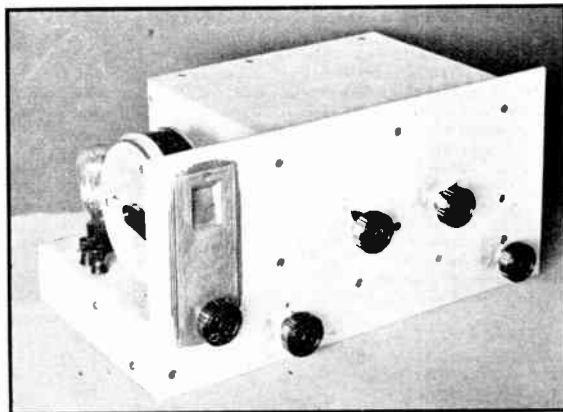


FIG. 518 — A MODERN THREE-TUBE TUNED R.F. AMATEUR BAND RECEIVER

It comprises a stage of r.f. amplification with controlled sensitivity, a stable regenerative detector and one-stage audio. It uses heater-type tubes for a.c. or 6-volt d.c. operation.

The tuning dial is placed at the left so the receiver can be operated without getting in the way of papers, log books, etc. To the right and below the dial is the regeneration control. The two upper knobs are the band-setting condensers. The sensitivity control is in the lower right-hand corner. The audio tube and the phone binding posts can be glimpsed behind the drum dial on the sub-base.

are obtained by means of voltage dividers and series resistors. If "B" batteries are to be used resistors R_5 and R_6 may be omitted and a separate lead brought out from R_{10} to the 45-volt tap on the "B" battery.

Resistor R_3 controls the amplification of the r.f. tube by varying the bias applied to its grid. The advantage of such a control is that it permits reducing the strength of strong signals and thus prevents the detector from "blocking" or "pulling in." A strong signal will occupy much more space on the dial than a weak one unless its strength can be reduced. The sensitivity control does this and thereby greatly increases the effective selectivity of the receiver.

The antenna input has been arranged so that a doublet antenna can be used with the receiver (see Chapter Twelve). With an ordinary antenna and ground, one of the antenna posts should be

connected to the ground post to complete the circuit.

Should the set not work right at the first trial, check over the wiring and apply the tests outlined later in this chapter. These tests also apply to the two-tube a.c.-d.c. receiver previously described.

Superhet Receivers — Frequency Converters

▲ As has been mentioned previously, the superhet-type receiver differs from the simpler regenerative autodyne types in that the incoming signal frequency is first converted to a fixed intermediate radio frequency (usually of from 450 to 500 kc. in high-frequency superhets) and is then amplified at the intermediate frequency prior to audio-frequency detection. The frequency conversion is accomplished by a heterodyne process; that is, the incoming signal and the output of a local oscillator are simultaneously

detected in a stage whose output circuit is tuned to the intermediate frequency. The output product selected is the beat between the incoming signal and local oscillator voltages and is therefore of a frequency equal to the difference between the signal and oscillator frequencies. Whatever modulation (speech or code keying) there may be on the incoming signal wave is identically reproduced in the i.f. beat output of the first detector. Consequently, the i.f. circuits and second detector behave with respect to the i.f. signal exactly as a conventional tuned r.f. amplifier and detector circuit receiving a signal of the frequency to which the circuits are tuned.

The frequency converter is the heart of the superhet receiver and on its operation depends largely the performance of the

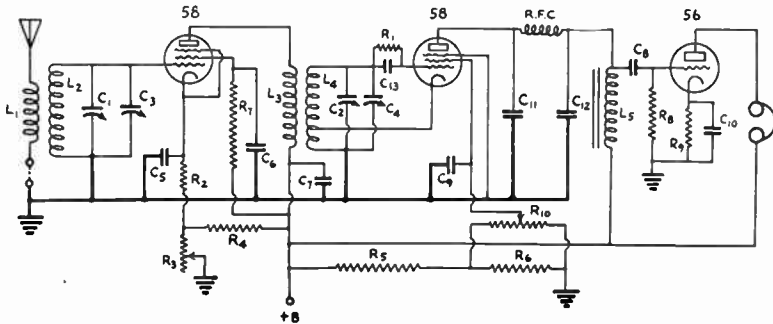


FIG. 519 — CIRCUIT DIAGRAM OF THE THREE-TUBE RECEIVER

The tube filaments (heaters) and the dial light are wired in parallel. The tubes indicated on the diagram, are for 2.5-volt a.c. operation. The 58's would be replaced by 73's or 6D6's, the 56 by a 37 or 76, and a 6-volt dial light should be used for 6-volt d.c. operation. With battery B supply resistors R_5 and R_6 should be omitted, and the positive terminal of the regeneration control R_{10} should be connected to the plus-45-volt battery tap; also, a d.p.s.t. switch should be included to cut off both sides of the B supply when the receiver is not in use, in addition to a switch in the filament circuit. The negative-B connection is made to the chassis (ground). Heavy lines indicate "ground" connections which should be made to a single common point on the chassis. Power-pack design for a.c. operation is given in Chapter Ten.

- $C_{1,2}$ — 35- μ fd midjet condensers (Hammarlund MC-35-S). See text.
- $C_{3,4}$ — 100- μ fd. midjet condensers (Hammarlund MC-100-S).
- $C_{5,6,7,8}$ — .01- μ fd. mica condensers.
- $C_{9,10}$ — 1- μ fd. non-inductive paper condensers.
- $C_{11,12}$ — 100- μ fd. fixed mica condensers.
- C_{13} — 250- μ fd. mica condenser.
- R_1 — 5-megohm resistor.
- R_2 — 250 ohms, 2 watt.
- R_3 — 10,000-ohm wire-wound potentiometer, tapered.
- R_4 — 50,000 ohms, 2 watt.
- R_5 — 14,000 ohms, wire-wound, 5 watt.
- R_6 — 5000 ohms, wire-wound, 5 watt.
- R_7 — 100,000 ohms, 1 watt.
- R_8 — 1 megohm.
- R_9 — 2000 ohms, 1 watt.
- R_{10} — 50,000-ohm potentiometer.

Coil Data

L_1, L_2 on same form; L_3, L_4 ditto.

Band	L_1	L_2	L_3	L_4
1750	10	55	30	55 tapped at 3rd turn
3500	10	28	20	28 " " 1st "
7000	5	11	9	11 " " 1/2 "
14,000	3	5	5	5 " " 1/4 "

All primaries (L_1 and L_3) are wound with No. 36 d.s.c. wire. The 3500-kc. grid coils are wound with No. 20 d.c.c.; 1750-kc. grid coils with No. 28 d.c.c.; both close-wound. The 7000- and 14,000-kc. grid coils are wound with No. 18 enamelled wire spaced to occupy a length of 1 1/4 inches. Taps are from the ground end of detector coils. National 5-prong coil forms (diameter 1 1/2 inches) are used. Spacing between coils on form is approximately 1/8 inch.

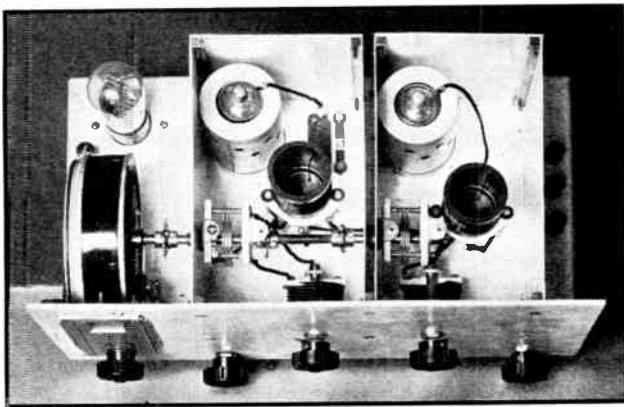


FIG. 520 — PLAN VIEW OF THE THREE-TUBE AUTODYNE WITH SHIELD COVER REMOVED

The detector stage is next to the drum dial. The ganged tuning condensers are mounted on the left-hand wall of each shield. The isolantite coil sockets are mounted on small pieces of brass tubing which lift them far enough above the base to prevent grounding of the contacts. The detector grid condenser and leak are just behind the coil in the detector compartment. The tubes, also mounted in sub-panel sockets, have individual shields.

whole set. Since the intermediate-frequency value adopted for short-wave supers represents a considerable difference between the signal and local oscillator frequencies, it is not feasible to use a simple autodyne detector having one tuned circuit as in the autodyne regenerative receivers used for beat-note c.w. reception. Separate circuits must be used, that of the first detector input being tuned to the signal frequency and that of the oscillator being tuned higher or lower by an amount equal to the intermediate frequency. Because of circuit convenience and other factors, it is general practice to have the oscillator tuning intermediate frequency higher than the first detector input circuit.

With the two tuned circuits, oscillator and first detector, two separate tubes may be used; or there may be a single tube designed to provide separate sets of elements for oscillator and detector circuits. Arrangements of both types are shown in Figs. 523, 524 and 525. These figures show three types of oscillator-detector arrangements. That of Fig. 523 is most common in amateur-type short-wave receivers at the present time. The signal input circuit L_1C_1 is tuned to the incoming signal and the oscillator circuit L_2C_2 is tuned intermediate-frequency higher. The oscillator is of the electron-coupled type, its output being coupled to the control grid of the first detector through a

small capacitance. The 100,000-ohm plate load resistor of the oscillator may be replaced by a high-frequency r.f. choke in some instances, the operation being equivalent. The essential feature of this arrangement is that both the signal and oscillator voltages are impressed on the same grid. The conversion gain (ratio of i.f. voltage output to signal voltage input) and input selectivity are generally good, so long as the sum of the two voltages impressed on the grid does not exceed the grid bias and run the grid positive. Since the i.f. voltage produced is the product of the signal and oscillator voltages, it is desirable to make the oscillator voltage as high as possible without exceeding this limitation. In practice, with the circuits tuning over a number of bands and therefore likely to give wide fluctuations in oscillator output, oscillator r.f. voltage is made

considerably less than the maximum limit.

The circuits of Fig. 524 are considerably less critical in this respect, since the signal and oscillator voltages are applied to separate grids. The circuit at 524-A uses a combined detector-oscillator tube having internal electron coupling between the two sets of elements, such a tube being known as a pentagrid converter. Quite high conversion efficiency can be obtained as well as good input selectivity. The tube is not a particularly desirable one for high-frequency work when used in this way, however, because the output of the oscillator drops off as the frequency is raised and because the two sections of the tube

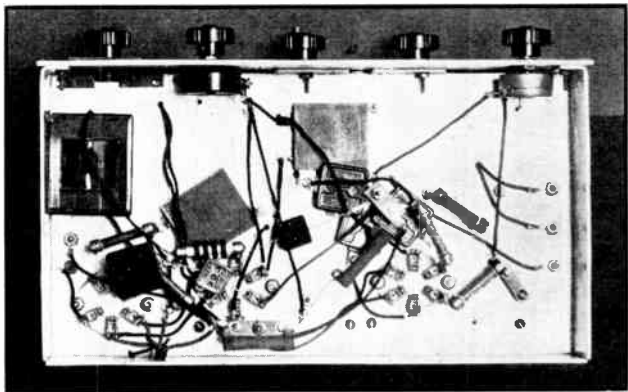


FIG. 521 — UNDER THE BASE OF THE THREE-TUBE RECEIVER

Resistors, by-pass condensers, chokes; all placed where most convenient. The only thing to keep in mind in this sub-base wiring is to make all the r.f. grounds at one point on the chassis. The audio coupler is mounted on the side at the left.

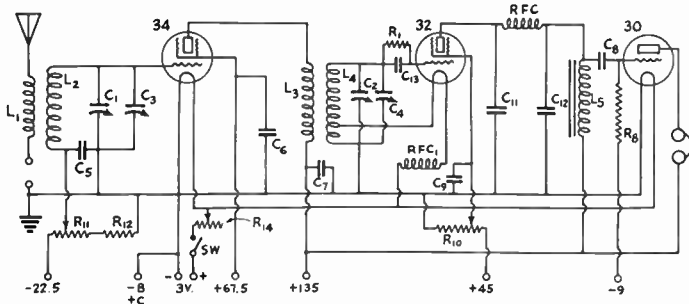


FIG. 522 — THE THREE-TUBE RECEIVER CIRCUIT MODIFIED FOR USE WITH TWO-VOLT TUBES

Components have the values given in Fig. 519 with the following additions: R_{11} , 50,000-ohm potentiometer; R_{12} , 5000 ohms, 1-watt rating; R_{14} , 10-ohm rheostat; RFC's, same specifications as given in Fig. 517. R_{11} and R_{12} constitute the gain control circuit in the r.f. amplifier; R_{12} is used to make certain that a small amount of grid bias will be applied to the tube even though R_{11} is set at its minimum-bias end. Filament supply may be from an Air-Cell battery or from two dry cells connected in series.

To prevent "B" and "C" battery discharge through the voltage-dividers when the receiver is not in use, switches may be installed in series with the "-22.5" and "+15" terminals.

are not well enough isolated to prevent "pulling," or the tendency of the detector tuning to affect the oscillator frequency. An arrangement which overcomes these defects is shown at Fig. 524-B. In this circuit the oscillator grid (No. 1) of the pentagrid converter is used as the mixing element, but is fed from a separate oscillator. The better performance of the 56 or 76 tubes as contrasted with the oscillator section of the 2A7

or 6A7 at high frequencies results in more uniform output over the high-frequency range. In the circuits of Fig. 524 the oscillator voltage is not critical, so long as enough is supplied, and the grid-current limitation of the circuit of Fig. 523 is absent.

A third type of first-detector-oscillator coupling is given in Fig. 525. In these diagrams the suppressor grid of a pentode-type detector is used as the means for introducing the oscillator voltage into the detector circuit to beat with the incoming signal. Suppressor-grid coupling offers the same advantages as the circuit of Fig. 524-B, but usually will require a greater oscillator voltage because of the lesser control factor of the suppressor grid as compared to the inner grid of a pentagrid converter tube. The oscillator voltage is not critical, however, and does not affect the input selectivity of the detector.

In all these circuits it is essential that the oscillator be completely shielded from the detector. Coupling other than by the means intended, especially between the tuned circuits, will result in "pulling" and will render accurate tuning difficult. Several types of oscillator circuits are shown for purposes of illustration; in many cases one oscillator circuit can be substituted for another without affecting the functioning of the detector or mixing circuit, since the two are generally entirely separate except for the coupling by which the oscillator voltages is introduced into the detector circuit. In a few of the oscillator circuits a "tracking" condenser is indicated; it is used when the oscillator and detector tuning condensers are ganged for single control tuning, its purpose being to limit the tuning range of the oscillator so that a constant frequency difference between the two circuits will be maintained. Its value will depend upon the frequency range to be covered and upon the intermediate frequency, and is usually of the order of .001 or .002 μ fd.

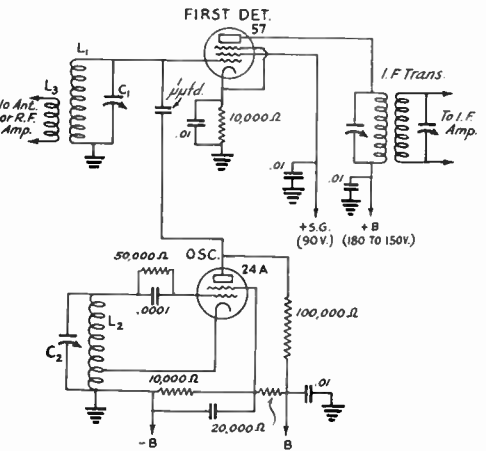


FIG. 523 — A POPULAR SUPERHET FREQUENCY CONVERTER CIRCUIT USING SCREEN-GRID PLATE DETECTOR AND ELECTRON-COUPLED OSCILLATOR

This circuit, which employs capacity coupling between detector and oscillator, is discussed in the text

Intermediate-Frequency Amplifiers — Beat-Note Reception

▲ The intermediate-frequency amplifier (i.f. amplifier) of a superhet is, as mentioned, simply a tuned radio-frequency amplifier designed to work at a fixed frequency, generally in the region of 450 to 500 kc. for short-wave superhets. The tuned circuits of i.f. amplifiers usually are built up in pairs as transformers, consisting of a shielding container in which the coils and condensers are mounted. The coils are of the universal-wound or honeycomb type and are very small in size so that the magnetic field will be restricted. Tuning condensers are of the midget type and may have

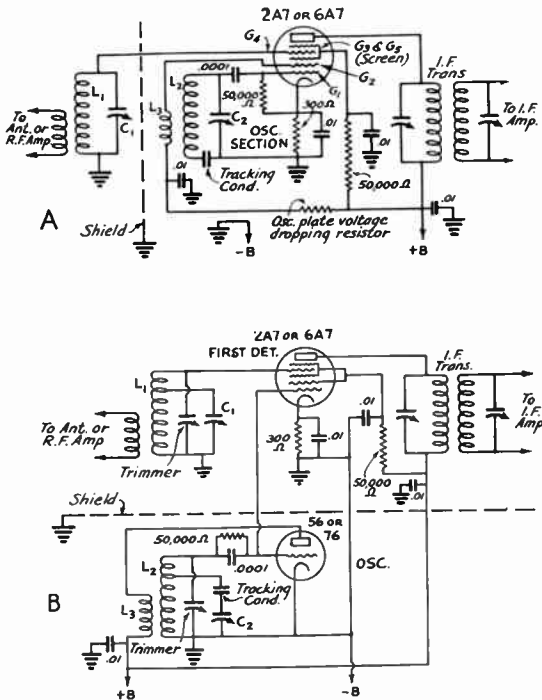


FIG. 524 — THESE FREQUENCY-CONVERTER CIRCUITS ARE FOR USE WITH PENTAGRID TUBES

The circuit at A shows how the tube is used as a combined detector-oscillator. A better arrangement for high-frequency work, making use of a separate oscillator with the pentagrid tube as detector or "mixer," is shown at B.

either mica or air dielectric, air-dielectric superhets because their capacity is practically unaffected by changes in temperature. Such stability is of great importance in highly selective i.f. amplifiers or single-signal superhets equipped with quartz crystal filters because a slight change in tuning capacity can greatly impair the performance of the receiver.

Intermediate frequency amplifiers usually consist of two stages. With modern tubes and transformers, two stages will give all the gain usable, considering the noise level, so that additional stages would have no particular advantage. If regeneration is introduced into the i.f. amplifier — as is done in the receiver to be described later — a single stage will give enough gain for all practical purposes.

For reception of c.w. signals it is necessary to provide, at the second detector, a locally-generated frequency which will beat with the i.f. signal to produce an audible heterodyne. This is most satisfactorily accom-

plished by installing an oscillator which is tunable about the intermediate frequency over a range of a few kilocycles on either side. The voltage from this heterodyne or beat oscillator can be introduced into the second detector circuit by any of the methods shown in Figs. 523, 524 or 525, depending upon the type of detector tube used. Simple capacity coupling as given in Fig. 523 is applicable to practically any type of detector tube. Still another method is shown in the diagram of the regenerative single-signal superhet to be described.

Short-Wave Converters

▲ Since a broadcast receiver, at the low-frequency end of its range, tunes approximately to the frequency region most suitable for intermediate-frequency amplifiers, it is possible to use such a receiver as the basis for a short-wave superhet simply by providing a first detector-oscillator combination (called a converter) which can be coupled to the antenna input terminals of the receiver. An arrangement of this kind results in a quite satisfactory short-wave receiver, particularly for the reception of amateur 'phone and short-wave broadcast transmissions. Any type of broadcast receiver may be

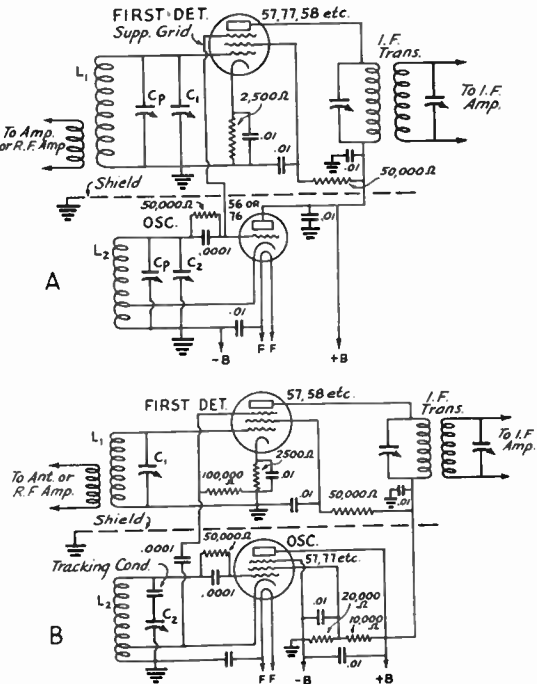


FIG. 525 — TWO WAYS IN WHICH THE OSCILLATOR VOLTAGE CAN BE INTRODUCED INTO THE FIRST DETECTOR CIRCUIT VIA THE SUPPRESSOR GRID OF THE DETECTOR TUBE FOR FREQUENCY CONVERSION

used, either tuned r.f. or superhet; the sensitivity will be as good as that of the receiver itself, and the quality of reproduction also will be the same.

A practical converter using the pentagrid circuit is shown in Figs. 526-528, inclusive.

The circuit of the converter, shown in Fig. 529, is little different from Fig. 524-A except for the i.f. output. To provide a favorable coupling between the converter's high-impedance plate circuit and the low-impedance antenna input circuit of the b.c. receiver, a step-down transformer is used. This transformer has a tuned primary and a smaller untuned secondary that is tightly coupled to the primary, so that the secondary and antenna coil of the b.c. receiver provide a low-impedance link coupling of good efficiency and small pick-up between the converter and the receiver with which it is used.

The high-frequency input and oscillator circuits have been designed to make use of standard short-wave plug-in coils, thereby simplifying construction for the many builders who already have such coils on hand. The coils used in this instance are from a National SW3 (the same as used also in the SW5 and SW45). To give suitable tracking of oscillator and first-detector tuning a few grid turns are removed from some of the oscillator coils, and to give adequate oscillator feedback a few turns are added to the oscillator tickler windings, as explained later. With the tank-condenser system of tuning used, satisfactory

tracking is obtained without adding separate series (tracking) condensers for each oscillator coil. Single-control band-spread tuning in suitable slices anywhere in the 1400 to 19,000 kc. total range obtained with the five sets of coils is provided by the two-section midget gang condenser

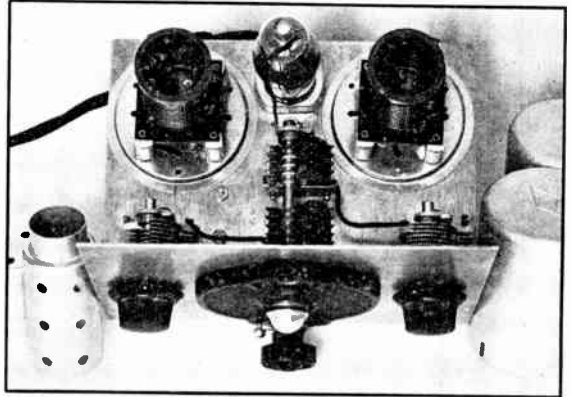


FIG. 527 — TOP VIEW OF THE SINGLE-TUBE HIGH-FREQUENCY CONVERTER

Tube and coil shields are removed showing the simplicity of the top section which is practically devoid of wiring. The detector padding condenser is at the left with band-spread condenser in the middle and oscillator padding condenser at the right. The tube is directly in back of the band-spread condenser. The supply cable at the rear contains four wires for heater and plate supplies.

having the separate 100- μ fd. midgets as "paddingers" in parallel.

The first step in construction is to pick out some aluminum sheets for the panel and base. One piece 7 by 9 inches serves for the panel and a piece 8 by 9 inches is for the base. The base piece is bent at the rear to form an inverted "L," the 2-inch lip leaving the horizontal base 6 by 7 inches. Quarter-inch brass rod drilled and tapped for 6-32 machine screws serves to hold the base rigidly against the panel. Parts are then placed on the base, starting with the split-stator tuning condenser centered and flanked on either side by detector and oscillator circuit padding condensers. These condensers are fastened to the base, the two padding condensers being of the single-hole mounting type so that they act as further support for the panel. The dial used to tune the main condenser is a Type B National which provides a bearing and support for the condenser shaft. Directly in back of the band-spread condenser a hole is cut or punched for the sub-panel tube socket. Each coil mounting is placed over the base of its coil shield, the coil assemblies being mounted one either side of the tube and directly behind their respective padding condensers. Next comes the mounting of the resistors and condensers under the base of the converter. A fiber angle is used to anchor many of the terminals in this case. Exact placement is not important, al-

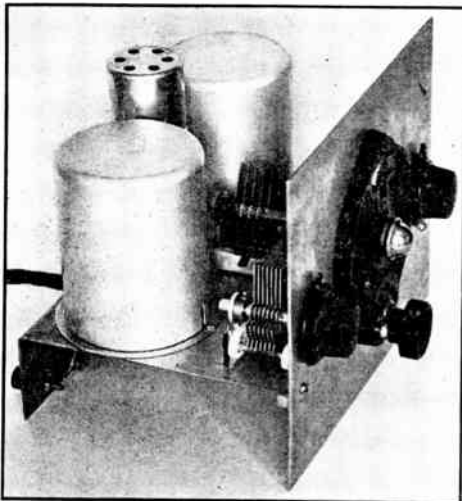


FIG 526 — A SINGLE-TUBE CONVERTER, USING A PENTAGRID TUBE, WHICH CAN BE USED IN CONJUNCTION WITH A BROADCAST RECEIVER TO MAKE A SENSITIVE SHORT-WAVE SUPERHET

though the desirability of short leads should be kept in mind.

All leads are run according to the axiom, "a straight line is the shortest path between two points." Soldering lugs under several of the screw heads serve as grounds in convenient places. The tube socket terminals should be marked in pencil before much wiring is done, a bottom plan of the Type 'A7 connections being shown with the diagram of Fig. 529.

In the i.f. output transformer, the plate coil is a standard universal-wound i.f. coil of inductance between 1 and 1.2 millihenry. The secondary or output coil is of the same size with half of its turns removed. The two coils are jammed together on a wooden dowel and mounted inside a cut-down tube shield so that there is a clearance of about $\frac{3}{8}$ -inch on all sides. The shielded "walnut" condenser tunes the primary to approximately 600 kc.

As previously mentioned, standard manufactured coils are used because of their wide availability, although similar coils can be made up by the constructor. The detector coils need no alterations, the green winding of a few turns in the slot being used for the antenna coil, L_2 , and the original grid winding, which is the main winding of solid wire, is used for L_1 . The interwound primary is not used. In all cases it was found advisable to add a few turns of No. 30 d.s.c. wire to the oscillator tickler, L_4 . This corresponds to L_2 on the detector coil and is wound in the slot at the bottom of the form. The table shows the correct number of turns for each set of coils.

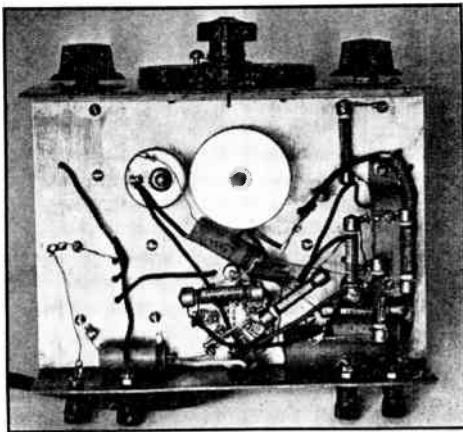


FIG. 528 — BOTTOM VIEW SHOWING THE RESISTORS AND FIXED CONDENSERS

The binding posts at the left are for antenna and ground; those at the right being the converter output posts. The shielded mounting for the plate circuit transformer is shown in the center, with its midget condenser at the left.

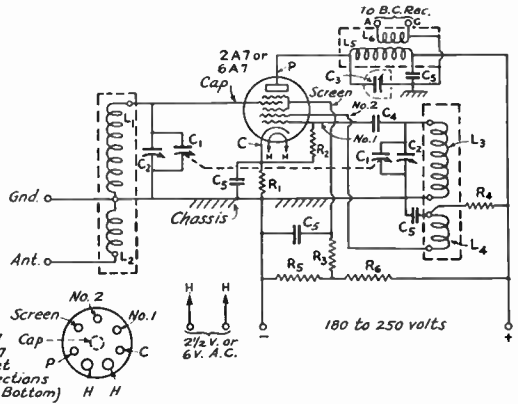


FIG. 529 — CIRCUIT DIAGRAM OF THE ONE-TUBE CONVERTER

- L_1, L_2, L_3 and L_4 — Detector and oscillator coils. See table and text.
 - L_5 — 1.2-millihenry i.f. transformer winding (465- or 500-ke. type).
 - L_6 — Same as above with approximately half the turns removed.
 - L_5 and L_6 coupled as closely as possible. See text.
 - C_1 — Two-section midget tuning condenser, 35- μ fd. per section (Hammarlund MCD-35-X).
 - C_2 — Padding condensers, 100- μ fd. midgets (Hammarlund MC-100-M).
 - C_3 — I.f. tuning condenser, 100- μ fd. shielded midget (National W-100).
 - C_4 — 250- μ fd. mica (grid condenser).
 - C_5 — 0.1- μ fd. paper (by-pass condensers).
 - R_1 — 250- or 300-ohm 1-watt (cathode resistor).
 - R_2 — 25,000-ohm 1-watt (oscillator grid leak).
 - R_3 — 25,000-ohm 1-watt (screen-grid series resistor).
 - R_4 — 60,000-ohm 1-watt (oscillator plate series resistor).
 - R_5 — 10,000-ohm 1-watt (voltage divider resistor).
 - R_6 — 60,000-ohm 1-watt (voltage divider resistor).
- Oscillator and detector coil shields are National Type B30, 3-inch diameter. The i.f. transformer shield is a cut-down National TS tube shield (1½-inch length, 2-inch diameter).

COIL DATA

Coil No.	Band Coverage	Detector Coil		Oscillator Coil		Wire Size*
		L_1	L_2	L_3	L_4	
1—Black	19,000–11,250	6¼	3	6¼	5	16
2—Red	12,500– 7,000	12	4	12	7	18
3—White	7,500– 4,100	19	3	15	8	18
4—Green	4,200– 2,400	35	4	27	12	24
5—Blue	2,500– 1,400	62	4	50	24	28

* Refers to L_1 and L_3 . L_2 and L_4 are all wound with No. 30 d.c.c. wire. Complete windings of L_1 and L_3 occupy 1½ inches on the forms.

ing) tracks over the entire range and the only change is the addition of 3 turns on the oscillator tickler coil, L_4 . Oscillator coil No. 2 (red) has 5 turns added to L_4 . Two turns are removed from L_3 on the No. 3 set of coils and seven turns added to L_4 . The oscillator coil of the No. 4 set has 6 turns removed from L_3 and 14 turns added to L_4 . The last set, No. 5, has 10 turns removed from L_3 and 20 turns added to L_4 on the oscillator coil. After these changes are made the two padding condensers should track evenly over the entire range of each coil set.

After a final check in wiring, the converter is ready for work. It should be placed close to the intermediate-frequency amplifier or broadcast set with which it is to be used so that the leads will be short and direct. Disconnect the antenna and ground from the broadcast set and connect to the proper terminals on the converter. Then run a short twisted pair of wires from the converter output to the antenna and ground posts on the broadcast set, making sure that the grounded side of the converter output connects to the receiver ground terminal.

The broadcast-receiver dial should be set at about 600 kc. With the gain control advanced fairly well and with the converter turned on its side, the shielded midget condenser is adjusted to tune the converter output circuit to the frequency of the receiver. This is done with any set of coils in place, making sure the coils are in their proper sockets, the detector coil at the left and oscillator coil at the right. As the i.f. tuning approaches resonance, the background noise will rise until there is a definite peak, either of background hiss alone or of signal if the converter happens to be tuned on a signal. This adjustment is permanent providing the receiver frequency is not changed.

If the oscillator coils have been pared as given in the table, the detector padding condenser will track at least approximately with the oscillator padding condenser over the entire range of each set of coils. The band setting is done with the right hand or oscillator padding condenser and the detector condenser is tuned to resonance (same setting on the knob as its twin) and all tuning done with the main dial or band-spread condenser.

Single-Signal Selectivity

▲ In c.w. reception with an autodyne receiver two beat notes are heard as the oscillating receiver is tuned through the incoming signal, one on the high-frequency side and one on the low-frequency side. The same thing occurs with a superhet in which the beat oscillator is tuned nearly or exactly to the same frequency as that of the i.f. amplifier, assuming that the selectivity of the i.f. amplifier is normal — that is, designed to pass a band of frequencies about 5 to 10 kc. wide for the reception of voice or music. Therefore there are actually *two* audible signals, each

capable of causing interference, because of the method of reception, although only one signal is transmitted.

The second beat note or "other side of zero beat" is eliminated in the single-signal superhet. This type of receiver resembles the standard superheterodyne, but has in addition to the conventional tuned r.f. circuits a circuit in which extremely high selectivity is obtained either by means of a quartz-crystal (piezo-electric) filter or by regeneration. A separate beat oscillator, tuned to a frequency suitably different from the i.f. peak, gives the audio beat note for c.w. reception. Because of the high selectivity the signal response drops to a negligible value when the tuning is more than a few hundred cycles off resonance, therefore the tuning controls must be set exactly to resonance. The audible response also is greatest at this point, since the beat oscillator is "offset" from the i.f. peak by a frequency difference which gives a suitable heterodyne. The practical result is that only one beat note is heard for each signal; the "other side of zero beat" has but a very small fraction of the strength of the main signal. The extreme selectivity also reduces noise and other types of interference.

The single-signal superhet should be provided with a means for varying the selectivity so that the receiver will be made suitable for the reception of voice as well as c.w. telegraph signals, since a wider band must be passed for faithful reproduction of voice modulation. This provision is made in the selective systems to be described.

Image Interference

▲ The tuning of the first detector grid circuit is especially important in the minimizing of high-frequency image interference, a type of interference peculiar to superhet receivers. This interference results when signals twice intermediate frequency removed from the desired signal get through to beat with the high-frequency oscillator signal in the first detector and occurs because there is insufficient selectivity ahead of the first detector to discriminate against them. It is aggravated when the first detector circuit is off-tune for the desired signal frequency. The first detector therefore should be tuned as precisely as possible to the desired-signal frequency.

For further improvement in signal-image response ratio, a tuned r.f. stage, exactly like that shown earlier in the chapter and having a tuned circuit identical with that of the first detector, can be added ahead of the first detector. Images also can be reduced by using a simple wave-trap, of the type described in Chapter Eleven, tuned to the image frequency (1000 kc. above signal frequency) and connected in the antenna lead as closely as possible to the receiver's antenna terminal.

The most satisfactory method of reducing image interference is by the use of the tuned r.f.

or preselector stage, since it not only improves the selectivity but also adds to the gain of the receiver. The regenerative single-signal super now to be described is equipped with a preselector stage. Its design is representative.

A Regenerative Single-Signal Receiver

▲ The six-tube regenerative single-signal superheterodyne shown in Figs. 501, 530 and 532 illustrates the design and construction of modern amateur high-frequency superhets. It has a preselector stage, first detector with separate oscillator, a single stage of high-gain regenerative i.f., power second detector, and separate beat oscillator.

The photographs show the general arrangement and Fig. 531 gives the wiring diagram. The left-hand shield in Fig. 501 contains the high-frequency oscillator. Directly behind the drum dial is the 2A5 second detector. In the center compartment is the first detector and its tuning circuits, with the oscillator coupling condenser, while in the right-hand compartment is the r.f. preselector-amplifier.

On the back deck, at the extreme left, is the c.w. beat oscillator coil and condenser unit, T_3 , with the beat control knob projecting at the top. Next is the c.w. beat oscillator tube. The center can contains the i.f. transformer assembly, T_2 , with the i.f. amplifier tube to its right. At the extreme right is the regenerative i.f. transformer assembly, T_1 .

Looking at the front of the panel, the upper row of knobs are, left to right: h.f. oscillator tank, C_5 ; first detector tank, C_4 , and r.f. tuning condenser, C_1 . At the bottom of the panel, the left-hand switch, SW_1 , controls the high voltage supply to the receiver. Next is the c.w. beat oscillator "on-off" switch, SW_2 , cutting the screen voltage. The knob below the illuminated dial is the main tuning control operating the ganged condensers C_2 and C_3 , with the gain control, R_3 , next. The knob at the right operates the i.f. selectivity control, the regeneration attenuator R_2 .

Doublet antenna connections are made to insulated binding posts on the outside shield of the r.f. stage, with the ground binding post nearby on the main deck. With a conventional single-wire antenna connected to one insulated post, the other is connected to ground. Of course the doublet antenna should be used if possible, since it makes possible considerable additional gain.

Insulated 'phone tipjacks on the left end of the chassis provide connections for 'phones and speaker.

Once the tank condensers have been set for a given band, the selectivity adjusted to the desired degree, and the c.w. beat note fixed, the receiver is in effect single-dial tuning with operating controls for volume, frequency and c.w. note convenient for one position of the hand.

The structural part of the receiver is all of sheet aluminum. The chassis or main deck is made from a piece of $\frac{3}{32}$ -inch aluminum 21 inches by 12 inches. From two corners on one long side of this piece, 2-inch squares are cut out and then three sides are bent down at right angles so as to form the sides and back of a deck 17 by 10 inches and 2 inches high.

All of the inter-stage box shields are cut from $\frac{1}{16}$ -inch aluminum. The six sides are 7 inches long by $4\frac{3}{4}$ inches high, while the three ends are $4\frac{1}{4}$ inches wide by $4\frac{3}{4}$ inches high. The shields are held together at the corners by $\frac{1}{4}$ -inch square brass rods drilled and tapped for $\frac{9}{32}$ machine screws. The corner posts are fastened to the main deck by screws into their lower ends.

The front panel is of $\frac{1}{8}$ -inch thick aluminum, 18 inches long by 7 inches high. It is fastened by screws to the front posts of the shield boxes. A cover fitting over all the shields is a sheet of $\frac{1}{16}$ -inch aluminum 16 inches by 7 inches held in place by flat springs on its under side, pressing against the sides of the shield boxes.

The Isolantite five-prong coil sockets are mounted above-deck on pillars long enough to clear the contacts. Similar tube sockets (six-prong) are mounted below the base under their $1\frac{1}{2}$ -inch holes. With this arrangement a minimum of wires need pass through the base. Complete tube shields are provided for all tubes. A $\frac{1}{2}$ -inch length of $\frac{1}{8}$ -inch rubber tubing slipped

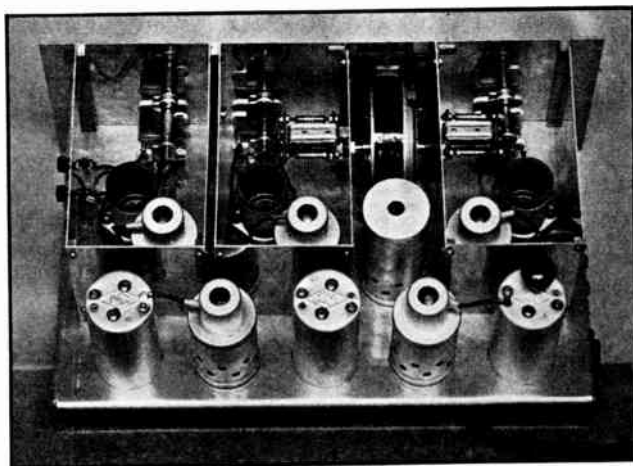


FIG. 530 — A REAR VIEW OF THE REGENERATIVE SINGLE-SIGNAL SUPERHETERODYNE

This supplements the front view of Fig. 501 and shows more clearly the construction of the intermediate-frequency amplifier.

over each grid wire, before soldering on the grid clip and afterwards pushed up on the clip, prevents any possible grounding of the grid on the grid-cap shield.

The National 500-kc. i.f. transformers each require minor alterations to adapt them to the circuit, and they should be removed from their cans for this purpose. The first operation is on the regenerative i.f. transformer, T_1 .

As supplied, the grid coil, L_7 , is at the upper end of the dowel, nearest the condensers, and the plate coil at the bottom. In order to couple the tickler coil, L_8 , to the grid coil, the external connections from the unit T_1 must be changed so that the grid coil is the lower one. This means that one of the wires that normally passes out through the bottom of the can should be brought out the top through a piece of shield braid; and

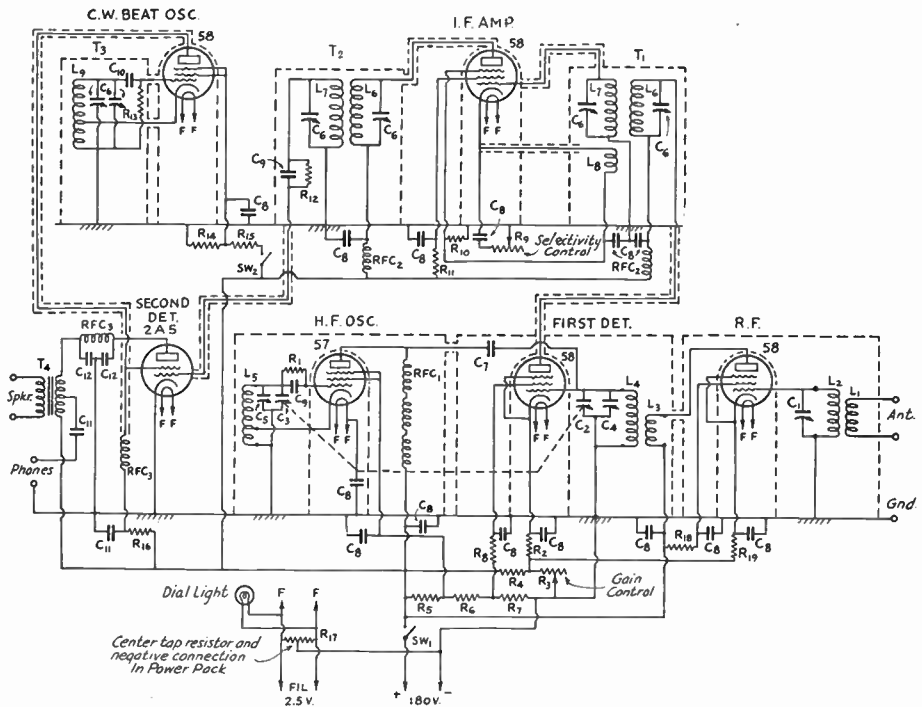


FIG. 531 — CIRCUIT OF THE SIX-TUBE REGENERATIVE S.S. RECEIVER

Dotted lines indicate shielded leads.

L_1, L_2, L_3, L_4 and L_5 — See coil table.

L_6 and L_7 — 500-kc. i.f. transformer windings.

L_8 — See text.

L_9 — 500-kc. beat oscillator coil. (See text.)

C_1 — 110- μ fd. midget condenser (Hammarlund MC-140M).

C_2, C_3 — 25- μ fd. midget condenser (National SE-50 cut down to 3 stator plates).

C_4, C_5 — 100- μ fd. midget condensers (Hammarlund MC-100M).

C_6 — 70- μ fd. midget condenser (in National i.f. units).

C_7 — H.f. oscillator coupling condenser. (See text.)

C_8 — 0.01- μ fd. r.f. by-pass condensers, tubular paper.

C_9 and C_{10} — 250- μ fd. mica grid condensers.

C_{11} — 1- μ fd. audio by-pass and coupling condensers.

C_{12} — 250- μ fd. plate by-pass condensers, tubular paper.

R_1 — 50,000-ohm 1-watt oscillator grid leak.

R_2 — 5,000-ohm 1-watt first detector cathode resistor.

R_3 — 12,000-ohm variable resistor, right-hand taper (Electrad).

R_4 — 100,000-ohm 1-watt.

R_5 — 10,000-ohm 5-watt.

R_6 — 7,000-ohm 2-watt.

R_7 — 3,000-ohm 2-watt.

R_8 — 50,000-ohm 1-watt.

R_9 — 2,000-ohm variable resistor, left-hand taper (Electrad).

R_{10} — 300-ohm 1-watt (i.f. amplifier cathode resistor).

R_{11} — 50,000-ohm 1-watt.

R_{12} — 1-megohm $\frac{1}{2}$ -watt second detector grid leak.

R_{13} — 50,000-ohm $\frac{1}{2}$ -watt beat oscillator grid leak (Integral with National oscillator unit).

R_{14} — 2,500-ohm 2-watt.

R_{15} — 50,000-ohm 2-watt.

R_{16} — 25,000-ohm 5-watt.

R_{17} — 20-ohm center-tap resistor (in power supply).

R_{18} — 50,000-ohm 1-watt.

R_{19} — 300-ohm 1-watt r.f. cathode resistor.

T_1 and T_2 — National 500-kc. air-tuned i.f. transformers. (See text.)

T_3 — National 500-kc. beat oscillator assembly.

T_4 — Universal push-pull output transformer (Kenyon).

RFC_1 — 2 $\frac{1}{2}$ -mh. sectional choke (National No. 100).

RFC_2 — 10-mh. single-section universal wound r.f. choke.

RFC_3 — 60-mh. single-section universal wound r.f. choke.

SW_1 and SW_2 — Single-pole panel switches.

the wire originally at the top is brought out through the bottom.

A one-inch length of $\frac{1}{2}$ -inch dowel is fastened by means of a wood screw to the end of the dowel carrying the coils in the unit. At the lower end of the new dowel, the tickler L_8 is bunch-wound with 25 turns of No. 30 d.s.c. wire. If this tickler is wound in the same direction as the other coils, the final connections from T_1 are as follows: Inside end of upper or plate coil L_6 to B+, outside to first detector plate through shield braid; inside end of middle or grid coil L_7 to ground, outside through shield braid from top of can to grid cap of i.f. amplifier; inside end of lower or tickler coil L_8 to i.f. suppressor, outside end through shielded lead to i.f. cathode. If the i.f. circuit cannot be made to oscillate with R_9 in the maximum resistance position or disconnected, then the tickler connections should be reversed at the coil terminals. If oscillation should fail with the tickler connected either way, the number of tickler turns should be increased a few at a time until oscillation is obtainable.

For T_2 the connection out of the top of the shield is removed and brought down inside to the detector grid condenser and leak which are placed within the can. Plate and grid leads from T_2 also should be shielded with flexible copper braid.

In the beat oscillator unit the grid condenser and leak are also mounted within the can. The only other operation required is to shield the grid lead from the top of the can to the oscillator tube.

High-Frequency Circuits

▲ The high-frequency oscillator coupling condenser C_1 is made of two brass angles, having faces about $\frac{3}{4}$ by $\frac{3}{8}$ inch, mounted on a small piece of bakelite in the detector compartment with the faces spaced $\frac{1}{8}$ inch. The connection from the plate of the h.f. oscillator to C_7 is in shielded braid but may be left unshielded.

The coils are wound on National 5-prong forms according to specifications given in the table. No attempt has been made to make the tuned circuits track exactly. The over-all gain of the receiver is high enough so that, by judicious use of the gain control, c.w. reception is possible throughout an entire amateur band without touching the tank condensers. Better tracking can be secured easily by removing a few turns of wire from the oscillator coils L_5 . A further refinement would be to gang an additional condenser, similar to C_2 and C_3 , for the r.f. amplifier.

The power supply leads are brought in through a flexible cable in the rear. The B+ voltage is conveniently distributed from a terminal strip attached to SW_2 . Although only four wires are essential to the power supply cable, cables with four wires having two which are of suitably low resistance for heater currents are not readily available. Accordingly, a standard 8-wire cable is used with three wires in parallel for each of the heater leads. By this means the filament voltage drop from power supply to set is kept to a value of less than 0.1 volt. Care must be taken, however, that all the paralleled wires are securely soldered to the terminal plug at the supply end of the cable.

The power supply may be of the type described in Chapter Ten. The filament winding of 2.5 volts should be capable of delivering the 8 amperes necessary for the tubes and dial light. High voltage under 50-ma. load should be approximately 180 volts.

To align the i.f. amplifier, set the selectivity control at minimum selectivity, and apply a 500-kc. signal to the grid of the i.f. tube. The *second* i.f. transformer is then adjusted to resonance as indicated by maximum second-detector output, an insulated socket wrench being used to tune the condensers C_8 at the top of the can. The oscillator is then coupled to the first detector grid and the same procedure is used to tune the *first* i.f. transformer. The beat oscillator may be isolated from the second-detector circuit and used as a signal source, but preferably a separate test oscillator should be used. If a modulated signal is used, the output can be judged by ear. For an unmodulated signal a 0-50 milliammeter should be placed in the plate circuit of the second detector, when resonance will be indicated by plate current dip to minimum.

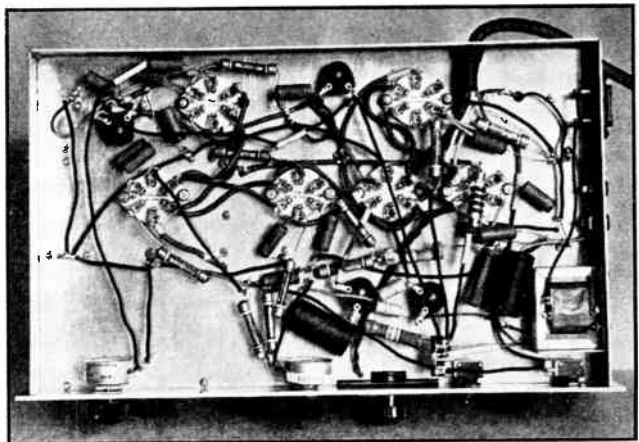


FIG. 532 — A BOTTOM VIEW OF THE SIX-TUBE SUPERHET

By-pass condensers and resistors are placed in the most convenient locations. The detector output transformer is mounted on the side wall of the chassis, and can be seen in the lower right-hand corner.

After aligning the i.f., the high-frequency circuits are aligned, using an oscillator or frequency meter giving a signal in an amateur band. The three condensers C_1 , C_2 and C_3 will have nearly the same settings, although the oscillator (being tuned 500 kc. higher than the detector) will have a somewhat lower capacity setting.

When everything is aligned the c.w. beat oscillator should be set so as to give about a 1000-

HIGH-FREQUENCY COIL DATA

Band Kc.	L_1 Turns	L_2 Turns	L_3, L_4 and L_5 Turns	Tap on L_4 — Turns from Ground End
1,750	10	30	55, No. 28 d.c.c. ¹	18
3,500	6	20	28, No. 20 d.c.c. ¹	9
7,000	5	9	11, No. 18 enam. ²	3
14,000	5	5	5, No. 18 enam. ²	2

¹ Close-wound.

² Spaced to make coil length $1\frac{1}{4}$ inches.

L_1 and L_5 all close-wound with No. 36 d.s.c., spaced $\frac{1}{8}$ -inch from L_2 or L_4 . Forms are National R-39, five-prong.

cycle tone when heterodyning a signal tuned in "on the nose." Then the selectivity control should be brought up to just below oscillation, as indicated by the "ringing" sound. The signal will increase in intensity and, with tuning through zero beat, the audio image or "other side of zero beat" should be hardly audible. Careful manipulation of the alignment adjustments will bring out this desired single-signal feature to its fullest.

The value of the tickler L_3 has intentionally been left so that oscillation in the i.f. circuits can occur with the control resistor R_9 almost, but not quite, at its point of highest resistance. The receiver never should be operated with the i.f. self-oscillating.

Quartz Crystal I. F. Filters

▲ As has been mentioned previously, high i.f. selectivity can be obtained by the use of a quartz crystal filter and such filters are used in a number of s.s. receivers, some of commercial manufacture. When connected in a suitable series circuit, a quartz crystal having a resonant frequency corresponding to the receiver's intermediate frequency is capable of several hundred times the selectivity obtainable in the usual transformer-coupled i.f. amplifier. The selectivity obtainable is, in fact, considerably greater than is practicable for some types of communication, especially 'phone, unless means for modifying it are provided. Such provision is made in the variable-selectivity filter developed by J. J. Lamb and described in several *QST* articles (August, 1932; March, June and November, 1933).

As shown in the filter portion of the diagram of Fig. 533, the variable parallel impedance of the input transformer secondary in series with the crystal (which is equivalent to a high-Q electrical

circuit) effects variation in the effective resistance in the crystal circuit, thereby varying the selectivity in accordance with the principles of resonant circuits discussed in Chapter Four. The applied voltage is proportional to the parallel impedance, increasing as the effective resistance increases, so that the effective sensitivity of the receiver for a single-frequency signal is but little affected over a selectivity (band-width) range of approximately 10 to 1. Minimum selectivity occurs with the parallel circuit turned to resonance, when it is purely resistive, and maximum selectivity when the parallel circuit is tuned to be considerably reactive. The crystal is connected in a bridge circuit to provide counter voltage of controllable phase, through an adjustable condenser, so as to modify the resonance curve and shift the anti-resonant frequency of the crystal, thus giving particular rejection for an unwanted signal (of a frequency from several kilocycles above to several kilocycles below the crystal's resonant frequency), in addition to the sharply peaked response given for the desired signal.

In Fig. 533 the output transformer of the filter consists of the tuned circuit C_3L_4 closely coupled to the untuned coil L_3 , which has but a fraction of the turns on L_4 . The purpose of this is to provide an impedance transformation suitable to match the crystal impedance to the grid circuit of the following amplifier and thus improve the efficiency of the filter.

Automatic Gain Control

▲ With the wide variation in signal strength and severe fading encountered in high-frequency reception there is considerable advantage in automatic gain (or volume) control in the receiver, with the receiver gain governed by the strength of the received signal. Such a system is applicable for 'phone reception, with a continuous carrier, but is not useful for amateur c.w. reception where the carrier is intermittent. Although there is a wide variety of a.g.c. systems, all operate on the same principle; namely, that rectified and filtered carrier voltage is used to provide proportionately varying bias for the r.f. amplifier tubes of the receiver. This bias may be obtained from the detector circuit (*QST*, November, 1933), from a separate tube having its grid excited by r.f. bled off from the second-detector input, or by the use of a multi-purpose tube designed for a.g.c. work.

A typical circuit of the latter type applied to a superheterodyne receiver is shown in Fig. 534. It uses a 2B7 or 6B7 tube, a type which includes an r.f. pentode amplifier and two separate diode rectifiers in one bulb. One of the rectifiers is used as the second detector and is coupled to the audio amplifier through the medium of the potentiometer R_1 , which also serves as a volume control. The other diode rectifier provides the rectified voltage for the control of bias on the r.f.

amplifier stages in the receiver. Only the parts of the receiver circuit essential to the a.g.c. operation are shown; dotted lines in the r.f. grid circuits indicate that the control voltage is to be fed through whatever apparatus is in the grid circuit so that it reaches the grids of the tubes. The resistors marked R_2 and the switch SW_4 are provided so that the time constant of the a.g.c. circuit can be varied to take care of different types of fading. A slow time constant (more resistance at R_2) is best for slow fading such as is encountered in the broadcast band; a lower time constant (low resistance or none at all at R_2) will handle the rapid fading characteristic of high-frequency reception. A too-small time constant cannot be used because the a.g.c. will then tend to operate on the carrier variations caused by the intended modulation, with the result that the quality of reproduction will be impaired.

Since a diode rectifier consumes power from its source of excitation, it would reduce the gain of the amplifier preceding it and broaden the resonance curve if coupled directly to the stage which ordinarily precedes the detector. For this reason the pentode section of the 'B7 tube is used as an additional i.f. stage in the diagram shown. The additional amplification compensates for the loss which would be incurred if the diode were coupled directly to the second i.f. stage, and the selectivity is likewise left undisturbed.

Trouble Shooting

▲ The most useful instruments for locating faults in a defective receiver are a multi-range ohmmeter and a high-resistance d.c. voltmeter. A simple combination ohmmeter and d.c. voltmeter suitable for general receiver testing is diagrammed in Fig. 535. As an ohmmeter it consists of the 0-1 d.c. milliammeter, 3-volt battery, fuse and 2800-ohm resistor in series. The ends of the leads are tapped across the circuit whose resistance is to be checked. It is essentially a 3-volt voltmeter, giving full-scale reading when the terminals are shorted with the 3-volt battery in series. It can be used for fairly accurate measurement of resistances between the values given in the calibration table, which calibration can be plotted on graph paper. The ohmmeter should never be connected across a circuit in which current is flowing; that is, the receiver power should be turned off when resistance measurements are made.

As a four-range d.c. voltmeter it has a characteristic resistance of 1000 ohms per volt, with full-scale reading (1 ma.) on each range corresponding to the maximum voltage specified for that range, lesser voltages on each range being in direct proportion to the scale reading 80% maximum voltage at 0.8 ma., 50% at 0.5 ma., etc.).

Lacking such an instrument, rough checks for circuit continuity (indicated by audible clicks) can be made with a pair of 'phones and a "B" battery in series, connected across the circuit under check; or with a low-range d.c. voltmeter and battery in series. An a.c. voltmeter should be used for checking the line and filament voltages in a.c. operated sets.

If the tubes do not light, check the filament supply (transformer or battery) and connections. Zero voltage across the primary will result with a blown fuse in the primary of an a.c. supply. Check the voltage at the socket terminals of a single tube that fails to light when others come on. If voltage checks OK, the tube may be burned out or there may be a defective contact in the socket.

Unreasonable hum in an a.c. receiver usually indicates either an open filament center-tap resistor or a tube with low resistance (leakage) between heater and cathode. Such a tube should be replaced. Less likely causes of excessive hum are an open filter or by-pass condenser in the supply circuits, or a defective rectifier tube. An open receiving tube grid circuit also may cause bad hum, usually accompanied by low output and serious distortion. Periodic clicking accom-

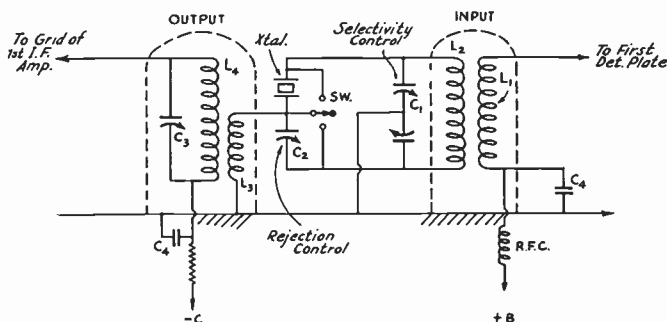


FIG. 533 — VARIABLE-SELECTIVITY FILTER WITH IMPEDANCE-MATCHING OUTPUT TRANSFORMER

- L_1 — 5.5-mh. universal-wound primary.
- L_2 — 1.5-mh. universal-wound secondary, close-coupled to L_1 .
- L_3 — Low-impedance output primary, approximately 300- μ h., universal wound.
- L_4 — 1.5-mh. universal-wound secondary, close-coupled to L_3 .
- C_1 — Balanced input tuning condenser (selectivity control), 140- μ fd. per section.
- C_2 — Phasing condenser (rejection control), 10- or 15- μ fd. max.
- C_3 — Output secondary tuning condenser, 75- μ fd., midget.
- C_4 — R.f. by-pass condensers, 0.01- μ fd. or larger.

The crystal resonant frequency is approximately 525 kc., which is also the intermediate frequency of the receiver. The input and output transformers are in separate shields.

panied by poor sensitivity in a regenerative receiver may indicate an open detector grid leak or one of excessively high resistance. Replace the leak, using one of lower resistance if necessary.

If the filaments light but there is no output (set "dead"), first check the B-supply voltage and connections to the output stage. Even with no signal coming through there should be strong clicks when the headset or speaker is connected and disconnected. If the output circuit checks OK, clip a pair of 'phones across the output of each preceding audio stage, including the detector, until the signal is picked up, thus locating the circuit in which the fault lies. Check the tube, resistors, bypass and coupling condensers, etc. in the defective stage, both for shorts and opens, using an ohmmeter or its equivalent.

If strong clicks result when the grid of the detector is touched, but there is no signal or only very weak signal output, it is likely that the fault is in a r.f. circuit ahead of the detector. Check the r.f. tube or tubes and the plate circuits of preceding stages for opens and shorts. An open secondary circuit or grid coil may cause periodic

clicking like that resulting from a defective detector grid leak, in which case the grid circuit should be tested for open circuit with an ohmmeter or 'phones and battery. If a circuit should test neither shorted nor open but does not "tune," look for a defective connection between coil and tuning condenser.

Noticeably weak signal response will result with an open antenna coupling coil or open connection in the antenna-ground circuit. A shorted grid condenser, either in a detector circuit or an r.f. amplifier using capacitive coupling, will have the same effect. This may be checked by removing the grid resistor, which should cause the periodic clicking sound in the output. Shorts of this kind can be caused by a blown condenser or by soldering paste smeared between the terminals. Needless to say all soldered connections should be thoroughly wiped with a clean cloth to prevent such leakages.

A regenerative receiver may "howl" just as the detector starts to oscillate. This "fringe howl" is most likely to result with transformer or impedance-coupled detector output and the

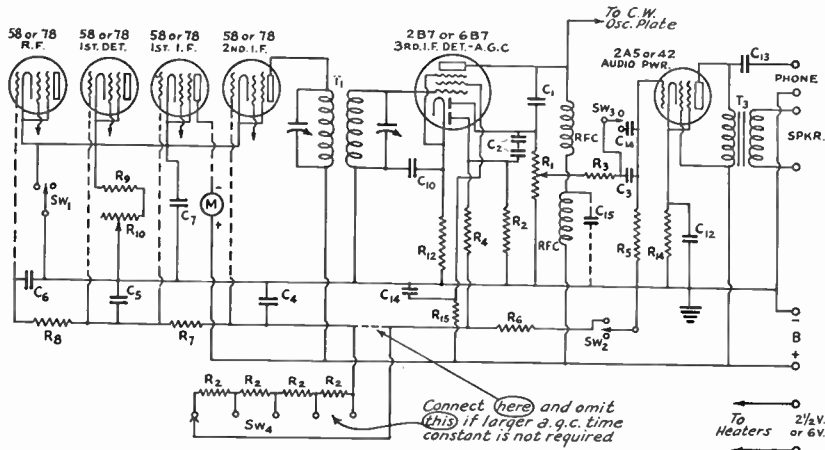


FIG. 534 — AN ILLUSTRATIVE ADAPTATION OF THE -B7 TYPE TUBE AS A COMBINED I.F. AMPLIFIER DIODE DETECTOR AND SEPARATE DIODE A.G.C. RECTIFIER REPLACING THE USUAL TRIODE OR SCREEN-GRID SECOND DETECTOR OF A TYPICAL SUPERHET

In this arrangement the r.f. voltage applied to the diode circuits is taken off across the plate choke of the -B7. Circuit constants are usual except as specified below.

R1 — 2.0-megohm unshielded manual volume control.

See text.

R2 — 3.0-megohm $\frac{1}{4}$ -watt, each.

R3 — 0.5-megohm $\frac{1}{4}$ -watt.

R4 — 4.0-megohm $\frac{1}{4}$ -watt.

R5 — 10.0-megohm $\frac{1}{2}$ -watt.

R6 — 50,000-ohm $\frac{1}{4}$ -watt.

R7 — 0.25-megohm $\frac{1}{4}$ -watt.

R8 — 0.25-megohm $\frac{1}{4}$ -watt.

R9 — 100-ohm $\frac{1}{4}$ -watt.

R10 — Manual gain control, 1,000 ohms (approx.).

R12 — 500-ohm $\frac{1}{4}$ -watt.

R14 — 400-ohm 2.0-watt.

R15 — 60,000-ohm 1-watt.

C1 — 50- μ fd. mica.

C2 — 100- μ fd. each mica.

C3 — 250- μ fd. to 50- μ fd. mica.

C4, C5, C6 — 0.002- μ fd. above 1500 kc., 0.005- μ fd. below 1500 kc., 600-volt mica.

C7 — 0.5- μ fd. 200-volt.

C10 — 0.1- μ fd. or less, 200-volt (see text).

C12 — 10.0- μ fd. 50-volt electrolytic.

C13 — 0.1- μ fd. 600-volt.

C14 — 0.01- μ fd. mica.

C15 — 250- μ fd. mica (if used).

RFC — 10- to 30-mh. r.f. chokes.

SW1 — S.p. cathode resistor shorting switch. See text.

SW2 — A.g.c. on-off switch.

SW3 — Audio tone control (Phone-c.w.).

SW4 — A.g.c. time constant control.

T1 — Standard i.f. transformer.

T3 — Audio output transformer.

best precaution against it is to use an audio transformer or choke of the better grade rather than one of the cheaper type with inadequate primary windings. If it does occur with the transformer that must be used, however, it can be reduced or eliminated by connecting a resistor across the secondary of the audio transformer. In most cases a resistance of 100,000 ohms will be sufficiently low. A grid leak of lower value also may help in some cases. These expedients reduce the receiver output, of course, and must be considered as less desirable than the substitution of an audio coupler having better characteristics.

"Stringy quality" or poor base-note response usually can be traced to an open or inadequate bypass capacitance in a detector or audio amplifier circuit. Too-small capacitance across a cathode resistor is a common source. An open or too-small grid condenser in a grid-leak detector also may be the cause of this trouble.

Servicing Superheterodyne Receivers

▲ In addition to the general receiver servicing suggestions given in the preceding section, there are a few others for troubles peculiar to superhet type receivers. Generally poor performance, characterized by broad tuning and poor sensitivity, calls for checking of the circuit tuning and alignment as previously described in connection with the adjustment of the five-tube receiver.

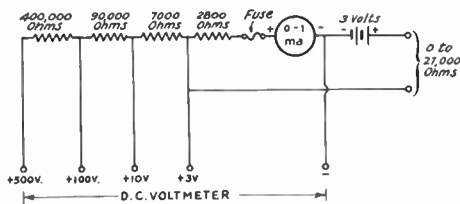


FIG. 535 — A COMBINATION OHMMETER AND D.C. VOLT METER SUITABLE FOR RECEIVER TESTING

It may be assembled on a bakelite panel in an instrument case. The 0-1 ma. d.c. milliammeter should be of the low-resistance type. Two flash-light cells in series serve as the battery. The resistors preferably should be "precision" type. A 1/100-amp. low-voltage type Littelfuse should be connected as shown. If it is omitted, the 2800-ohm resistor should be replaced by one of 3000 ohms. The approximate ohmmeter calibration is as follows:

Meter Scale (Ma.)	Ohms	Meter Scale (Ma.)	Ohms
1.0	0	.375	5000
.96	100	.30	7000
.85	500	.25	9000
.75	1000	.20	12,000
.60	2000	.15	17,000
.50	3000	.10	27,000

The procedure is to start with the receiver output (audio) and work back through the second de-

tor i.f., and high-frequency circuits, in the order named.

In case of oscillation in high-frequency amplifier and first detector circuits, as evidenced by squeals or "birdies" with varying of their tuning, look for poor connections in the common ground circuits, especially to the tuning condenser rotors. Inadequate or defective bypass condensers in cathode, plate and screen grid circuits also can cause such oscillation. In some cases it may be advisable to provide a baffle shield between the stators of pre-r.f. amplifier and first detector ganged tuning condensers, in addition to the usual tube and inter-stage shielding. Improper screen-grid voltage, as might result with a shorted or too-low screen-grid series resistor, also could be responsible.

Oscillation in the i.f. circuits, independent of high-frequency tuning and indicated by a continuous squeal when the gain is advanced with the c.w. beat oscillator on, will result from similar defects in i.f. amplifier circuits. Inadequate cathode resistor bypass capacitance is a very common cause of such oscillation. Additional bypass capacitance, 0.1 to 0.25 μ fd., usually will remedy this type of oscillation. The same applies to screen-grid bypasses of i.f. tubes.

"Birdies" and "mush" occurring with tuning of the high-frequency oscillator may indicate that it is "squegging" or oscillating simultaneously at two frequencies. This may be caused by a defective tube, too-high oscillator plate or screen-grid voltage, excessive feed-back in the oscillator circuit or excessive gridleak resistance. If the latter, replace with a new resistor, using one of lower resistance if necessary.

Excessive "hiss" may be caused by a defective h.f. or i.f. tube, by an open grid circuit, or by too-large first oscillator r.f. input to the first detector circuit. The first oscillator plate (or screen) voltage should be no greater than that necessary for good signal response and the coupling between oscillator and first detector should be the minimum required. It may be helpful to reduce the oscillator screen voltage, in the case of an electron-coupled oscillator, or the plate voltage in the case of a triode. The same symptoms and remedies apply to the c.w. beat oscillator and its coupling to the second detector. There should be some increase in hiss when the latter is switched on, of course, as a result of the i.f. noise components beating with the carrier it furnishes in the second detector. The oscillator input to the second detector should be just enough to cause a noticeable change in second detector plate current. (About 0.05 ma. increase in the case of a self-biased triode second detector, for instance.)

MONITORS AND FREQUENCY METERS

ONE might suppose that, having finished the receiver, the next piece of equipment to be built would be the transmitter. But before the job of adjusting a transmitter to maximum effectiveness can be tackled, the amateur must have some means of checking its performance — particularly, how it is going to *sound* to other amateurs — and of making certain that the frequency of the signals is inside the band in which the transmitter is supposed to be working. Without the facilities to determine definitely whether the frequency of his transmitter is within the limits of the band the amateur has no right in the world to send even a single dot.

It is fortunate that when the station has been equipped with a monitor — which is nothing but a simple shielded oscillator — it is also provided with what is without doubt the cheapest and most effective apparatus for setting the transmitter frequency within the band. More elaborate instruments, which we call frequency meters, can be constructed for precise frequency measurement, but an inexpensive monitor, intelligently used, will insure against committing the unforgivable sin of amateur radio — working “off-frequency.”

Building a Monitor

▲ A monitor is a miniature receiver, usually having only a single tube, enclosed with its batteries in some sort of metal box which acts as a shield. It need not be a costly or elaborate affair. The example shown in Fig. 601 illustrates the simplicity of a typical monitor. The constructional work probably would not occupy more than an hour or two.

The requirements of a satisfactory monitor are not difficult to satisfy. It should oscillate steadily over the bands on which the station is to be active; the tuning should not be excessively critical, although the degree of band-spreading ordinarily considered desirable for receivers is not essential; the r.f. pick-up from the 'phone cord should be sufficiently nullified and the shielding

complete enough to permit the monitor to be set near the transmitter and still give a good beat note when tuned to the fundamental frequency of the transmitter (this is usually impossible with the receiver because the pick-up from power supply leads is so great); and it should be constructed solidly enough so that it can be moved around the station without the necessity for retuning when listening to a fixed signal.

Almost any sort of metal can or box can be used as a shield for the monitor, provided it is large enough to contain the necessary components. The can shown in Fig. 601 is an ordinary cracker tin having a diameter of six inches; tins of this sort will be found in most homes or can be purchased in practically every grocery store. To disguise its origin and make it look like a piece of radio apparatus, the can has been given a coat of black lacquer. The circuit diagram of the monitor is given in Fig. 602. A Type 30 tube is used in a simple oscillating circuit; the number of parts required has been reduced to a minimum.

All parts except the “A” and “B” batteries are mounted on the under side of the lid. The data under the circuit diagram includes a complete list of the material

needed. The placing of the parts is not especially important; they should simply be mounted so there is no crowding. The tube sockets into which the coil and tube are plugged are held to the lid by means of machine screws. The tuning condenser, C_1 , the switch, S , and the pin jacks for the 'phones come provided with mounting nuts. The pin jack which connects to the negative terminal of the “B” battery must be insulated from the lid, as indicated in Fig. 602. Care must be taken to see that other wiring which is not “grounded” or connected to the lid, does not inadvertently touch any metal part of the lid or can.

The “A” battery is a single 1.5-volt dry cell of the type that is used in tubular flashlights. The “B” battery is a small-size 22½-volt block, such as the Eveready



TYPICAL FREQUENCY METER CONSTRUCTION

This photograph is a panel view of the two-tube frequency-meter-monitor described in the text. Among the essentials in frequency-meter design are mechanical construction of high stability and the use of a dial having a true vernier scale.

No. 763. These two batteries are taped together and connected to the monitor proper with rubber-covered leads also taped together. This is necessary to keep the battery leads from moving or vibrating after the monitor has been assembled, since movement or vibration of the leads will affect the frequency of oscillation and destroy the usefulness of the device in checking the quality of the transmitter signal. Cotton batting or wadded paper may be packed around the batteries when they are placed in the bottom of the container so that they will not move when the monitor is carried around. Any paint that may be on the upper lip of the can should be scraped off so the lid will make good electrical contact to the body of the can when the monitor is assembled. If the contact is poor the shielding will be impaired and the monitor is likely to be noisy and unstable in operation.

Many amateurs make a practice of continuously monitoring all their transmissions — a good idea not only because a constant check is kept on the frequency and the note, but because listening to one's own keying makes for accurate and clean-cut sending. When this is done, however, the monitor must operate without interruption over rather long periods, which increases the strain on the "A" battery. In such cases it is advisable to use a larger shield box or can so that a full-size No. 6 dry cell can be accommodated. A single No. 6 cell will operate a monitor of the type illustrated for a matter of months with ordinary use.

The data under the diagram should be used chiefly as a guide, because it may be found that slight changes in the number of turns on the plate coils will be required to maintain smooth oscillation over the entire tuning range, since the monitor has no regeneration control.

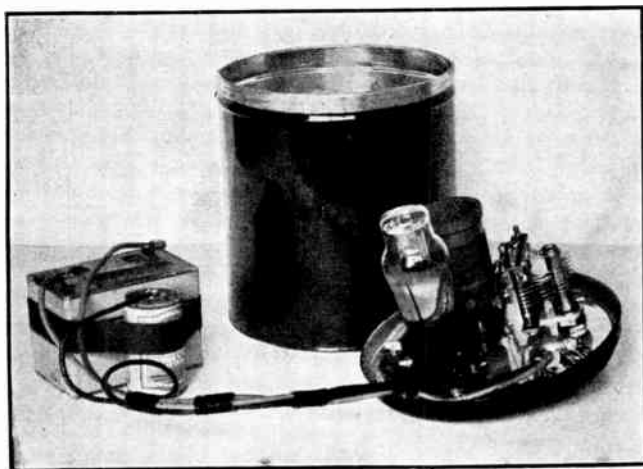


FIG. 601 — AN INEXPENSIVE MONITOR BUILT IN A CRACKER TIN
The simple construction shown above is typical. The monitor, despite its simplicity and low cost, is an indispensable piece of station equipment

Installation and Adjustment

▲ A monitor has two functions to perform, the first being that of providing a means of listening to the transmitter signal under conditions similar to those at distant receiving stations; that is, with the signal weak enough so that its tone and general characteristics can be distinguished readily. The second function is that of acting as a small transmitter radiating a weak signal which can be picked up in the regular receiver for the purpose of aiding in setting the transmitter frequency by the method described in a subsequent section.

In order to make full use of the monitor it must be placed carefully with respect to the receiver and transmitter so that the signal in it from the transmitter is not too loud and so that the signal produced by it in the receiver also is of reasonable strength. If the receiver is located several feet from the transmitter a satisfactory location for the monitor will be found alongside the receiver. If the receiver is across the room from the transmitter it will be necessary to move the monitor to a spot convenient to the transmitter whenever adjustments are to be made. Of course, the monitor can be placed alongside the receiver for frequency setting and monitoring of the transmitter during transmissions. It may be found that the pick-up with the lid of the shield closed is not enough to give a pleasantly loud signal. In such a case the lid can be opened until the required signal strength is obtained, and then left in that position for monitoring.

It is a very worthwhile plan to fit the receiver with a small double-pole double-throw switch so that the 'phones can be thrown from the receiver to the monitor. In this way it is possible to monitor all transmissions simply by flipping over the switch when a change is made from the transmitter to the receiver. Ordinarily the transmitter makes a tremendous and very uncomfortable thump in the receiver 'phones during operation. If it is possible to throw the 'phones over to the monitor this thump is then replaced by a moderate signal which will be almost a replica of the signal that the other fellow has to copy. This makes for much snappier and more readable sending and provides a continuous check on the signal. Should anything go wrong with the transmitter or antenna to cause the frequency to change, the trouble is immediately apparent.

Checking the Transmitter Frequency

▲ In the absence of more elaborate frequency-measuring equip-

ment, a monitor is an absolute necessity in the highly-important operation of setting the frequency of a self-excited transmitter (or oscillator-amplifier transmitter with a self-controlled oscillator) within an amateur band. While not wholly

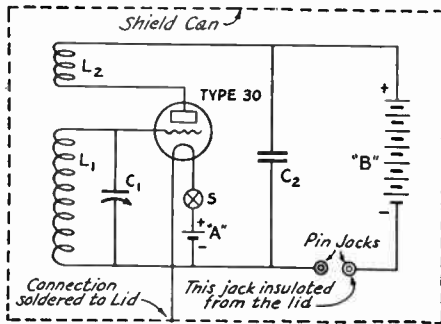


FIG. 602 — WIRING DIAGRAM OF THE MONITOR

The circuit components have the following values: C₁ — 50- μ fd. (.00005 μ fd.) midget variable condenser. C₂ — .002- μ fd. fixed condenser. S — Single-pole toggle switch.

Band	L ₁	L ₂
1750 kc.	70	20
3500 kc.	35	10
7000 kc.	15	6
14,000 kc.	5	4

The coil forms are 1½ inches in diameter. All coils are wound with No. 30 d.s.c. wire.

Other materials required include two 4-prong tube sockets, a Type 30 tube, a pair of 'phone-tip jacks, a small-size 22½-volt "B" battery (Eveready No. 763 or equivalent), and a single-cell 1.5-volt flash-light battery. Two or even three of these cells can be connected in parallel for longer life.

The coils L₁ and L₂ are wound on the same plug-in coil form (4 prong) and are wound in the same direction, L₁ at the upper end of the form. The upper terminal of L₁ connects to the grid of the tube, the lower terminal to the filament of the tube; the terminal of L₂ nearest L₁ goes to the positive side of the "B" battery and the remaining terminal to the plate of the tube. The arrangement of the pins on the form may be anything convenient.

essential for this purpose when the transmitter is crystal-controlled — provided the crystal frequency is accurately known — the monitor is desirable for keeping watch on the quality and stability of the signal.

Before any frequency checking can be done, however, it is necessary to calibrate the receiver tuning dial in terms of frequency. After the receiver has been in use for a little time the locations of the amateur bands are pretty definitely known, because large numbers of amateur stations can be heard working on the more important bands at almost any hour. First get the receiver working on the band in which the transmitter is to be set and note the limits between which amateur stations are heard. Often high-power commercial stations will be heard working just outside these limits, and the frequencies of these stations can be looked up in lists such as the one in the *Radio Amateur Call Book*. Similar lists are

also occasionally published in *QST*. These commercial stations generally are accurately set on their assigned frequencies and furnish a means for making an approximate calibration of the receiver. Amateurs call them, appropriately enough, "marker stations."

No specific examples will be given here because the frequency assignments are changed from time to time, and the latest call book should be consulted for accurate information. Suppose, however, that a station is heard whose frequency, as shown by the list, is 6980 kc. This is only 20 kc. outside the 7000-kc. band, and therefore serves as an approximate marker for the 7000-kc. end. On the high-frequency end of the band we might find a station listed at 7350 kc. which will help in locating the 7300-kc. limit. Obviously the transmitter cannot be tuned to all frequencies between these two markers because both are somewhat removed from the actual limits of the band, and it would easily be possible for the transmitter to be set to some frequency not assigned to amateurs. Due allowance must therefore be made for the fact that marker stations are never actual markers of the band limits, but are outside the bands by an appreciable amount.

The receiver may be calibrated roughly by

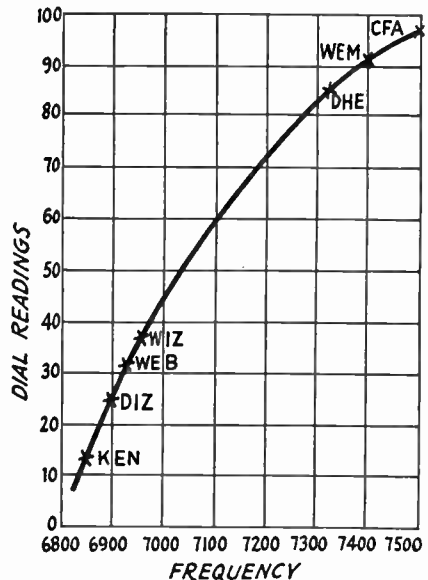


FIG. 603 — SAMPLE CALIBRATION CURVE

made from calibration points supplied by commercial "marker" stations. Such a curve may be made for the receiver or monitor, and will aid in determining the limits of the amateur bands. It is impossible to measure frequency exactly with this type of calibration, so the transmitter should be set well inside the indicated limits to be certain that all transmissions will be inside the band. Each of the above blocks represents a half-inch square on ordinary cross-section paper. The intermediate lines are not shown because of the difficulty of reproduction in printing.

picking up a number of such marker stations at various frequencies near the amateur bands and plotting the tuning-dial readings for each frequency, in the fashion shown in Fig. 603. The regular transmissions of A.R.R.L. Standard Frequency Stations will provide calibration points at the edges of bands and at several intermediate points, as described later in this chapter. The general shape of the curve can be determined from the plotted points and drawn in. In the illustration shown the actual limits of the band would be at 44 and 83 on the tuning dial, although the nearest marker stations are outside these limits. A curve plotted in this way is not entirely accurate, but is good enough to show approximately where the band lies.

After the band limits have been determined to a fair degree of certainty, a suitable working spot should be picked within the band and the receiver left running at that setting. The monitor now should be put into operation. If an extra pair of 'phones is not available a bent piece of bare No. 14 wire may be plugged into the 'phone tip jacks of the monitor so that its plate circuit will be closed. Next tune the monitor condenser slowly across the band, stopping when the signal from it is heard in the receiver. The monitor will now be set exactly on the frequency to which the transmitter is to be tuned. If no signal is heard, check the monitor to make sure it is oscillating (the same tests should be applied as were described for oscillating detectors in Chapter Five), move it closer to the receiver, or open the lid so that the shielding will not be so great. Make certain that the right coil is in the monitor.

With the monitor setting determined, transfer the headset from the receiver to the monitor, start up the transmitter, set its tuning controls at approximately the point where the band should be, and tune carefully until a signal from the transmitter is heard in the monitor. Set the transmitter frequency to "zero beat" — the silent space between the two beat notes — and the transmitter frequency will be exactly on the spot picked out. Since the calibration obtained

as described above is only approximate, the frequency upon which the transmitter is set should be well inside the limits indicated by the calibration curve. Take no chance of operating outside the band.

This method does not provide the means for setting the transmitter on any definite frequency unless there is a known station there to mark it, but it does enable the transmitter to be tuned to, say, the center of the band, to a spot a quarter of the way from the top, or to any roughly estimated point. It is not often that the amateur finds it essential to tune his transmitter to within a few kilocycles of a given frequency but if such is the case there are means involving greater difficulties which can be used. They will be detailed later. The prime requisite usually is to have the transmitter within the limits of the band and perhaps in some particular section of it. For this work the simple monitor is all that is necessary.

Absorption Frequency Meters

▲ Setting the transmitter frequency as described above is subject to a possible error which, particularly with high-power transmitters, may lead to off-frequency operation unless the approximate transmitter-control settings for the band are known. All vacuum-tube oscillators, in addition to generating oscillations at the frequency to which the coil and condenser tune, also set up *harmonics*, or oscillations at other frequencies which are integral multiples of the frequency set by the coil and condenser (the *fundamental* frequency). For example, a 1750-kc. oscillator will have harmonics at twice 1750 kc., or 3500 kc., at three times 1750 kc., or 5250 kc., at four times 1750 kc., or 7000 kc., and so on. If this oscillator is a monitor, it will pick up signals from a powerful transmitter set to any of this series of frequencies, although the signal will be weaker the farther it is in frequency from the fundamental.

This sometimes leads to off-frequency operation, because the total tuning range will be large in a transmitter circuit using a large variable condenser and a small inductance, as nearly all self-controlled oscillators do. As an illustration, suppose a self-controlled high-*C* oscillator such as one of those described in Chapter Seven is to be tuned to a frequency in the upper half of the 3500-kc. band; say, 3800 kc. The second harmonic is 7600 kc.; it is possible for the monitor to pick up signals on either of those frequencies if the transmitter power is high and the monitor is close to the transmitter. Unless the operator is thoroughly familiar with the tuning of his transmitter it would easily be possible for him to set the transmitter on 7600 kc. — which is not included in any amateur band — under the impression that he was putting it on 3800 kc.

An error of this sort can be discovered very readily by the use of an absorption frequency meter. This consists simply of a coil and con-

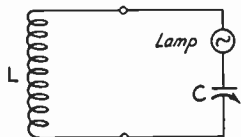


FIG. 604 — ABSORPTION FREQUENCY METER CIRCUIT

An absorption meter can be made in a few minutes from an old variable condenser, *C*, having a maximum capacity of about 350 $\mu\text{fd.}$, and a series of coils, *L*, to cover a large range of frequencies. The meter should be arranged so that the coils are readily interchangeable, although the construction need not be elaborate. The lamp acts as a resonance indicator when the absorption meter is used with a transmitter, its use is not essential, although it is a convenience. The absorption meter is not adapted to accurate measurement of frequency but is helpful in approximately locating an unknown frequency, as described in the text.

denser, often with a small flash-light lamp in series although the lamp is not strictly necessary. See Fig. 604. Such a frequency meter can be made from spare parts to be found in every amateur station and is well worth the few minutes' time involved in building it. Although it is not adapted to accurate frequency measuring nor to setting the transmitter frequency inside the band once the approximate settings of the transmitter controls are known, it can be useful in a variety of ways.

A series of coils should be provided for the absorption meter so that it will cover a continuous frequency range from about 1500 kc. up to the highest frequency likely to be needed—perhaps 20,000 kc. A rather large condenser should be used; a variable with 350 $\mu\text{mfd.}$ maximum capacity is about right. Coils to cover the range with a condenser of this size may be made as shown in the table below. The frequency ranges are approximate only. The specifications are for coils wound on a two-inch form with No. 20 d.c.c. wire, no spacing between turns.

Range	Turns
1500–5000 kc.	25
3000–10,000 kc.	10
6000–20,000 kc.	5

It is not necessary to have calibration curves for these coils nor even to have permanent calibration points. The use of the meter can best be explained by continuing the example already cited. To make sure that the transmitter is actually on 3800 kc. and not 7600 kc., the coil which covers the range from 3000 to 10,000 kc. should be connected to the condenser and coupled loosely to the tuning coil in the detector circuit of the receiver. Set the receiver to 3800 kc. with the detector oscillating gently and turn the dial on the absorption meter condenser. At some point toward the high-capacity end of the condenser the meter will absorb enough energy from the detector to cause it to stop oscillating. Move the meter a little farther away until this occurs at one very definite point on the meter dial. The meter will then be set approximately to 3800 kc.

Now turn on the transmitter and couple the meter, without changing its dial setting, to the transmitter tank coil. When the meter is equipped with a lamp indicator, the lamp will glow if the transmitter is tuned to 3800 kc. Always use the loosest possible coupling in making this kind of test; that is, keep far enough away from the tank coil so that the lamp shows only a faint glow at a definite point on the meter dial. A "broad" indication, or one in which the lamp lights over a considerable range of meter tuning, is not nearly so good. Should the meter be without a lamp indicator, the same effect can be obtained by watching the plate milliammeter on the transmitter. It will show a slight increase as the

absorption meter is tuned through resonance with the transmitter.

Continuing the example, if no indication of resonance appears when the meter is coupled to the transmitter, the chances are that the transmitter is tuned to a harmonic of the monitor instead of to its fundamental frequency. This can be checked by decreasing the capacity of the condenser in the meter, upon which the indication should appear toward the low-capacity end of the scale. If the receiver can tune to 7600 kc. the order of the frequency to which the transmitter is tuned can be checked quite easily by following the method described in the paragraph second above, this time varying the detector tuning and holding the absorption meter condenser setting constant.

An absorption meter is also useful when, as sometimes happens, a doubling stage in a crystal-controlled transmitter is accidentally tuned to the third harmonic instead of the second. A few minutes spent in checking often will prevent off-frequency operation.

More Precise Methods

▲ So far we have outlined the simple procedure necessary to determine definitely whether the transmitter frequency is within the limits of the band and roughly in what part of the band it is located. Many amateurs will be interested in knowing how a transmitter can be tuned to within a few kilocycles of a given frequency. For this work some calibrated standard will be necessary against which to compare the frequency of the transmitter. Such a standard is the heterodyne frequency meter.

The heterodyne frequency meter somewhat resembles the monitor in that it is a small oscillator, completely shielded, but the refinement and care in construction is carried to a high degree so that the frequency meter can be accurately calibrated and will retain its calibration over long periods of time. The oscillator used in the frequency meter must be very stable; that is, the frequency of oscillation at a given dial setting must be practically the same under any conditions. No plug-in coils are used in the frequency-meter; one solidly built and firmly mounted coil is permanently installed in it, and the oscillator covers one band only. A low-frequency band is used for this purpose, and when the meter is to be used on the higher-frequency bands its harmonics instead of the fundamental oscillation are used. The single coil can be mounted in a much more solid fashion than could plug-in coils, and since it is not subject to continual handling such as plug-in coils receive, the turns will not be loosened or pulled out of place.

The frequency meter must possess a dial which can be read precisely to fractions of divisions. To obtain accuracy it is necessary to read the scale to at least one part in 500; ordinary dials

such as are used for receivers are not capable of such precision. The National 4" Type N and 6" Type N and NW dials are provided with vernier scales for reading to a tenth of a scale division (one part in 1000), and are well suited to this

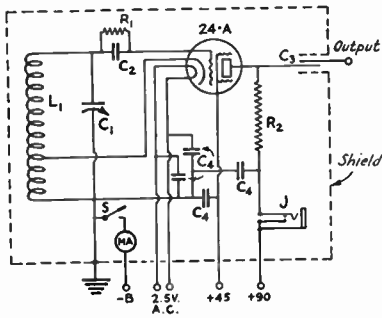


FIG. 605 — CIRCUIT OF THE ELECTRON-COUPLED FREQUENCY METER

This circuit is for use with indirectly heated tubes such as the 24-A and 36.

C_1 — Band-spread condenser, minimum capacity 53 $\mu\text{f}.$, maximum capacity, 81 $\mu\text{f}.$, approximately. (Such as General Radio Type 556.)

C_2 — 250- $\mu\text{f}.$ mica condenser.

C_3 — Approximately 10 $\mu\text{f}.$ See text for details.

C_4 — .01- $\mu\text{f}.$ mica ty-pass condenser.

R_1 — 100,000-ohm grid leak.

R_2 — 50,000-ohm 1-watt resistor, pigtail type, non-inductive.

J — Closed-circuit 'phone jack.

S — On-off switch, s.p.s.t.

L_1 — Approximately 90 turns of No. 30 d.s.c. wire close-wound on a 1-inch bakelite tube, tapped at the 30th turn from the grounded end. A few more or less turns may be needed to spread the 1750-kc. band over the dial scale to the best advantage.

work. The General Radio 704 and 706 series dials also are excellent. There are a few other good dials on the market. Care should be used to select one which has fine lines for division marks, and which has an indicator very close to the dial scale so that the readings will not be different when the dial is viewed from different angles.

The frequency meter also can be used as a monitor if desired with a resulting simplification in checking transmitter frequency. For maximum accuracy, however, the frequency meter should be left permanently in a fixed place on the operating table, since handling the meter may jar it enough to destroy its calibration unless it is very solidly constructed. A monitor, on the other hand, is a much handier instrument if it can be carried around when tests or adjustments are being made on the transmitter.

The Electron-Coupled Frequency Meter

▲ One of the most stable oscillator circuits, electrically, that has been devised, is the electron-coupled oscillator circuit. In this circuit the oscillation frequency is practically independent of moderate variations in supply voltages, provided

the plate and screen voltages applied to the screen-grid tube used are properly proportioned. Variations in plate and filament supply voltages constitute probably the greatest source of frequency change attributable to electrical causes in vacuum tube oscillators. Furthermore, by using the grounded screen grid as the anode in the oscillatory circuit, the other elements in the tube are electrostatically shielded from the plate, just as they are in an ordinary receiving screen-grid amplifier, and it becomes possible to take output from the plate circuit with practically no reaction on the frequency of the oscillator. This is a feature of great value, because it means that the frequency meter can be coupled to the receiver with no danger of changing its calibration. A third feature of the electron-coupled oscillator which makes it ideally suited to use in frequency meters is that strong harmonics are generated in its plate circuit so that the meter is useful over an extremely wide range of frequencies.

Circuit diagrams for electron-coupled frequency meters are given in Figs. 605 and 606. The former is for use with tubes having indirectly-heated cathodes, such as the 24-A, 35, and 36. Fig. 606 is a circuit for filament-type tubes such as the 32. With these tubes it is necessary to provide an extra winding, L_2 , in series with one leg of the filament so that both filament terminals will be at the same r.f. potential. In general, the types of tubes just mentioned (all of them are four-element tubes, or tetrodes) will be better suited for use as electron-coupled oscillators than the screen-grid pentode receiving types such as the 34, 39-44, and 78, because in these types the

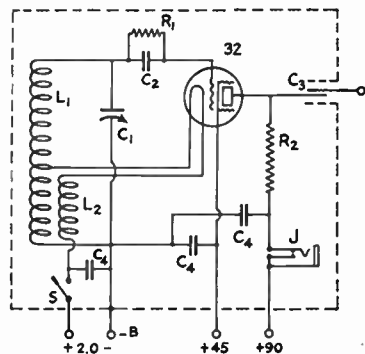


FIG. 606 — ELECTRON-COUPLED FREQUENCY METER CIRCUIT FOR USE WITH DIRECTLY-HEATED TUBES SUCH AS THE 32

The circuit is essentially the same as that of Fig. 605 except that both sides of the filament must be fed through coils to prevent grounding the filament. L_1 has the same specifications as in Fig. 605. L_2 has the same number of turns as the tapped portion of L_1 . It may be wound over the corresponding part of L_1 or directly on the coil form between the turns of the tapped portion of L_1 . The other components have the same values as in Fig. 605. In this circuit the filament switch as well as the output binding post and 'phone jack must be insulated from the shield.

suppressor grid, connected to the cathode inside the tube, nullifies the shielding when the tube is used as an electron-coupled oscillator. The 77, 6C6, 6D6, 57 and 58 will be satisfactory, however, because the separate base connection of the suppressor grid makes it possible to tie this grid either to ground or to the regular screen grid.

Mechanical considerations are most important in the construction of a frequency meter. No matter how good the instrument may be electrically, its accuracy never will be good if it is flimsily built. Mount everything solidly; make connections with stiff wire and place all leads so they cannot be moved in the course of ordinary handling. Thoughtful care in the construction of the frequency meter makes the difference between the precise instrument and just an ordinary oscillator.

The construction of the two-tube frequency-meter monitor shown in the frontispiece and Fig. 607 is illustrative of good practice in building a frequency meter. The same layout can, in fact, be followed in using the circuit diagrams of Figs. 605 and 606, even though the separate detector tube is not used.

It is desirable to design the frequency meter so that the oscillator operates in the 1715-2000-ke. band, with a "spread" such that almost the entire dial scale is used to cover the band. While the specifications for the oscillator inductance under Fig. 605 will be found to work out closely, it may be necessary to add or subtract a few turns to get the band-spread just right. For the higher-frequency bands harmonics of the oscillator are used. Thus the second harmonic will cover the 3500-4000-ke. band, the fourth the 7000-7300-ke. band over part of the scale, and so on to the highest frequencies used by amateurs. Strong harmonics can be taken from the frequency meter even on the 56,000-ke. band, which is the highest-frequency band amateurs have used for practical communication.

The cathode tap on the coil L_1 usually will be set at about $\frac{1}{2}$ the length of the coil from the grounded end. The location of the tap is not critical, but if too many turns are used between cathode and ground it sometimes happens that a species of multiple oscillation will be set up, corresponding to the howl a regenerative detector will give if too much regeneration is used. This results in the production of an ex-

tended series of beats on either side of the desired one. Such a condition can easily be cured by moving the cathode tap toward the ground end of the coil or by using a grid leak, R_1 , having a lower value of resistance. When the coil has been completed and the tap correctly placed the winding should be coated with lacquer or collodion to hold the wires firmly in place.

The coupling condenser, C_3 , in Figs. 605 and 606 should have very small capacity — about 10 to 15 micromicrofarads. A midget variable condenser will do — both sides must be insulated from the shield — or a small "trimmer" condenser can be used. Alternatively, a suitable condenser can be made from two pieces of metal strip measuring approximately one-half by one inch, arranged to face each other with a space of about $\frac{1}{8}$ inch between their surfaces.

The signal from the frequency meter can be fed into the receiver by connecting a wire from the output post on the meter to the antenna post on the receiver. This will give strong signals on all harmonics; in fact the signals may be stronger than is deemed desirable. If this should be the case the wire from the output post can be disconnected from the receiver but left in the vicinity of the receiving lead-in. Satisfactorily loud signals from the frequency meter ordinarily can be obtained even with such loose coupling.

The frequency-meter can be used as a monitor by connecting a pair of headphones in the screen circuit through the medium of the jack, J .

When the frequency meter is first turned on some little time is required for the tube to reach its final operating temperature, and during this

period the frequency of oscillation will drift slightly. Although the drift will not amount to more than two or three kilocycles on the 3500-ke. band and proportionate amounts on the other bands, it is desirable to allow the frequency meter to "warm up" for about a half hour before calibrating, or before making measurements in which the utmost accuracy is desired. This applies particularly with indirectly-heated tubes. The directly-heated tubes, because of the smaller filament power required, warm up much more quickly. The on-off switch in Fig. 605 is a useful adjunct to the meter because the "B" supply can be cut off independently of the filament supply, permitting the operator to keep the frequency meter up to tem-

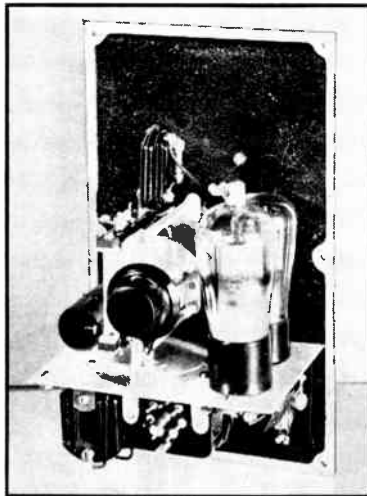


FIG. 607 — AN INTERIOR VIEW OF THE TWO-TUBE E.C. FREQUENCY-METER-MONITOR

Careful attention to small details of construction is repaid by a high order of accuracy in the frequency meter.

perature without wasting "B" current when no measurements are being made.

With careful construction, a good readable dial, and an accurate calibration made as described in a later section, measurements made with the electron-coupled frequency meter can be depended upon to be accurate to within 1 part in 1000, or one-tenth of 1%, an accuracy more than sufficient for amateur work.

A Combined Frequency Meter-Monitor

▲ Although an electron-coupled frequency meter constructed according to the diagrams, Figs. 605 or 606, can be used as a monitor as explained in the previous section, the monitoring function will be performed more satisfactorily if a separate detector tube is added to the unit. Installation of the extra tube will result in a stronger signal for monitoring purposes, and will eliminate such slight changes in oscillator frequency as may be occasioned by plugging the headphones into the plate lead of the oscillator. The separate detector adds little to the cost of the frequency meter.

A combined frequency meter-monitor of this type is illustrated in Figs. 607 and 608 and on the first page of this chapter. The circuit diagram of the oscillator is the same as that of Fig. 605 up to the "output" terminals, where condenser C_3 replaces C_2 in Fig. 605. The oscillator output is fed into the grid circuit of a Type 56 tube connected as a plate or grid-bias detector. This tube operates both as an amplifier of the radio-frequency output of the oscillator and as a detector when

the oscillator output or one of its harmonics is made to beat with the signal from the transmitter.

The construction of the unit should be evident from the two photographs. The case is a sturdy aluminum box measuring 10 by 6 by 5 inches. An aluminum shelf bolted to the panel holds all the parts. The oscillator and detector tubes are at the right in Fig. 607, at the center are the two tuning condensers, C_1 and C_2 , C_2 being used as an adjustable fixed section to set the minimum capacity in the circuit to spread the 1750-ke. band over most of the dial scale. It need only be adjusted when the frequency meter is first built, and therefore is not controllable from the front of the panel. The grid condenser, C_3 , and grid leak, R_1 , are mounted by a small bracket on the upper stator-plate terminal of C_2 to make a short, direct connection to the grid of the 24-A oscillator tube. To the left of C_1 and C_2 , near the shelf, is the oscillator coil, L_1 . By-pass condensers and resistors are mounted underneath the shelf, together with a cable socket for the heater and plate-supply connections.

If desired, it is possible to include a power supply for the frequency meter-monitor in the same cabinet if the space for a small power transformer and a compact rectifier-filter is available. Since the plate current requirements of a unit of this type are very low — about two milliamperes at the most — a simple filter of the resistance-capacity type will be sufficient. The power transformer can be of the midget type. As a general rule, however, it is better to use a separate power supply because of the possibility of vibration and hum

pickup from the power unit. Alternating current can be used on the tube heaters in conjunction with "B" batteries, or all the power can come from a receiver power unit — from the same unit used with the receiver, in fact.

Calibrating the Frequency Meter

▲ When the frequency meter is finished it must be calibrated before it can be put into service. After its tuning range has been checked to be certain that it covers the 1750-ke. band with a little overlap at each end, an approximate calibration may be made using marker stations. These markers may be near any of the amateur bands, not necessarily only in the vicinity of 1715 and 2000 ke. For example, stations in the vicinity of 4000 ke. can be used as markers, the actual

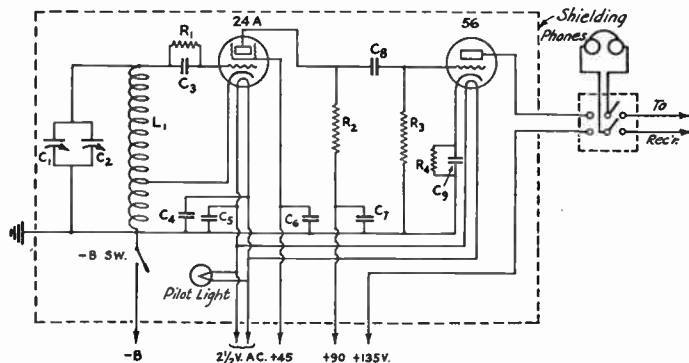


FIG. 608 — CIRCUIT OF THE TWO-TUBE FREQUENCY-METER-MONITOR

C_1 — 3-plate Cardwell Midway Type #01-B, maximum capacity 26 $\mu\text{fd.}$, minimum capacity 7 $\mu\text{fd.}$ (See text.)

C_2 — 5-plate Cardwell Midway Type #02-B, maximum capacity 50 $\mu\text{fd.}$, minimum 8 $\mu\text{fd.}$

C_3 — .001- $\mu\text{fd.}$ fixed condenser.

C_4, C_5, C_6, C_7 — .01- $\mu\text{fd.}$ fixed by-pass condensers.

C_8 — 10- $\mu\text{fd.}$ fixed coupling condenser.

C_9 — .25- $\mu\text{fd.}$ fixed condenser.

R_1 — 100,000-ohm $\frac{1}{2}$ -watt size.

R_2 — 100,000-ohm 1-watt size.

R_3 — 1-megohm 1-watt size.

R_4 — 900,000-ohm 1-watt size.

L_1 — 79 turns No. 30 d.s.c. wire on a 1-inch diameter tube. Cathode tap should be at 23rd turn from "ground" end. The heater and "B" supplies may be from the receiver power pack.

frequency of the station being divided by 2 to get the calibration point since the second harmonic of the frequency meter is being used. Again, marker stations near 7000 kc. can furnish points for the low-frequency end of the scale, the calibration frequency being the marker station frequency divided by 4 because the checking will be done on the fourth harmonic of the frequency meter. A large number of points can be secured in this way for the purpose of making up a preliminary calibration.

The general procedure is to tune in the marker station on the receiver with the detector oscillating, then back off the regeneration control until the detector stops oscillating but is still giving a great deal of regenerative amplification, just as if a 'phone station were being tuned in. With a superhet receiver the signal would first be tuned in with the beat oscillator on; after setting the receiver to zero beat with the incoming signal the beat oscillator should be shut off. The dial on the frequency meter should now be turned until the signal from the meter is heard to beat with the marker station signal. This amounts to using the frequency meter as a separate heterodyne. Adjust the frequency meter to give zero beat with the marker signal and note the dial reading. The calibration point will be the marker station frequency divided by whatever harmonic of the frequency meter is being used. A number of these points will give a complete-enough calibration to make possible the drawing of an approximate calibration curve on regular graph paper.

After this approximate curve has been constructed, the current issue of *QST* should be consulted for information as to the next transmission of standard frequencies for calibration purposes. These transmissions are given once or twice each week by the stations comprising the A.R.R.L. Standard Frequency System, which consists of stations especially licensed to transmit calibration signals for amateur use, and located in different geographical sections of the United States. Each of the stations is equipped with a frequency standard which is accurate to better than one part in 10,000 or .01%. These individual standards have been calibrated directly against the national frequency standard located in the laboratory of the Bureau of Standards at Washington, and the calibration signals transmitted for amateurs are therefore based on the national frequency standard. Every amateur is urged to make the fullest possible use of the transmissions. In general the transmissions consist of signals which mark accurately the limits of the 3500-, 7000- and 14,000-kc. bands with intermediate points at 100 kc. intervals.

The date and exact form of each transmission are indicated in each issue of *QST*. The transmissions generally take the form of an eight-minute period for each frequency. The first part of each period is devoted to a QST — general call to all

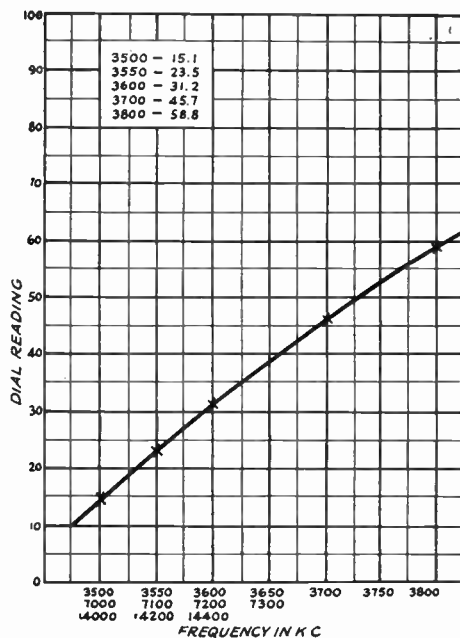


FIG. 609 — TYPICAL CALIBRATION CURVE FOR THE FREQUENCY METER

Each of the small blocks represents a half-inch block on ordinary cross-section paper. The chart must be large enough so that tenths of divisions can be read accurately on the dial reading scale, and the frequency scale must be spread out to facilitate making readings to within a few kilocycles.

A.R.R.L. stations — then follows a series of long dashes and an announcement of the exact frequency, then a final short period in which the frequency of the transmission to follow in a few minutes is announced.

The same procedure should be followed in calibrating from Standard Frequency Transmissions as in calibrating from marker stations. The purpose of the marker station calibration is simply to serve as a guide in locating the Standard Frequency signals.

After the dial readings for various frequencies have been secured, they should be plotted carefully on a curve sheet. The curve should not be "cramped" — that is, the scale should not be so small that it is difficult to make accurate readings. Fig. 609 shows a satisfactory way of making up such a curve. The paper used is standard cross-section paper (20 lines to the inch); each of the blocks shown in the drawing represents a half-inch block on the paper. It may be necessary to use two sheets to draw the entire curve, one for the low-frequency half of the band and the other for the high-frequency half. The illustration shows calibrations only for the three bands on which Standard Frequency Transmissions are sent. For the 1750-kc. band the 3500-kc. readings would be divided by two.

TRANSMITTERS

IN ONE respect the transmitter is the most important piece of equipment in the amateur station — it is the mouthpiece through which the operator conveys his thoughts to other amateurs the world over. Distant amateurs must therefore judge the station by the quality of the transmitter's output and by the way it is operated. A steady signal with a clean "pure d.c." note is the finest testimonial an amateur station can have. It is well worth attaining, not only because it indicates possession of a good transmitter intelligently operated but also because it shows that the station's operator is not "hogging" more than his share of the amateur bands — as he would with a rough, wobbly, creeping signal.

The design and construction of an amateur transmitter offers a very wide field for interesting experiment. The past few years have seen so many new developments in circuits and equipment that the possible combinations of apparatus to produce the result desired are almost endless. It is also true, fortunately, that wholly satisfactory results can be secured from extremely simple and inexpensive apparatus. Indeed, the range of a transmitter depends more upon judicious choice of frequency and the skill of the operator than upon the amount of power used. Although amateur stations are permitted to use power inputs up to one kilowatt, a comparatively small number use more than a quarter of that power, while the great majority do excellent long-distance work with less than one hundred watts. "DX" does not depend especially upon power, although the higher the power of the transmitter, the more consistent will be the results through good conditions and bad.

Amateur transmitters can be divided into two general classes, those intended for operation on the medium and long distance frequency bands — 1.75 to 28 mc., inclusive — and those for the ultra-high frequencies — 56 mc. and higher. This chapter will treat the design, construction and operation of transmitters of the first class. A somewhat different technique is usually employed in transmitters for ultra-high frequency work, and this type of transmitter is discussed in a separate chapter.

Types of Transmitters

▲ All amateur transmitters employ the vacuum tube as a generator of the high-frequency alternating current necessary for the production of radio signals. Present-day amateur transmitters are of two general types: those which employ "self-controlled" oscillators and those in which a

crystal-controlled oscillator is used. The first of these types is called "self-controlled" because the frequency of the oscillations generated in the transmitter depends on the constants of the circuit (chiefly the size of the coil and condenser used in the plate circuit of the oscillator). The crystal-controlled transmitter, on the other hand, makes use of a special type of crystal (usually quartz) in the oscillator. In this case, the crystal is the chief factor in determining the frequency on which the transmitter operates.

When an oscillator of either type is used to feed the antenna directly, the transmitter is said to be "self-excited." If, however, the oscillator drives one or more amplifier tubes which in turn feed the antenna, the arrangement is known as an "oscillator-amplifier" transmitter. One may have either a self-controlled or a crystal-controlled oscillator-amplifier transmitter.

Of all transmitters, the crystal-controlled type of set is by far the most satisfactory. In its usual form it is somewhat more complicated than the self-controlled self-excited transmitter but the advantages to be gained in its operation and in the signal it produces far outweigh the added cost. The crystal-controlled transmitter is fast becoming universal throughout the world. There is, of course, still a place for the low-powered self-excited self-controlled transmitter. Its simplicity and its low cost make it attractive to the beginner in amateur radio. Further, it must be admitted that such a transmitter, when built and operated very carefully, is capable of good performance.

Transmitting Apparatus

▲ The apparatus used in transmitters is of the same general character as that used in receivers — in fact, many of the components used in low-power transmitters are identical with those found in receiving sets. In more powerful transmitters, however, it will be found that condensers have higher voltage ratings, inductances are made with heavy conductors, resistors have greater power-dissipating ratings, and larger tubes of special characteristics are used.

The performance of the transmitter will be dependent to a considerable extent upon the quality and suitability of the individual pieces of apparatus which comprise the whole. The importance of using high-grade apparatus cannot be over-estimated. Insulation is particularly important because of the high voltages used in the transmitter and the heavy radio-frequency currents which must be handled. Without any external indication there can be radio-frequency leaks through

the insulation which will make it impossible to obtain a clean note from the transmitter: often the signal emitted under such conditions is a rough hash and no amount of careful tuning will improve it. It is therefore a wise plan to use only apparatus of reputable manufacture — the equipment advertised each month in *QST* can be depended upon, since all apparatus advertised is inspected and approved by the technical staff of the magazine before being permitted to appear in its pages.

In the descriptions of actual apparatus which appear in this chapter, the manufacturer's name and type number of the parts used frequently are given. This is done for the convenience of the constructor who wishes to duplicate the equipment. It does not mean, however, that parts of different manufacture having the same electrical values and of equal quality cannot be used. So long as the electrical specifications given are followed, the substitution of a different component for the one named will make no difference in the performance of the set. It may, however, make necessary some alterations in the physical layout because of different mechanical design. This is unimportant so long as the principles of good construction are not violated.

Transmitting Tubes

▲ An excellent variety of power tubes is available to the amateur contemplating the construction of a high-frequency transmitter. The large number of tubes is, in fact, often a source of confusion to the beginner because it is difficult for him to decide upon the type best suited to his particular purpose. Broadly speaking, however, tubes may be classified according to the power output to be expected from them. Thus, a group of small tubes of the receiving type, adapted by amateurs to use in low-power transmitters, show power outputs of the order of 5 to 15 watts; a group of medium-power tubes is rated at 35 to 50 watts output; a third group carries a nominal rating of 100 watts, and so on. Obviously, then, the first decision the amateur has to make in the choice of a transmitting tube is that of the power output he wants. The table of transmitting tubes gives the important characteristics and operating ratings of the tubes most suitable for use as radio-frequency oscillators and power amplifiers.

The tubes listed in the table are divided into two classifications, triodes or three-element tubes comprising the first. They are useful as oscillators or power amplifiers. All are capable of working well on the four lower-frequency amateur bands which carry the bulk of amateur communication — the 1.75-, 3.5-, 7- and 14-mc. bands. The types marked with an asterisk (*) are especially designed for very high frequency work, and in addition to giving excellent performance on the four bands just mentioned, also will be found to be well suited to work on 28 and 56 megacycles.

Of the tetrodes and pentodes listed in the second classification, those designed especially for transmitting are intended particularly to be used as radio-frequency power amplifiers. They are of the screen-grid type and can be used without neutralization (see later section). The small receiving tubes are generally used in special oscillator circuits, chiefly with crystal control, but cannot be used as amplifiers without neutralization.

Self-Controlled Oscillator Circuits

▲ Fundamentally there are two general divisions of self-controlled oscillator circuits; those employing capacitive coupling (condensers) to feed back energy from the plate to the grid circuit, and those using inductive coupling (coils) for the same purpose. All circuits are modifications of these two general classes.

The operation of the vacuum tube as an oscillator has been explained in Chapter Four. The maximum amplitude to which oscillations will build up depends upon the characteristics of the tube, the circuit constants, the grid bias and the plate voltage. The frequency of oscillation will be determined principally by the inductance and capacity values in the tuned circuit, although other circuit constants such as the inter-electrode capacitances of the tube also will affect the frequency.

The choice of a circuit is not of great importance, for if the circuit is arranged to suit the particular tube or tubes used, and is adjusted properly, similar results can be obtained with any of them. In every oscillator provision is made to tune the condenser-coil circuits to the required frequency and to vary the amount of energy fed into the grid circuit from the plate circuit (the grid excitation). Other means are provided to adjust the grid bias and to adjust the load to that value which will allow the most efficient transfer of energy from the plate circuit. Some method of making all of these adjustments is to be found in every satisfactory circuit.

The circuits in most general use are the Hartley, Armstrong or tuned-grid tuned-plate, Colpitts and ultraudion.

In the Hartley oscillator the tuned circuit (generally called the "tank" circuit because the r.f. energy is stored in it) has its ends connected to the grid and plate of the tube. The filament circuit of the tube is connected to the coil at a point between the grid end and the plate end. In this way the coil is really divided into two sections, one in the grid circuit and one in the plate circuit. Oscillations are maintained because of the inductive coupling between these two sections.

In the tuned-grid tuned-plate circuit there are two tank circuits, one connected between the grid and the filament of the tube and the other between the plate and filament. In the high-frequency oscillator these two circuits are not

TRANSMITTING TUBES TRIODES

Type	Nominal R.F. Output (watts) ¹	Fil. Volts (E _f)	Fil. Amps. (I _f)	Max. Plate Volts ² (E _b)	Max. Plate Ma. (I _p)	Neg. Grid Bias Volts ³ (E _c)	Max. Grid Ma. (I _c)	Grid Driving Power (watts)	Safe Plate Dissipation (watts)	Amp. Factor (μ)	Interelectrode Capacitances (μfd.)			Grid Leak (ohms)
											Grid to Fil.	Grid to Plate	Plate to Fil.	
45	10	2.5	1.50	400	50	180		2.0	10	3.5	5.0	8.0	3.0	50,000
46	10	2.5	1.75	400	50	180 ⁴ 22 ⁵		2.0	10	5.6 30.0				50,000 1,000
59	10	2.5†	2.0	400	50	135 ⁴ 22 ⁷		3.0 2.0	10	6.0 30.0				25,000 1,000
843	10	2.5‡	2.5	425	40	90	7.5		15	7.7	5.0	6.0	5.0	10,000
10	15	7.5	1.25	500	60	135	15	3.0	15	8.0	4.0	7.0	3.0	10,000
841	15	7.5	1.25	500	60	30	20	2.0	15	30.0	5.0	8.0	3.0	5,000
801*	25	7.5	1.25	600	65	150	15	4.5	20	8	4.5	6	1.5	10,000
800*	50	7.5	3.25	1000	75	135	25	5.0	35	15.0	2.8	2.5	1.0	10,000
825*	50	7.5	3.25	1000	75	180		5.0	40	10.0	2.0	3.0	1.0	10,000
830	50	10.0	2.15	750	110	180	18	5.0	40	8.0	4.9	9.9	2.2	10,000
RK-18*	50	7.5	2.5	1000	85	135	15	4.0	40	18.0	3.8	5.0	2.0	10,000
304-A*	85	7.5	3.25	1250	100	200	20	8	50	11	2	2.5	0.7	10,000
203-A	100	10.0	3.25	1250	175	100	60	14.0	100	25.0	6.5	14.5	5.5	10,000
211	100	10.0	3.25	1250	175	200	50	14.0	100	12.0	8.0	15.0	7.0	15,000
242-A	100	10.0	3.25	1250	150	150	50	14.0	100	12.5	6.5	13.0	4.0	15,000
852*	100	10.0	3.25	3000	100	350	40	20.0	100	12.0	2.0	3.0	1.0	10,000
354*	150	5	7.75	3000	175	275	40	15.0	150	11.0	9.0	3.7	0.4	10,000
150T*	200	5	10.0	3000	200	300	25	15.0	150	12.0				10,000
F-108-A*	200	10.0	11.0	3000	200	350	50	25.0	175	12.0	3.0	7.0	2.0	15,000
204-A	350	11.0	3.85	2500	275	250	80	60.0	250	25.0	18.0	17.0	3.0	10,000
849	450	11.0	5.0	2500	350	300	125	75.0	300	19.0	17.0	33.5	3.0	10,000
831*	500	71.0	10.0	3000	350	300	100	75.0	400	14.5	3.8	4.0	1.5	10,000
F-100*	500	11.0	25.0	2000	500	300		75.0	500	14.0	4.0	10.0	2.0	10,000

TETRODES AND PENTODES

Type	Nominal R.F. Output (watts) ¹	Fil. Volts (E _f)	Fil. Amps. (I _f)	Max. Plate Volts ² (E)	Max. Screen Volts (E)	Neg. Grid Bias Volts (E)	Max. Grid Ma. ² (I _p)	Max. Grid Ma. (I _c)	Grid Driving Power (watts)	Safe Screen Dissipation (watts)	Safe Plate Dissipation (watts)	Interelectrode Capacitances (μfd.)		
												Grid to Cathode	Grid to Plate	Plate to Cathode
41	5	6.3‡	0.4	300	100	22	40		1.0					
42	10	6.3	0.7	400	100	45	50		2.0					
47	10	2.5	1.75	400	100	45	50		2.0			8.6	1.2	13.0
2A5	10	2.5‡	1.75	400	100	45	50		2.0					
89	10	6.3‡	0.4	400	100	45	40		2.0					
59	10	2.5†	2.0	400	100	45	50		2.0					
844	5	2.5‡	2.5	500	150	10	30	5	1.0	3	15	10.0	0.07	8.5
865*	15	7.5	2.0	750	150	75	60	15	2.5	3	15	10.0	0.05	7.5
254-A*	20	5.0	3.25	750	175	90	60		3.0	5	20	4.6	0.1	9.4
254-B*	25	7.5	3.25	750	150	135	75		3.0	5	25	11.2	0.085	5.4
282-A*	50	10.0	3.0	1000	250	150	100		5.0	5	70	12.2	0.2	6.8
RK-20*	50	7.5	3.0	1000	300	75	85		3.0	10	40	11.0	0.01	9.5
850	100	10.0	3.25	1250	150	150	175	40	10.0	10	100	17.0	0.2	26.0
860*	100	10.0	3.25	3000	250	200	100	40	15.0	10	100	8.5	0.05	9.0
861*	540	11.0	10.0	3500	500	200	350	100	50.0	35	400	17.0	0.1	13.0

¹ Conservative rating based on normal plate input and operating conditions. The actual output will depend upon the efficiency and the power supplied to the tube plate.

² Maximum recommended values, unmodulated d.c. With modulation, d.c. plate voltage should be 25 to 30 per cent lower.

³ Recommended value for operation as oscillator or Class-C power amplifier.

⁴ With outer grid connected to plate.

⁵ With grids connected together.

⁶ Grids Nos. 2 and 3 connected to plate.

⁷ Grids Nos. 1 and 2 connected together; grid No. 3 connected to plate.

[†] Indirectly-heated cathode.

^{*} Especially designed for very high-frequency use.

coupled inductively and the grid-plate capacity of the tube itself is utilized to provide the coupling between the grid and plate circuits which is necessary to cause oscillation.

The Colpitts circuit is arranged so that the filament is connected to the junction of two condensers which are in series across the coil. In this way the grid and plate circuits share the voltage drop across the condensers, the phase relationship being correct for production of oscillations.

A fourth circuit is the ultraudion. It belongs to the Colpitts family of circuits, and is used by only a comparatively small number of amateurs.

The Hartley and tuned-plate tuned-grid circuits are most popular, probably because the adjustments which regulate feedback and frequency of oscillation are more independent in those two circuits, thus making them somewhat easier to handle.

Many modifications of the fundamental circuits are possible. One of the most popular is the so-called "TNT" circuit, in which the grid tank of the tuned-grid tuned-plate circuit is replaced by a coil which, with its own distributed capacity and the capacity of tube and wiring connected across it, is broadly resonant at the operating frequency. Its chief advantages are its economy and the fact that it is a very simple circuit to tune once the proper size for the grid coil has been determined.

Screen-grid tubes can be used in the electron-coupled circuit (described in Chapter Six) to give in one tube some of the beneficial effects of the oscillator-amplifier arrangement. With suitable care in design and operation, electron-coupled oscillators will provide a high order of frequency stability. The use of the electron-

coupled circuit in amateur transmitters has generally been limited to low-power sets using indirectly-heated type receiving tubes, however, because of the necessity for operating the cathode at a different r.f. potential than that of the ground and power-supply equipment. In the electron-

coupled circuit of Fig. 701, the screen grid, cathode and control grid are connected in a Hartley circuit to generate the oscillations, while the amplified r.f. energy is taken from a tank circuit connected in series with the plate. The plate or output circuit may be tuned to a harmonic of the oscillator circuit as well as to the same frequency. The output usually drops off rapidly on harmonics above the second, however.

Throughout this chapter reference frequently will be made to "ground" or the "grounded" part of the circuit. In many instances this does not mean that an actual ground connection is necessary, but simply refers to the part of the circuit which is at the same radio-frequency potential as the earth, and which therefore could be connected to earth without in any way disturbing the operation of the circuit. The "grounded" part of the circuit nearly always will be the part which is connected to the negative terminal of the high-voltage power supply. Parts of the circuit at ground

potential usually are connected together with direct wire connections or through bypass condensers, the latter being used when the two parts so connected are at the same r.f. potential but have different d.c. or a.c. voltages on them.

Frequency Stability of Oscillators

▲ An oscillator incapable of maintaining a high degree of frequency stability is characterized by a

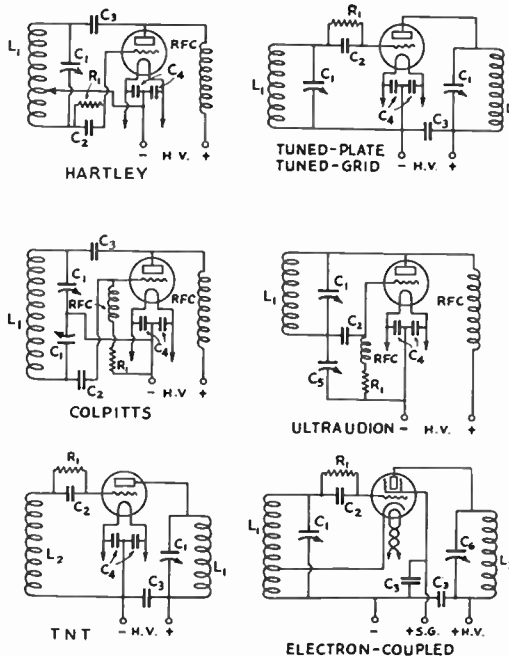


FIG. 701 — SELF-CONTROLLED OSCILLATOR CIRCUITS

All are capable of giving good frequency stability and efficiency with careful design and adjustment. For the benefit of the experimenter, the following suggestions are given for circuit constants: L_1 , C_1 , depending upon frequency band to be used; consult coil table for inductances, using a 500- μfd . condenser at C_1 . The grid condenser, C_2 , may be from 100 to 250 μfd . in all circuits; its value is not generally critical. The plate blocking condenser, C_3 , should be .002 μfd . or larger. Filament bypass condensers, C_4 , may be .002 μfd . or larger. For value of grid leak, R_1 , consult tube table. In the ultraudion circuit, C_5 , the excitation control condenser, should have a maximum capacity of 100 to 250 μfd . The output tank circuit, L_3 , C_6 , in the electron coupled circuit should be designed for low-C operation; use a 250- or 100- μfd . condenser for C_6 and corresponding inductance from the coil table for the frequency in use.

In the circuits using parallel feed, the r.f. choke coils shown should not be omitted.

broad, creeping signal and a mushy or rough note. Such a note causes needless interference and is likely to result in trouble for the amateur responsible for it, since the amateur regulations call for a steady unmodulated or "pure d.c." signal.

The causes of frequency instability can be roughly divided into two groups, those which are "mechanical" in nature and those which are "dynamic." Mechanical instability results from variations in the circuit constants due to mechanical vibration and thermal effects. Mechanical vibration will cause rapid fluctuations in frequency by varying the spacing between condenser plates, the separation between coil turns or the distance between the tube elements. These are avoided largely by rigid construction and by reducing the vibration. Frequency fluctuation ("creeping") due to thermal effects results from variation in spacing of the tube elements (variation in inter-element capacity) with changes in temperature. Creeping can be minimized by keeping the power dissipated in the tube at or below its normal rating, by choosing tubes having internal construction particularly intended to reduce frequency-creeping, and by using circuits which have large capacities in parallel with the tube's input and output capacities. Such circuits are popularly known as "High-C" circuits. The use of a large shunting capacity in the plate circuit is particularly effective.

"Dynamic" instability is caused by anything which affects the tube's characteristics, especially its plate impedance, during operation. A variation in plate impedance will cause a change in frequency. The principal cause of dynamic frequency instability — sometimes called "frequency flutter" — is the variation in plate voltage which results when a poorly-filtered plate supply is used. To prevent dynamic instability it is essential that the plate supply be the best "pure d.c." obtainable and that the grid bias — or grid leak — be sufficiently high in value. Moreover, too much care cannot be exercised in adjusting the grid excitation. Dynamic instability can be reduced by careful circuit design and here again the use of a High-C plate tank is very effective. Such a tank circuit is capable of reducing the amplitude of frequency fluctuations with variations in plate impedance.

Oscillator Efficiency

▲ The characteristics of the load circuit (which include the plate tank circuit and the antenna circuit or the input circuit of a succeeding tube amplifier) and the losses in the grid circuit affect the oscillator's plate efficiency. The plate efficiency is the ratio of radio-frequency power output to plate power input. The losses in the grid circuit are largely the power dissipated by the grid leak (because of the flow of rectified grid current through the leak during the positive half-cycle of

excitation voltage) and the losses due to radio-frequency displacement currents between the grid and filament. The latter may be considerable at high frequencies with tubes having large grid-filament capacity.

There is no simple method of determining the plate efficiency of a high-frequency oscillator, since it is difficult to measure power accurately at radio frequencies. Rough calculations can be made with the aid of incandescent lamps used as dummy antennas (see Chapter Twelve). In general, highest efficiency will be obtained by the use of relatively high plate voltage and low plate current for a given power input, by careful adjustment of excitation, and by the use of a grid leak of sufficiently high resistance to bias the tube to two or three times the plate current cut-off value. The leak resistance needed depends upon the characteristics of the tube; the tube table gives optimum values. The bias under operating conditions can be determined by measuring the current flowing through the leak; the bias voltage will be the product of the leak resistance times the d.c. grid current expressed in amperes.

A Practical Oscillator Transmitter

▲ Although experienced amateurs prefer the crystal-controlled oscillator-amplifier type of transmitter, the beginner often looks with favor on the simple self-controlled oscillator because it is quite easy to build, and will give a moderate power output with little expense. It is a fact, too, that excellent results can be obtained provided the oscillator is adjusted and operated with care. Since the oscillator can be adjusted to any frequency within the range of its tuning apparatus, particular care must be taken to be certain that it is tuned to a frequency within an amateur band. The frequency stability is also at the mercy of many external factors, so that careful attention must be paid to those adjustments which minimize frequency variations under operating conditions. Before attempting to put such a transmitter on the air the information on frequency measurement and monitoring in Chapter Six should be thoroughly digested. A monitor, in fact, is a prime necessity if the oscillator transmitter is to be operated properly.

There are many ways of mounting the parts of a transmitter to give good electrical performance. Many amateurs use vertical panels with apparatus mounted on frames or racks, as the illustrations in the chapter on station layouts will show. For the simple transmitter, however, the "breadboard" type of construction, in which all parts are mounted on a flat baseboard to give short leads and effective placement with respect to each other, is the simplest and most satisfactory. It is inexpensive and lends itself readily to experimenting with different circuits and parts. The low-power transmitter shown in Fig. 702 is an example of breadboard construction.

This transmitter is perhaps the simplest and most nearly fool-proof ever designed. It contains the very minimum of parts and is therefore extremely low in cost. The construction is in no

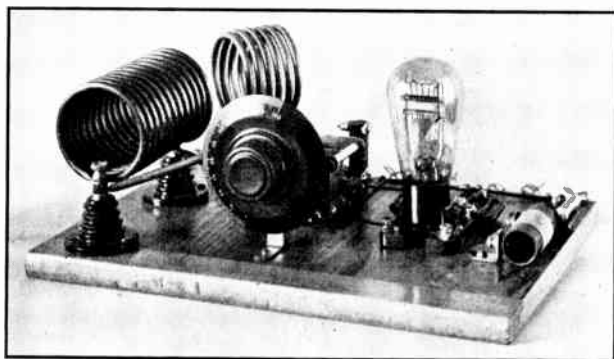


FIG. 702 — THE LOW-POWER SINGLE-TUBE TRANSMITTER

The plate tank circuit is at the left. The grid coil, leak and grid condenser are to the right of the Type 10 tube. The antenna coil is shown swung away from the plate coil to give loose antenna coupling.

way complex and the adjustment is easily accomplished by even the inexperienced operator if the detailed tuning instructions are carefully followed. The circuit is the TNT.

The frequency is determined by the tuning of the plate tank circuit and the excitation is dependent on the constants of the grid circuit. Since one excitation adjustment is satisfactory over a considerable range of plate-tank tuning, it is possible to use a fixed coil in the grid circuit for each amateur band. An antenna coupling coil is provided in the set but an external antenna tuning condenser (perhaps two of them) will usually be found necessary, depending upon the type of antenna used. The set is designed for a Type 10 tube with a 500-volt d.c. plate supply and a 7.5-volt a.c. filament supply, a Type 45 tube with a 350-volt d.c. plate supply and a 2.5-volt a.c. filament supply, or a Type 01-A tube with a 135-volt d.c. plate supply and a 6-volt d.c. filament supply.

Construction of the Set

▲ The schematic wiring diagram is given in Fig. 703, together with the constants, and the photographs show how the set looks when constructed. The layout chosen is one which allows short r.f. leads.

The baseboard is $12\frac{1}{2}$ inches long by 10 inches wide. Two porcelain stand-off insulators are mounted at one end, as shown in the photographs, to support the plate coil, L_1 . These insulators should be placed $4\frac{1}{2}$ inches apart between centers. This mounting is very solid mechanically, and allows easy changing of coils. The tuning condenser C_5 , in this case a 21-plate Cardwell, is mounted on small brass angles. Connections be-

tween the condenser and the coil are made by pieces of copper tubing, since the leads in the tank circuit must be as heavy as the inductance itself. The connection to the insulator at the rear of the baseboard should be from the rotary plates (the condenser frame); that to the front insulator goes to the stationary plates.

The plate by-pass condenser, C_2 , is mounted close to the tuning condenser on the baseboard. The radio-frequency choke, L_4 , is just behind it. The filament by-pass condensers, C_3 , are directly behind the tube socket. The purpose of these condensers is to provide an easy path for radio-frequency currents flowing to the filament of the tube, which would otherwise have to go through the resistor R_1 . When the filament of the tube is heated from alternating current the "center-tap" resistor is necessary to avoid having the alternating voltages on the filament reach the grid, for this would cause modulation or "ripple" on the transmitted signal. The voltage at the leads to the filament is constantly

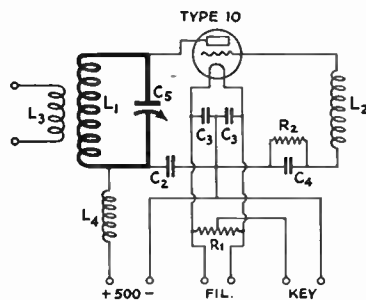


FIG. 703 — THE CIRCUIT OF THE TRANSMITTER
 L_1 , L_2 and L_3 — Plate, grid and antenna coils. The specifications are given under the illustration of the coils.

- L_4 — A commercial "short-wave" receiving-type radio-frequency choke will do or one can be made by winding a two-inch length of half-inch tubing or wooden dowel with No. 34 d.s.c. or d.c.c. wire.
- C_2 — 2000- μ fd. (.002 μ d.) mica fixed condenser, receiver type, if plate voltage does not exceed 500.
- C_3 — 5000- μ fd. (.005 μ d.) mica fixed condenser, receiver type.
- C_4 — 250- μ fd. (.00025 μ d.) mica fixed condenser, receiver type.
- C_5 — 500- μ fd. (.0005 μ d.) variable condenser. Any good receiving condenser will be satisfactory.
- R_1 — Center-tapped resistor, 75 to 100 ohms total resistance.
- R_2 — Grid-leak resistor, 10,000 ohms for Type 10. Consult tube table for value with other types of tubes.

Three General Radio or similar stand-off insulators will be necessary, as well as 8 Fahnestock clips, some miscellaneous small machine screws and nuts, and a few feet of bus wire.

changing at the 60-cycle supply frequency but the voltage at the center point of the resistor R_1 is constant. Another method of accomplishing the same result is to use a center tap in the filament-supply winding of the transformer. The center-tap resistor arrangement is sometimes preferable, however, since it permits the use of a filament rheostat in the secondary of the filament transformer instead of the primary. Rheostats for the secondary winding are more readily available than the other type.

The grid condenser, C_4 , and leak, R_2 , are to the right of the filament by-pass condensers. The condensers in this set are mounted flat by means of machine screws running up through the base-board. The filament center-tap resistor, R_1 , is mounted directly on top of the filament by-pass condensers.

All connections are run to the rear of the board where they terminate in Fahnestock clips. From left to right in the photograph, the first pair of clips is for antenna or feeder connections, the second for "plus" and "minus" high voltage, the third for filament supply and the fourth pair for the key. The wiring of the whole set is quite simple, and in case it is to be duplicated no difficulty should be experienced in following the diagram and photographs.

The plate coils, L_1 , are $\frac{1}{4}$ -inch soft copper tubing, wound around a pipe $2\frac{3}{8}$ inches outside diameter. The ends of the coils are flattened in a vise and drilled to fit over the machine screws in the mounting insulators. The 3500-ke. coil should have the turns so spaced that when finished it will just fit on the insulators without having the ends bent out, as is done on the coils for the higher-frequency bands. The spacing between turns on the 7000-ke. coil is about $\frac{3}{16}$ -inch, and on the 14,000-ke. coil about $\frac{1}{8}$ -inch.

The grid coils, L_2 , are wound with No. 30 d.c.e. wire on $2\frac{1}{2}$ -inch lengths of 1-inch tubing, which may be of Bakelite, paper, wood or any other of the common insulating materials. The coils should be given a coat of collodion or clear Duco varnish to maintain their characteristics. Two small brass angles serve both as connections and supports for these coils, the ends of the winding being brought out to small machine screws inserted at the ends of the coil forms.

The antenna coil, made in similar fashion to the tank coils, is mounted on an insulator immediately behind the tank condenser. Connection to the far end of this coil is made by means of a clip and a small piece of flexible wire. The coil may thus be swung away from the plate tank coil in order to vary the antenna coupling.

Tuning the Transmitter

▲ The tuning of any transmitter is a matter of the greatest possible importance. The performance of even the best transmitter can be spoiled by the slightest misadjustment, and on the other hand almost any transmitter can be made to perform well by an amateur experienced in the work. Even the most experienced amateur, however, cannot tune the transmitter effectively unless he is able to listen to it as he adjusts the controls. The use of some sort of monitor to listen to the signal as the transmitter is tuned is essential. A detailed description of a simple monitor will be found in Chapter Six. It should be studied and a monitor built before any attempt is made to tune the transmitter.

In addition to the monitor, an extremely desirable aid to tuning is a "tuning lamp." This is nothing more than a flash-lamp bulb connected in series with a single turn of wire about two or three inches in diameter. In use, the turn of wire is coupled to the tank coil of the oscillator or amplifier and induced currents cause the lamp to glow. With practice, it soon becomes possible not only to detect the presence of r.f. current in the tank coil with such a lamp but also to gain a very useful idea of the amount of r.f. energy in the tank.

Before the transmitter can be tuned, it is obviously necessary to have available a suitable power supply, antenna and keying circuit. The 350-volt power supply described in Chapter Ten is an excellent one to use with this transmitter when the tube is a Type 45. This power supply

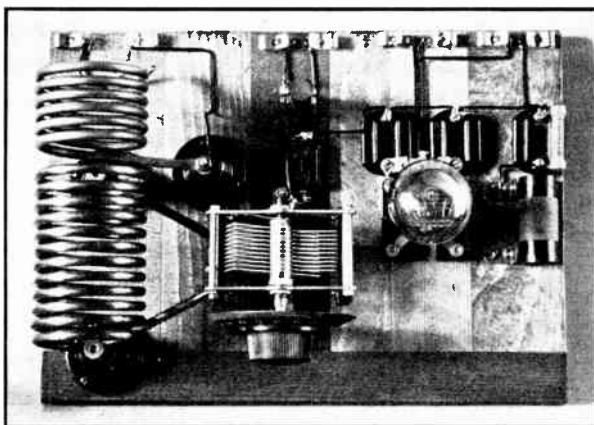


FIG. 704— PLAN VIEW OF THE TRANSMITTER

The antenna coil, L_3 , is to the rear of the plate inductance. The fixed condenser, C_2 , and the radio-frequency choke are behind the tuning condenser, C_3 . The two fixed condensers behind the socket are the filament by-pass condensers C_3 . The filament center-tap resistor, R_1 , is mounted on top of these condensers. The grid condenser, C_4 , and grid-leak resistor, R_2 , are to the right of the socket. The grid inductance, L_2 , is in front of the grid condenser and leak. The connections to the Fahnestock terminals are explained in the text.

may also be used to supply plate voltage for a Type 10 oscillator, in which case a separate 7.5-volt filament transformer for the 10 will be required. Alternatively, a 550-volt supply for a Type 10 tube may be built up from the information given in Chapter Ten. Most 550-volt power

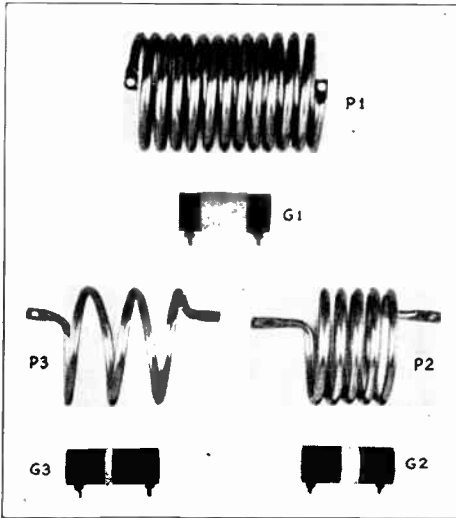


FIG. 705 — THE PLATE AND GRID COILS

A description of these coils is contained in the text, while the number of turns on each is given below.

Coil	Band	Turns
P-1	3500	12
P-2	7000	5
P-3	14,000	3
G-1	3500	60
G-2	7000	25
G-3	14,000	9

For the 1750-kc. band, a plate coil of 25 turns of No. 14 d.c.c. on a 3" diameter form with spacing between turns equal to the diameter of the wire; a grid coil of 150 turns on the same size form as the other grid coils. The number of turns on the grid coils may require some modification. Turns should be added or removed until the set operates stably and efficiently over the required frequency band.

The antenna coil is of 6 turns exactly similar to those used in coil P-1. A clip on this coil enables the best number of turns to be selected.

transformers intended for radio use have 7.5 volt filament-heating windings for the oscillator or amplifier and rectifier tubes, in addition to the plate windings. If a Type 01-A receiving tube is used, the plate supply can be a 135-volt "B" substitute or 135 volts of "B" batteries. Filament supply can be from a 6-volt battery, through a 6-ohm rheostat.

It will be assumed that the oscillator coils and leads have been made rigid; that the transmitter itself has been mounted in such a way as to escape vibration from keying and that the antenna and feeder wires have been made tight enough to avoid any swinging in the wind. We are ready to

start tuning only after all these matters have been given attention. Even then, we cannot expect to do a good job of tuning the set unless we have one or more meters. Of greatest importance is a plate current meter in the positive high voltage lead to the transmitter. Without such a meter, we have no idea of the power input and so are in danger of wrecking the tube and possibly other equipment right at the start. For a single tube transmitter like this one, the plate meter might well be a d.c. milliammeter reading to 100 ma. The other very desirable meter is a thermo-couple ammeter; its reading will give a good indication of changes of power in the antenna with changes in the transmitter adjustment. It is possible to dispense with the antenna meter and still tune the transmitter effectively if the operator is prepared to pay very careful attention to the plate meter and to make use of the tuning lamp.

Assuming that at least a plate meter is in the circuit, the first move is to switch on the filament supply, make certain that the tube lights, and then check the voltage at the filament terminals. Excessive filament voltage will soon ruin any tube. Then the antenna leads should be disconnected, the key opened and the plate tank tuning condenser set to approximately the correct position. If the constructional specifications have been followed closely, this setting will be with the rotor plates about four-fifths meshed for the 3500-kc. band; about three-quarters meshed for the 7000-kc. band; and about half meshed for the 14,000-kc. band. The antenna system should have been constructed to specifications for a frequency in one of the bands, preferably for about 3575 kc. in the 3500-kc. band.

Tuning for operation on the 3500-kc. band (with the 12-turn plate coil), set the condenser with the rotor plates four-fifths in, turn on the power supply and close the key. If the tuning lamp is now held near the front end of the plate coil the bulb should glow, indicating that the set is oscillating. The loop should not be held too close to the coil, however, because the bulb is likely to burn out. The frequency should now be checked with the frequency meter following the method described in the preceding chapter. If the frequency is outside the band, the transmitter should be retuned to a frequency inside the band.

During this process the plate current milliammeter should be watched to make certain that the plate current falls to a minimum as the plate tank is tuned to the desired setting. Should this minimum point occur at a frequency much lower than that desired, it is an indication that the grid coil has too many turns. If the minimum point occurs at too high a frequency, it shows that the grid turns should be increased. This trouble is not likely to happen, however, if the constructional specifications are followed carefully.

Coupling the Antenna

▲ With the oscillator operating on the desired frequency, the feeder or antenna may be connected and the antenna coil swung at an angle of about 45 degrees to the plate coil. As the antenna or feeder condensers are tuned it will now be found that the plate current rises as the antenna comes into tune with the oscillator. Also it will be seen that while the tuning lamp bulb may glow brightly (when the loop is placed near the tank coil) with the antenna detuned, it will become dim as the antenna comes into tune and takes power from the tank. These effects of the rising plate current and the dimming tuning lamp are of the greatest assistance in tuning the antenna circuit when no antenna meter is available. With an antenna ammeter, of course, it is merely necessary to tune the antenna or feeder circuit for maximum meter reading in order to locate the point of resonance.

The next adjustment to be made is that of antenna coupling. It must be kept closely in mind that there is an optimum value of coupling which allows the greatest transfer of power from the tank circuit to the antenna. Closer coupling than this results in lowered efficiency and, in the case of the self-controlled self-excited transmitter, invariably destroys the quality of the transmitted signal. Excessive coupling usually can be detected by the existence of two settings of the feeder or antenna condensers at which the feeder or antenna current rises to a peak. In a transmitter of this type, the antenna coupling must always be less than the optimum value just mentioned. Experience has shown that it is a good plan first to get the optimum coupling for greatest output and then to reduce the coupling until the feeder or antenna current reads about 85 per cent of the first value. Then, the antenna or feeder circuit should be detuned until the current drops a further 10 or 15 per cent. These adjustments should only be made while listening to the signal on the monitor since the most unexpected things may happen to the quality of the signal and its frequency. The signal quality is usually better with the antenna circuit detuned on one side of resonance than on the other.

It is difficult to give definite instructions with respect to the proper plate current since this depends so much on the plate voltage and on the manner in which the transmitter is adjusted. When the oscillator is operated at high efficiency, the input can be carried above the 500 volts and 60 ma. at which the Type 10 tube is rated. About the only practical procedure is to keep a careful watch for heating of the tube plate. Even a dull red plate is indication of excessive plate dissipation. The remedy is either decreased plate current or improved efficiency.

Finally, bear in mind always that the foremost aim of transmitter adjustment is that of obtain-

ing a clean, steady signal. "Forcing" the transmitter to get the maximum possible output definitely does not pay. Reducing the antenna current by as much as fifty per cent means only a barely perceptible decrease in signal strength — none at all, many times — but it may mean the difference between a good signal and a poor one. A steady, pure signal will be much more easily copied by receiving stations than a chirpy, wobbly one, to say nothing of lessened interference to other stations. Continuous and vigilant monitoring, combined with intelligent and careful adjustment, is the price of a good signal from the self-controlled oscillator transmitter.

Curing Unsteady Signals

▲ The oscillation frequency of a self-controlled oscillator is very sensitive to slight changes in circuit constants. Several causes of frequency instability have already been mentioned in the discussion on oscillators, but it is well to review them at this point.

First there is the frequency creep due to heating of the tube or other apparatus in the set. This can be reduced to a minimum by tuning the set for greatest efficiency. The greater the antenna power for a given input the less will be the heating of the tube. The aim is, therefore, to keep the input at or below the rated value and to tune the set until the tube operates with the least heating.

The detuning of the antenna circuit mentioned in the paragraphs on tuning does not result in appreciably lowered efficiency in the tube. When it is said that the greatest antenna current should be obtained for a given input to keep the tube coolest it is meant that the greatest antenna current *with the antenna detuned in the manner described* should be obtained. When the antenna is detuned the plate current drops; there may be an actual increase in the tube efficiency under these conditions despite the fact that the output is lowered.

Another common cause of frequency instability is vibration or swinging of the antenna or feeders. The effect of such vibration or swinging is reduced considerably by the detuning of the antenna circuit but it is essential that the antenna be supported in such a way that it is steady even in a high wind. This point will be given consideration in the chapter on antennas.

Leaky insulation also is often a serious offender. Not only can a leak destroy the character of the note but it can be responsible for a wobbly frequency. Trouble of this type often can be detected by removing the antenna circuit and listening to the transmitter in the monitor. Sometimes the leak is visible in the form of a thin arc. If the leak is through Bakelite a swelling on the surface of the insulation often will be noticed.

Perhaps the most common cause of all is vibration of the coils or wiring. A vibration which results in serious frequency instability often is too

slight to be noticeable. The coils and wiring should be watched very carefully during operation to make sure that the movements of a transformer or the vibration of a generator are not transmitted to the set. Mounting the set on rubber sponges often will aid in the elimination of the trouble. Power supply apparatus had best be built separately from the transmitter itself and located on a separate table or on the floor.

It is only by careful and prolonged attention to such details that the performance of the transmitter can be maintained at a high standard.

Using Two Tubes

▲ If one wants more power output from the transmitter than one tube can give and yet does not wish to go to the expense of installing the next larger size of power tube, it is possible to use two tubes in parallel or push-pull to double the power output. Tubes connected in parallel have their plates, grids and filaments respectively connected together; the oscillatory circuits used with them are otherwise exactly the same as for one tube. The push-pull oscillator circuits correspond to the push-pull amplifier circuits so common in present-day broadcast receivers; that is, the tubes are in effect connected in series in both input and output circuits. Although the total power output is the same with either method of connection, in actual practice the push-pull arrangement is preferable for oscillator circuits at the high frequencies used by amateurs.

Several push-pull circuits are given in Fig. 706. Their similarity to the fundamental circuits from which they are derived will be

recognized after inspection. The push-pull tuned-plate tuned-grid and TNT are perhaps most widely used by amateurs because of the simplicity of construction and adjustment. The push-pull Colpitts requires two tuning condensers (or a split-stator condenser) and provides no means of excitation control except through variable grid condensers. The push-pull Hartley is seldom used because the large number of taps on the coil makes a cumbersome mechanical job with the small coils used in High-C circuits.

The unity-coupled circuit resembles the Hartley except that separate coils, very closely coupled, are provided for the grid and plate circuits. In actual practice the grid coils are similar to the copper-tuning coils shown in Fig. 705, while the plate coil is made of small, well-insulated wire run through the center of the tubing. A hole is drilled in the center turn of the copper-tubing coil to allow a connection to be made to the center of the plate coil inside. Where a large number of turns is required, as for a 1750-ke. coil, the two coils may be wound of No. 14 wire on an insulating form, one coil being wound between the turns of the other.

Adjustment of the push-pull oscillator is carried out in exactly the same way as the single-tube oscillator, the antenna tuning being particularly important. The same precautions must be taken against vibration and excessive tube heating. Plate tank circuits must also have a suitably high ratio of capacity to inductance.

The Crystal-Controlled Oscillator

▲ In the discussion on tuning the self-controlled oscillator we

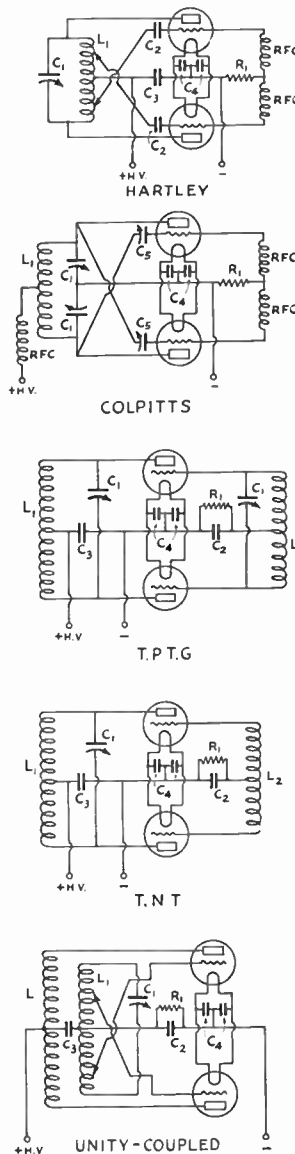


FIG. 706 — PUSH-PULL SELF-CONTROLLED OSCILLATOR CIRCUITS

Circuit constants are much the same as those for the single-tube circuits given in Fig. 701. Tank tuning condensers, C_1 , should have a maximum capacity of 500 μfd . Specifications for L_1 may be taken from the coil table, or coils similar to the copper-tubing coils shown in Fig. 705 may be used. Since the two tubes are in series in a push-pull circuit, the tank circuits can use a somewhat higher LC ratio than is generally recommended for single-tube circuits without detriment to the dynamic stability. The actual condenser capacity in use should be approximately 250 μfd . at

the operating frequency, and coils may be proportioned accordingly. Grid condensers, C_2 , may be 100 to 250 μfd ., except in the Colpitts circuit, where variable condensers (C_5) having a maximum capacity of 50 μfd . should be used, the correct operating value being determined by experiment. Plate blocking and filament bypass condensers, C_3 and C_4 , should be .002 μfd . or larger, although the values are not critical.

The resistance of the grid leak, R_1 , will in general be half that recommended in the tube table for a single tube. Slightly higher values may be found to give better efficiency and a better note.

have seen that the utmost care must be used to safeguard such an oscillator against frequency instability with its resultant bad effects on the character of the emitted signal. Most of these precautions are obviated by the use of the crystal-controlled oscillator. In the crystal oscillator variations in inductance, capacity or resistance have almost negligible effect on the frequency of oscillation.

The reason for this is that the frequency-controlling element is a small slab of piezo-electric crystal (usually quartz) which, because of its electro-mechanical properties, will oscillate at a frequency determined almost entirely by its dimensions. When it is properly connected in the controlling oscillator circuit, the line voltage can vary, the antenna can swing, and the tubes may heat without seriously affecting the output frequency of the transmitter. A ripple in the plate-supply voltage will cause amplitude modulation of the output of such an oscillator but can cause practically no frequency flutter. For this reason, the note produced by a transmitter driven from a properly adjusted crystal-controlled oscillator is always of a piercing musical character. Such a note is unmistakable evidence of a good amateur station.

Before considering the circuits of crystal-controlled oscillators let us examine the crystals themselves.

Crystal Cuts and Grinding

▲ A quartz crystal has three major axes, designated *X*, *Y* and *Z*. The *Z* axis is the optic axis. The *Y* axis is the mechanical axis. The *X* axis is the electric axis and is the one used as a reference in designating the cut of the plates used in oscillators. A plate cut with its major surfaces perpendicular to an *X* axis is known as an *X*-cut plate. This cut is also referred to as the "perpendicular" and "Curie" cut. Plates cut with their major surfaces parallel to an *X* axis are known as "*Y*," "parallel," and "30-degree" cuts. The most accepted terms for these two cuts are *X*-cut and *Y*-cut.

Each of these cuts has characteristics of its own and these characteristics determine its suitability for different services. For a given frequency, an *X*-cut plate is thicker than a *Y*-cut plate. The *X*-cut plate has but one major frequency of oscillation which is a function of its thickness but a *Y*-cut plate sometimes has two, generally a kilocycle or so apart. The *Y*-cut plate is usually the more ready oscillator, although properly ground and mounted plates of either cut oscillate quite persistently in well-designed power circuits. The *X*-cut plate is more generally used in power oscillators, although many amateurs have a preference for the *Y*-cut.

When a finished crystal or unground blank is purchased, a statement of the cut should be obtained from the seller. This is particularly important when a blank is purchased because the

grinding cannot be done so easily if the ratio of thickness to frequency is not known. For *X*-cut plates $f \times t = 112.6$ and for *Y*-cut plates $f \times t = 77.0$, where f is the frequency in kilocycles and t is the thickness in inches. From these relations the thickness for a desired frequency of a crystal of known cut can be determined quite accurately by measurement with a good micrometer such as the Starrett No. 218-C, $\frac{1}{2}$ inch. This tool also can be used to make sure that the crystal is the same thickness at all points and that bumps or hollows are not being ground in. The best crystals are about 1" square, perfectly flat, and the two major surfaces are parallel.

Since the thickness of an oscillating crystal is inversely proportional to its frequency, the plates become very thin and fragile at frequencies above those in the amateur 3500-ke. band. For this reason the most satisfactory amateur crystals are those ground for the 1750-ke. and 3500-ke. bands. If the transmitter is to be operated on the 3500-ke. and higher frequency bands only, a crystal having a suitable frequency in the 3500-ke. band will be best. The higher frequencies are obtained from such a crystal by means of the harmonic generators or frequency doublers to be described further on. Crystals for the 7000-ke. band are used by many amateurs, although they must be handled more carefully than the lower-frequency plates. With suitable oscillator circuits, however, they are quite reliable and the elimination of an extra transmitter stage may be worth while at the higher frequencies. Even 14-mc. crystals are obtainable, although their fragility has prevented them from coming into general use.

Grinding is usually done by rotating the crystal in irregular spirals on a piece of plate glass smeared with a mixture of No. 102 carborundum and water or kerosene. It is better to have the crystal stuck to a perfectly flat piece of thin brass or a glass microscope slide than to bear down on the surface of the crystal with the fingers. Even pressure over the whole area of the crystal is essential for flat grinding. The crystal will stick to the flat brass plate or slide if the top of the crystal is moistened with kerosene. The crystal should be frequently tested for oscillation in a test circuit such as one of those shown in Fig. 707. If the crystal should stop oscillating during the grinding process the edges should be ground as indicated in the illustration of an *X*-cut plate. The frequency also can be checked by listening to the signal in a receiver and measuring the frequency as described in Chapter Six. When the frequency is within a few kilocycles of the desired value it is well to use a finer grade of carborundum powder for finishing. The FF and FFF grades are suitable for the final grinding.

Crystal Mountings

▲ To make use of the piezo-electric oscillation of a quartz crystal, it must be mounted between two

metal electrodes. There are two types of mountings, one in which there is an air-gap of about one-thousandth inch between the top plate and the crystal and the other in which both plates are in contact with the crystal. The latter type is simpler to construct and is generally used by amateurs. It is essential that the surfaces of the metal plates in contact with the crystal be perfectly flat. Satisfactory mountings can be purchased from most dealers in crystals or can be made up by the amateur.

The simplest way for the amateur to rig his own mounting is to make up two flat brass plates, the crystal being placed on one of them and the other being arranged to rest on the crystal with no more pressure than that provided by the weight of the brass. A crystal mounting of this type is

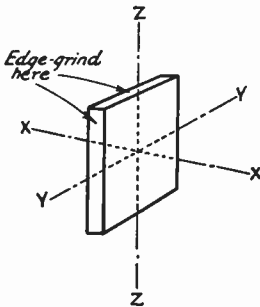


FIG. 707 — RELATION OF THE AXES OF AN X-CUT QUARTZ PLATE

illustrated. The plates preferably should be turned flat in a lathe and then ground to a fine finish. Successful plates can be made, however, by cutting them with a hack-saw from $\frac{1}{8}$ "-thick brass plate, then grinding them in much the same way as the crystal would be ground. A suitable size for the top plate for a 1750- or 3500-kc. crystal is about 1" square. The bottom plate may be made large enough to accommodate the whole mounting, as shown. Crystals for the 7000- and 14,000-kc. bands generally require special top

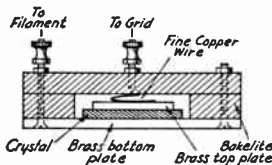


FIG. 708 — SIMPLE FORM OF CRYSTAL HOLDER

The flat brass bottom plate may be round or square, whichever is more convenient. The center part of the inner piece of bakelite is cut out to allow the crystal to rest upon the bottom plate. The top piece is solid and completely encloses the crystal and top plate. Three-sixteenths or quarter-inch bakelite should be used for the inner piece. The brass plates should be $\frac{1}{16}$ - or $\frac{1}{8}$ -inch stock.

plates, usually circular and smaller in diameter than the crystal itself, for best operation.

Though it is possible to operate the crystal merely by arranging the plates and the crystal in the form of a sandwich on a piece of insulating material or on the table top, it is a very much better plan to make up some form of holder out of which the crystal or plates cannot be jarred. The arrangement illustrated in Fig. 708 is one suitable type. Connection to the upper plate can be made by means of a very light leaf of spring brass but a small spiral of very fine copper wire usually is more satisfactory. This wire can be soldered to the plate if care is taken to use an absolute minimum of heat in the soldering process to avoid warping the plate.

Grit or an oily film on the surface of a crystal will affect its operation and will sometimes prevent oscillation. The crystal should be cleaned whenever erratic behavior or stoppage of oscillation gives evidence of a dirty condition. Carbon tetrachloride (Carbena) or grain alcohol are the best cleaning fluids. Plain soap and water will do quite well, however. Handling of the crystal is especially likely to give it an oily surface, and the crystal should always be cleaned after it has been touched by the hands.

Crystal Oscillator Circuits

▲ Power crystal oscillators operate as tuned-grid tuned-plate circuits, with the crystal replacing the grid tank circuit. Other fundamental circuit arrangements are possible, but have not met with much favor for power work. The simplest crystal oscillator circuit is the triode circuit shown in Fig. 709. When the plate tank circuit is tuned to a frequency slightly higher than the natural frequency of the crystal, the feed-back through the grid-plate capacity of the tube excites the grid circuit, and the crystal oscillates at approximately its natural frequency.

The power obtainable from the crystal oscillator will depend upon the type of tube used, the plate voltage, and the amplitude of vibration of the crystal, or more precisely, the amplitude of the r.f. voltage developed as a result of the mechanical vibration. If the feedback voltage is too great, the mechanical strain in the crystal as a result of vibration will cause the crystal to heat considerably and may eventually cause cracking, ruining the crystal. In the simple oscillator triode circuit of Fig. 709, the limit of plate voltage that can be used without endangering the crystal is about 250 volts, although this figure will vary with the crystal itself, its mounting, and the type of tube used. Tubes with low amplification factors — the 45, for instance — should be operated at lower plate voltage than tubes with medium or high μ 's, because low- μ tubes require a relatively large exciting grid voltage for a given output.

The power output that can safely be taken from the crystal oscillator can be increased by

the use of special circuits or tubes having more suitable characteristics than the simple triodes. A pentode is especially desirable because of its low grid-plate capacity (which reduces the feedback) and the fact that it is capable of delivering fairly large power output with a small exciting grid voltage. The pentode tubes designed for audio power work, such as the 47, 2A5, 41, 42, and 59 (with proper element connections), are excellent crystal oscillator tubes. For a given plate voltage the crystal heating will be less with a pentode than a triode as the oscillator tube; alternatively, for the same amplitude of crystal vibration, higher plate voltages can be used with the pentodes, resulting in greater power output. A typical pentode oscillator circuit is shown in Fig. 709. It has been found best to operate the screen grid of the tube at approximately 100 volts; plate voltages up to 500 may be used without danger to the crystal.

Crystal heating is not only undesirable from the standpoint of safe operation; the frequency of oscillation is dependent upon the temperature of the crystal, and when the crystal heats up the frequency will creep. The temperature coefficient of X-cut plates is negative, that is, the frequency goes down with rising temperature. The temperature coefficient for 30-degree cut plates is positive, the frequency increasing with rising temperature.

Since the crystal is a single-frequency device, many circuits have been devised to obtain harmonic output from the oscillator tube. One of the most successful is the "tri-tet" oscillator, which utilizes a multielement tube to act both as oscillator and frequency multiplier. The circuit is shown in Fig. 709, arranged for use with a screen-grid tube having an indirectly-heated cathode, such as the 24-A. In the tri-tet oscillator circuit the screen grid is operated at ground potential while the cathode assumes an r.f. potential above ground, hence the desirability of a cathode which can be isolated from the filament supply. The screen-grid acts as the anode of a triode crystal oscillator, while the plate or output circuit is simply tuned to the oscillator frequency or a multiple of it. If the output circuit is to be tuned to the same frequency as the oscillator, a well-screened tube such as the 24-A must be used otherwise the tube will oscillate as a t.p.t.g. oscillator. For harmonic generation only the 59 or 2A5 tubes will deliver good output, but are not sufficiently well screened for fundamental operation. Because of the way in which the cir-

cuit operates, a relatively large r.f. voltage appears across the crystal under some conditions. This will cause heating of the crystal if certain operating precautions are not observed. The cathode tank circuit, L_2C_3 , should not be tuned to the frequency of the crystal, as might be expected, but to a considerably higher frequency. For example, L_2C_3 will be tuned to approximately 5000 kc. when working with a 3500-kc. crystal, and the circuit constants should be proportioned accordingly. Tuning off in this manner not only reduces crystal strain but usually also increases the output on harmonics. The second factor affecting crystal heating is the voltage on the screen grid, which must be kept at the correct operating value for the type of tube in use. This will be discussed in detail in the practical examples of tri-tet oscillators to follow.

Triode or pentode crystal oscillators are quite simple to adjust. The plate tank circuit should, of course, be designed to tune to the frequency of the crystal. With plate voltage applied, the tank condenser should be rotated until the plate current drops suddenly, indicating the start of oscillation. A setting will be found which gives a minimum value of plate current; the tank capacity should be set to a slightly higher frequency than this, however, since at the minimum plate current setting a slight change in circuit constants may cause the crystal to stop oscillating. With the load

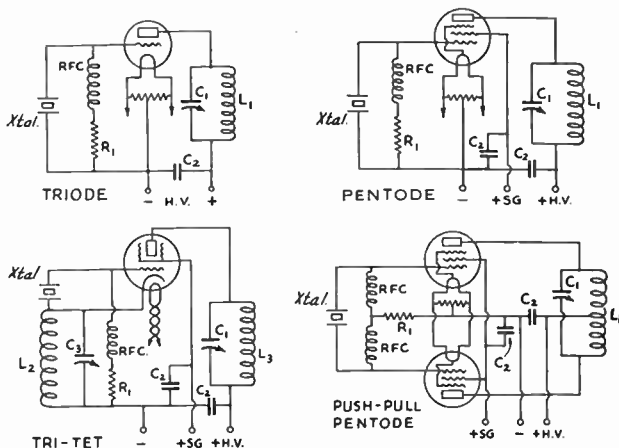


FIG. 709 — CRYSTAL OSCILLATOR CIRCUITS

In crystal oscillator output tank circuits it is generally advisable to use a fairly high LC ratio for best output and efficiency. The plate tuning condensers, C_1 , may have a maximum capacity of 100 to 150 $\mu\text{fd.}$, with tank coils, L_1 , having suitable inductance to make the circuit resonant at the crystal frequency. Coil specifications can be taken from the coil table. The cathode tank circuit, C_3L_2 , in the Tri-tet oscillator is adjusted as described in the text; the output circuit, C_1L_3 , will be similar to the output circuits used in the other crystal oscillators. Plate and screen bypass condensers, C_2 , may be .002 $\mu\text{fd.}$ or larger. The resistance of the grid leak, R_1 , may be taken from the tube table for the type of tube in use except in the Tri-tet circuit, where a leak of 25,000 to 50,000 ohms will be found advisable, especially if the output circuit is tuned to a harmonic.

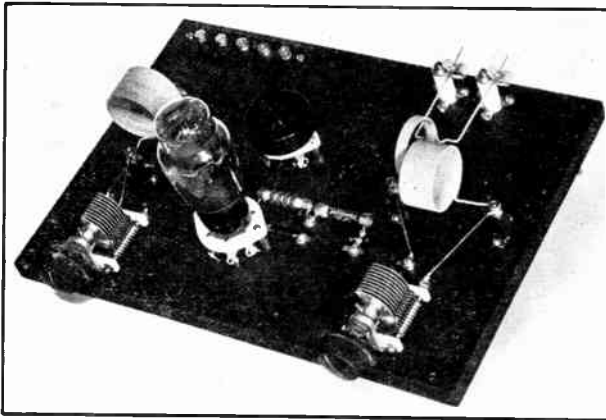


FIG. 710 — A SIMPLE CRYSTAL OSCILLATOR SUITABLE FOR LOW-POWER WORK
It will operate on two bands with a single crystal.

coupled to the oscillator the plate current will rise; the coupling may be increased until the tube is drawing normal plate current or until the oscillator is delivering maximum power output. Too great a load will cause the crystal to stop oscillating or will make it refuse to start again, once oscillations have stopped, without reducing the load and going through the adjustments again. The load always should be adjusted so that the oscillator will start quickly every time plate power is applied.

Crystal oscillators also may be arranged to use two tubes in push-pull, a pentode circuit being given in Fig. 709. A circuit of this type is useful for exciting a following push-pull amplifier on the same frequency. Push-pull crystal oscillators are not used to any great extent, however, because the push-pull connection balances out even harmonics, which are the ones wanted in multiplying frequency for operation on several bands with one crystal.

A Practical Low-Power Crystal Transmitter

▲ It is not difficult to obtain an output of five or more watts from a crystal oscillator, which makes its use without auxiliary amplifiers perfectly practical for low-power work. Using the tri-tet oscillator circuit for harmonic operation and the regular pentode circuit for the fundamental, a single tube and crystal can be made to work equally well on two bands so that a fair degree of flexibility is obtained. A circuit diagram of such an oscillator using a Type 59 tube is given in Fig. 711. Photographs of the set appear in Figs. 710 and 712. Since interchangeable coils are used, the transmitter can be used on any frequency for which a crystal is available. The change from tri-tet to pentode circuit is made simply by short-circuiting the cathode tuning condenser, C_1 , which is done by bending the tip of one rotary plate so that it touches the stator

when the condenser is turned with the plates fully interleaved. The screen grid and suppressor grid of the 59 are connected together at the tube socket to act as a single element.

The apparatus is mounted on a baseboard measuring 10 by 14 inches. The two tuning condensers, C_1 and C_2 , are mounted along the front edge, each $2\frac{1}{2}$ inches in from the edge, with C_1 at the left. The grid and plate coils, L_1 and L_2 , are mounted on small porcelain standoff insulators located behind their respective condensers.

The screen and plate by-pass condensers, C_3 and C_4 respectively, are mounted end to end just to the rear of and between C_2 and the socket for the 59 tube, by machine screws which pass through the condenser lugs to the under side of the baseboard. The tube socket is mounted

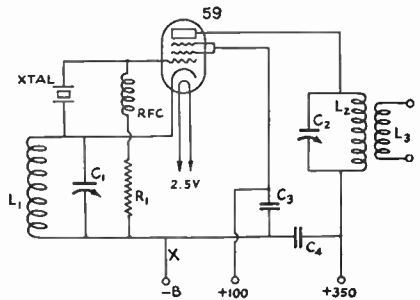


FIG. 711 — CIRCUIT OF THE SINGLE-TUBE CRYSTAL TRANSMITTER

C_1, C_2 — 100- μ fd. variable tank tuning condensers (National Type ST-100).

C_3, C_4 — 0.005- μ fd. fixed mica screen and plate bypass condensers (Dubilier Type 3).

L_1, L_2 — Cathode and plate coils. See coil table.

L_3 — Antenna coil; see text.

R_1 — Grid leak, 50,000 ohms, 2-watt (I. R. C.).

RFC — High-frequency choke (National Type 100).

The key is connected in the negative lead at the point marked with an "x."

No.	COIL DATA		
	Wire Size	Turns	Diameter
1	22 d.c.c.	75	1 5/8 inches
2	" "	45	" "
3	16 d.c.c.	40	" "
4	" "	18	" "
5	" "	16	" "
6	" "	7	" "
7	" "	8	" "

All coils close-wound.

Crystal Frequency	Coil at L_1	Coil at L_2	Output Frequency
1750-2000 kc.	s	No. 1	1750-2000 kc.
" "	No. 2	No. 3	3500-4000 kc.
3500-3650 kc.	s	No. 3	3500-3650 kc.
" "	No. 4	No. 5	7000-7300 kc.
7000-7200 kc.	s	No. 5	7000-7200 kc.
" "	No. 6	No. 7	14,000-14,400 kc.

"s" indicates short circuit across C_1 .

slightly to the left of the center of the board to accommodate the length of the by-pass condensers so mounted. The junction between C_3 and C_4 is used as a common "ground" point for the circuit. Just behind and parallel to C_3 is the grid leak, R_1 , and next to it the radio-frequency choke, RFC , which is connected between R_1 and the grid of the tube. The tube socket is mounted with the filament terminals (the two large holes) facing the front edge of the board.

The socket for the crystal holder is mounted behind the tube socket. Whether or not this type of socket will be needed will depend upon the type of crystal mounting used, of course. Whatever the mounting, the same position is a good location for the crystal.

Power supply connections are brought out to a bakelite strip mounted flat on the baseboard at the rear left-hand corner. Ordinary 6-32 machine screws are used as terminals. Five half-inch holes in the baseboard underneath the screw terminals give plenty of room for the screw heads and for running in the connecting wires. The two terminals at the left are for the filament supply; leads from the tube socket drop down through the baseboard and run underneath to the terminals. Next in line is the negative plate supply terminal, which connects to the common "ground" between C_3 and C_4 mentioned previously. The second terminal from the right is for the positive screen voltage; a wire from this terminal under the baseboard connects to the screen grid through the machine screw which fastens the left-hand end of C_3 to the baseboard. The extreme right-hand terminal is for the positive plate voltage; it is connected underneath the baseboard to the machine screw which holds the right-hand end of C_4 in place.

The output posts at the right are National Type WGS insulators. Fahnestock clips are mounted underneath the metal heads to hold the antenna coil.

The self-supporting coils used with the transmitter are wound with double cotton-covered wire on a celluloid base. In making the coils, a piece of sheet celluloid is wrapped around a cardboard tube of the proper diameter and held in place with string or rubber bands; the winding is then put on and given several coats of lacquer or prepared coil dope. After drying, the excess celluloid can be trimmed off and the coil ends bent to fit the mountings. Winding data is given under Fig. 711, together with information on using the coils with crystals of various frequencies. Limits of crystal frequencies for harmonic operation are indicated in the table; for operation at the fundamental a crystal having any frequency inside the band can be used.

Tuning the Crystal Oscillator

▲ The tuning procedure is best explained by an example. Let us suppose that the transmitter is

to operate on the 3.5- and 7-mc. bands and that a 3.5-mc. crystal of appropriate frequency is available. The filament and plate voltages are connected to the transmitter. The output frequency is to be the same as that of the crystal. A 0-100 d.c. milliammeter connected in the plate-supply "plus 350" lead will be helpful, as will also a neon lamp for indicating oscillation. Coil No. 3 should be used at L_2 . The first step is to set C_1 at maximum capacity, thus making it short-circuit itself. Then C_2 should be turned until there is a pronounced dip in plate current, indicating the beginning of oscillation. With a crystal of ordinary activity, the minimum point of the plate current dip will be in the neighborhood of 10 to 15 milliamperes; when the tube is not oscillating the plate current will probably be 60 or 70 milliamperes. It is generally better to set the condenser C_2 at slightly lower capacity than that which gives minimum plate current, because the oscillator will be more stable under those conditions. The antenna coil may then be coupled to L_2 and the tuning adjusted to give maximum antenna or feeder current. The method of antenna tuning will depend upon the antenna system; complete instructions are given in Chapter Twelve. The oscillator plate current should rise to 40 or 50 milliamperes when the antenna circuit is tuned to resonance. After adjusting the antenna circuit, C_2 should be retuned to give maximum output and to make certain that the oscillator "starts" quickly each time the plate circuit is closed. The transmitter should be keyed and the signals monitored to make certain that the keying is clean. It may be necessary to set C_2 slightly off the maximum output point to get the necessary keying stability.

To operate the transmitter as a Tri-tet with output at twice the operating frequency, in this case in the 7-mc. band, coil No. 4 would be connected at L_1 and coil No. 5 at L_2 . Condenser C_1 should be set at about 75% of full scale and C_2 at about 20% of full scale. Apply the voltages and adjust C_2 for minimum plate current, which should be 15 milliamperes or less. Touch a neon bulb to the stator plates of C_2 and adjust C_1 to give maximum glow. The tuning of C_1 will be quite broad, but there will be a definite region on its scale over which the second-harmonic output, as indicated by the brightness of the neon lamp, will be greatest. Also, the frequency stability will be best (no "creeping") with the lower capacity of C_1 . When these adjustments have been made the antenna may be coupled and tuned as before; it will not be found necessary to detune C_2 from the maximum output point in this case, however. The plate current should again be in the vicinity of 40 or 50 milliamperes with the antenna connected and tuned.

The tuning procedure for any other pair of bands will be similar. The coil L_1 may be left in place all the time, of course, since it will be shorted

out when condenser C_1 is set at maximum capacity for operation on the fundamental frequency of the crystal.

The 350-volt power supply shown in Chapter Ten can be used with this transmitter provided a voltage divider is installed to give 100 volts for

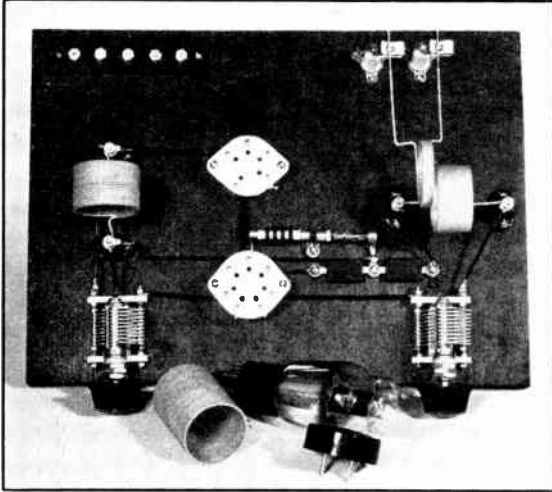


FIG. 712 — A TOP VIEW OF THE CRYSTAL OSCILLATOR WITH THE TUBE AND CRYSTAL HOLDER REMOVED

The coils in place are those used to operate the transmitter as a Tri-tet oscillator for 7000-kc. output from a 3500-kc. crystal. The 3500-kc. output coil and the Bliley crystal holder are in the foreground.

the screen grid. A satisfactory divider can be made by connecting a 7000- and 10,000-ohm resistor in series across the output of the supply, with the 7000-ohm unit at the negative side. The tap between the two will give approximately the correct voltage. It is important that the screen voltage be kept as nearly as possible at 100 volts. Lower voltage will reduce the output while higher voltage is likely to cause the tube to heat and perhaps stop oscillating after a few minutes' operation.

High-Power Crystal Oscillators

▲ Pentode-type power tubes lend themselves well to use as high-power crystal oscillators of the tri-tet type. The RK-20 tube is especially suitable, since the r.f. exciting grid voltage required for full output is very small. As a result the tube can be made to deliver outputs of the order of 60 watts on the fundamental and 30 watts on the second harmonic, while working well within the power-handling limitations of the crystal. A circuit diagram of such an oscillator is given in Fig. 713.

The circuit of Fig. 713 is much the same as that of the low-power oscillator of Fig. 711, with a few changes necessitated by the characteristics of the larger tube. Since the RK-20 does not

have an indirectly-heated cathode, the oscillator tank coil, L_1 , is inserted in series with one leg of the filament. To maintain both sides of the filament at the same r.f. potential, a second coil identical with the first is inserted in the other filament leg. The two coils must be coupled together very closely, and must be wound of fairly heavy wire to carry the filament current. The coupling will be satisfactory if the coils are wound side by side on the form or if the turns of one are wound between the turns of the other.

In this circuit provision has been made for supplying a small positive voltage to the suppressor grid, since it has been found that the output of the tube is increased by doing so. It is not necessary to go beyond the screen and suppressor grid voltages indicated, since to do so will reduce the efficiency and may possibly overload the crystal.

Adjustment procedure for the high-power oscillator is identical with that for the oscillator of Fig. 711. The cathode tank circuit is tuned to a frequency considerably higher than that of the crystal. The output circuit, L_2C_2 , is tuned to resonance either at the fundamental or a harmonic, C_1 then being adjusted for maximum output. The antenna tuning and coupling will be adjusted in accordance with instructions given in Chapter Twelve for the type of antenna system in use.

It is advisable to obtain the screen and suppressor grid voltages from a voltage divider across the plate supply. The screen-grid tap on the divider should be adjusted to give 400 volts or a current of 30 ma. under operating conditions. The plate current at full load should be between 80 and 100 milliamperes.

Oscillator-Amplifier Transmitters

▲ The progressive amateur will not be long content with a simple self-controlled oscillator transmitter, nor is it likely that he will care to continue indefinitely with a crystal oscillator of limited power output. As has already been explained, the crystal oscillator is practically a single-frequency device; it has a high order of dynamic stability and is free from frequency variations with minor changes in circuit constants. At the present state of the art, however, the crystal oscillator is nearly always used at low power — with the exception of special circuits and tubes such as were described in the preceding section — so that for higher-power work it becomes necessary to build up the output to the point desired. Radio-frequency power amplifiers are used for this purpose.

R.F. amplifiers can be used to build up the output of self-controlled oscillators as well, and their use results in a number of benefits. Since the

amplifier stage acts as a buffer between the oscillator and antenna circuit, changes in antenna constants caused by wires swinging in a wind have little effect on the frequency generated by the oscillator. Because of this, the antenna circuit can be tuned for maximum output in contrast to the detuning described in the section on tuning the self-controlled transmitter. The oscillator is still subject to dynamic instability, creeping, and other oscillator ills, however, so that most amateurs prefer to use crystal-controlled oscillators in oscillator-amplifier transmitters. The fact that a crystal will generate only one frequency may be either an advantage or disadvantage, depending upon the point of view. In comparison with the self-controlled oscillator, the frequency of which may be varied at will, it suffers from a lack of flexibility. This very inflexibility, however, is an asset when it is considered that there is little danger of off-frequency operation with a properly adjusted crystal transmitter. For some types of amateur work, it is distinctly desirable to have a fixed frequency on which the signal is sure to be found, particularly when schedules are kept with distant stations.

Amplifiers are of two general types, those in which the output tank circuit is tuned to the exciting frequency — called “straight” amplifiers — and those in which the output circuit is tuned to a harmonic of the exciting frequency — called “frequency multipliers.”

Straight Amplifiers

▲ High power output usually is the first consideration in the operation of an amplifier in the c.w. transmitter. The power output that can be obtained from a given tube is limited by the power that can be safely dissipated by the plate, the maximum safe plate voltage and the maximum permissible plate current. Since the power input is limited by the tube ratings, it is desirable to obtain high efficiency in the plate circuit so that the largest possible proportion of the power input will be converted to radio-frequency power output.

The efficiency of an amplifier is determined largely by the negative grid bias and the peak value of the excitation voltage applied to its grid, in relation to the plate voltage. For high efficiency the grid bias should be at least twice the value required to cut off the plate current at the plate voltage used, and the excitation voltage must be such that the grid is driven positive during part of the excitation cycle, causing grid current to flow. The L - C ratio in the plate tank circuit should be fairly high. In general, relatively high plate voltage accompanying low plate current will give better efficiency than the converse, assuming the same input in both cases.

The problem usually confronting the amateur in the design of an oscillator-amplifier transmitter is that of providing adequate excitation for a pre-

determined type of output tube operating on a given frequency. In the crystal-controlled transmitter, the power output of the crystal oscillator is usually five watts or less, and is ordinarily on a frequency in the 3500-kc. band. It then becomes necessary to decide upon the number of amplifier or doubler stages that will be necessary to give adequate excitation to the final amplifier on the final operating frequency. There are so many ways of arriving at the result that it is useless to give exact specifications. The tube table will be of value in the preliminary estimates, however. The power output ratings given are conservative when the tube is used as a straight amplifier; as a doubler, the output will usually be less — as a safe estimate, say fifty percent of the rated power output, assuming the recommended plate voltages and currents are applied.

The grid driving power required to produce rated output varies considerably with the type of tube. The data on driving power in the tube table will be of help in choosing a tube line-up. These figures are for straight amplification, not frequency multiplication; in the latter case more driving power will be required. Since power tubes usually are rated conservatively and many amateurs have learned to expect more than rated output from them, it may be necessary to increase the driving power if the recommended plate voltages and currents are exceeded. The table can be

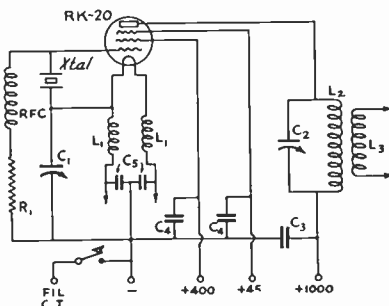


FIG. 713 — A HIGH-POWER TRI-TET OSCILLATOR CIRCUIT USING AN RK-20 PENTODE

- C_1 — 150- μ fd. cathode tuning condenser, receiver type.
 C_2 — 100- μ fd. plate tank condenser, transmitting type.
 C_3 — .002 μ d. plate bypass condenser, 1500-volt rating or more.
 C_4 — Screen and plate bypass condensers, .002 μ d.
 C_5 — Filament bypass condensers, .005 μ d.
 R_1 — Grid leak, 15,000 ohms, 2-watt rating.
 L_1 — Filament or cathode coils. Dual winding (see text) on 2 1/2-inch diameter form; each coil 10 turns No. 16 d.c.c. wire, close wound. (For 3500-kc. crystal.)
 L_2 — Plate coil; 3500 kc.: 30 turns No. 12 enamelled on 2 1/2-inch form, turns spaced diameter of wire.
 7000 kc.: 10 turns same.
 L_3 — Antenna coupling coil. Size depends upon antenna system.

used as a basis of design, however; for example if the tube to be driven requires a driving power of 10 watts, one of the tubes having that rated output — or somewhat more — should be chosen as a driver. Assuming an oscillator output of five watts — a reasonable figure for a crystal oscillator of the pentode or tri-tet type — it then becomes relatively easy to select a tube line-up for any desired power output. A later section on transmitter design will take up in more detail the other considerations involved.

R. F. power amplifiers may be either of the triode or screen-grid type, the latter classification including both tetrodes and pentodes. Since the input and output circuits of the amplifier tube are tuned to the same frequency, a tube having appreciable grid-plate capacity would break into self-oscillation as a t.p.t.g. oscillator if steps were not taken to prevent it. The process of counteracting feedback through the tube elements is called neutralization. True screen-grid tubes — that is, tubes in which the grid is thoroughly shielded from the plate — do not need to be neutralized because the grid-plate capacity is so low that the feedback is insufficient to produce oscillation. The small audio power pentodes used by amateurs for transmitting purposes are not well screened, however, and must be neutralized. Neutralizing methods will be detailed in a following section.

Interstage Coupling

▲ Whatever the type of amplifier tube, some means must be provided for feeding into its grid circuit the r.f. power generated by the preceding oscillator or driver. To do this effectively many types of inter-stage coupling have been devised. The type of coupling best adapted to efficient power transfer depends upon the characteristics of the driver and amplifier tubes. Several satisfactory arrangements are shown in Fig. 714.

The circuit at A is known as capacity coupling, because the radio-frequency power is fed from the driver to the amplifier through the coupling condenser *C*. The purpose of the condenser is to prevent the driver plate voltage from being impressed upon the grid of the amplifier tube while providing a low-impedance path for r.f. current. This method of coupling is generally most satisfactory when the amplifier tube is one having a low or medium amplification factor (μ of 8 or less). The bias for the amplifier is fed to the grid through the r.f. choke, *RFC*, which keeps the excitation voltage from leaking off through the bias supply and being wasted. Since the negative side of the driver plate supply and the positive side of the amplifier bias supply meet at the common filament connection between the two tubes, the coupling condenser *C* must have insulation good enough to stand the sum of these two voltages without breakdown. The fact that the condenser also is carrying a considerable

radio-frequency current makes it desirable that it have a voltage rating giving a factor of safety of at least 2 or 3.

Circuit B is practically equivalent to Circuit A; the coupling condenser has been moved to the plate circuit of the driver tube and the radio-frequency choke appears at the plate of the driver. This simply shifts the driver to parallel plate feed, and permits the use of series feed to the amplifier grid. In both circuits the excitation can be controlled by moving the tap on the tank coil; the nearer the tap is to the plate end of the coil the greater will be the excitation voltage up to the limit of the driver output. These circuits have the advantage of simplicity, but have the disadvantage that the interelectrode capacities of both the driver and amplifier tubes are connected across the tuned circuit, thus causing a reduction in the *L-C* ratio and reducing the efficiency at the very high frequencies. They operate quite satisfactorily with ordinary tubes at frequencies of 7 mc. and lower, and at 14 mc. with tubes having low interelectrode capacities, such as the 852,800-, 825, RK-18 and others with comparable capacities to be found in the tube table. The variable tap for regulating excitation is sometimes responsible for parasitic oscillation in the amplifier, a condition which is harmful to the efficiency.

Circuit C overcomes these two disadvantages, but requires two tuned circuits and a method for varying the coupling between the two coils. This circuit is particularly effective at 14 mc. and higher frequencies, where the increased complications are worth while in view of the greater efficiency. Circuit D is much the same as Circuit C, except that an untuned transmission line, inductively coupled to the tank circuits at both ends, is substituted for the variable inductive coupling. This system is more convenient mechanically, because the power transfer is governed by the relative number of turns on each coupling coil, and because the transmission line can be any reasonable length — up to several feet. Ordinary twisted lampcord will do nicely for such a line. In practical operation, the number of turns on the coupling coils is adjusted to give maximum excitation to the amplifier. From one to five turns will be sufficient in most cases provided the coils are closely coupled to the tank coils with which they are associated.

The push-pull circuit at E corresponds to the simple capacity-coupled circuit at A, while F is the same thing as D but arranged for push-pull. It should be pointed out that in circuits using the untuned coupling line or "link," as it is sometimes called, the coupling coils should be coupled to the tank coils at a point of low r.f. potential. This is indicated in Circuits D and F.

The use of power amplifier tubes with relatively high voltage-amplification factors — 15 and more — sometimes introduces complications in the coupling arrangement because such tubes

generally operate best with a lower exciting voltage than is developed by the driver tube. In other words, the grid impedance of such tubes is lower than the value of impedance which, when connected across the whole driver tank circuit, is optimum for maximum driver power output. "Tapping down" on the driver tank coil will take care of this condition but as pointed out above sometimes leads to parasitic oscillation in the amplifier. For this reason the inductive coupling methods are more satisfactory with high- μ amplifier tubes. Parasitic oscillation can be avoided in condenser-coupled systems (which includes circuit B) by taking the excitation directly from the plate end of the coil and using a coupling condenser having low capacity to avoid overloading the driver. The coupling efficiency is reduced by this compromise, however. The optimum coupling capacity will depend upon the type of amplifier and driver tube used and the operating conditions; in general it had best be determined experimentally for the individual layout. Where this consideration is not a factor — i.e., when the amplifier is a medium- or low- μ tube — the size of the coupling condenser is not critical. Usual values are 100 to 250 μfd .

Minor variations from the circuits given in Fig. 714 often appear in radio literature, but the fundamental arrangement usually can be recognized without difficulty. A modification of D which has found some favor employs an untuned grid coil for the amplifier, the coil being adjusted by cut-and-try to resonate, in conjunction with the tube and circuit capacities shunting it, at the proper frequency. This simplifies the tuning process once the coil size has been adjusted, and eliminates the need for a grid tuning condenser.

Coupling Between Single-Ended and Balanced Circuits

▲ One important coupling problem is that of connecting a single-ended oscillator or driver to a push-pull amplifier. Three methods of doing it are shown in Fig. 715. Circuit A shows the capacity-coupling scheme. The driver tank coil is tapped at the center; the end of the tank circuit opposite the plate of the tube is left free to assume an r.f. potential equal to that at the plate and opposite in sign, thus making the output voltage suitable for exciting a push-pull amplifier.

Inductive coupling is shown at Fig. 715-B and transmission line coupling in 715-C. Since all these methods have been discussed at length in the preceding section, we need not go into further detail here. The same advantages and disadvantages apply.

Occasionally it will be found necessary to couple a push-pull stage to a following single-ended amplifier. In such case the circuits of Fig. 716 are recommended. A capacity-coupled circuit, with the coupling condenser taken from one end of the push-pull tank coil and with the center-

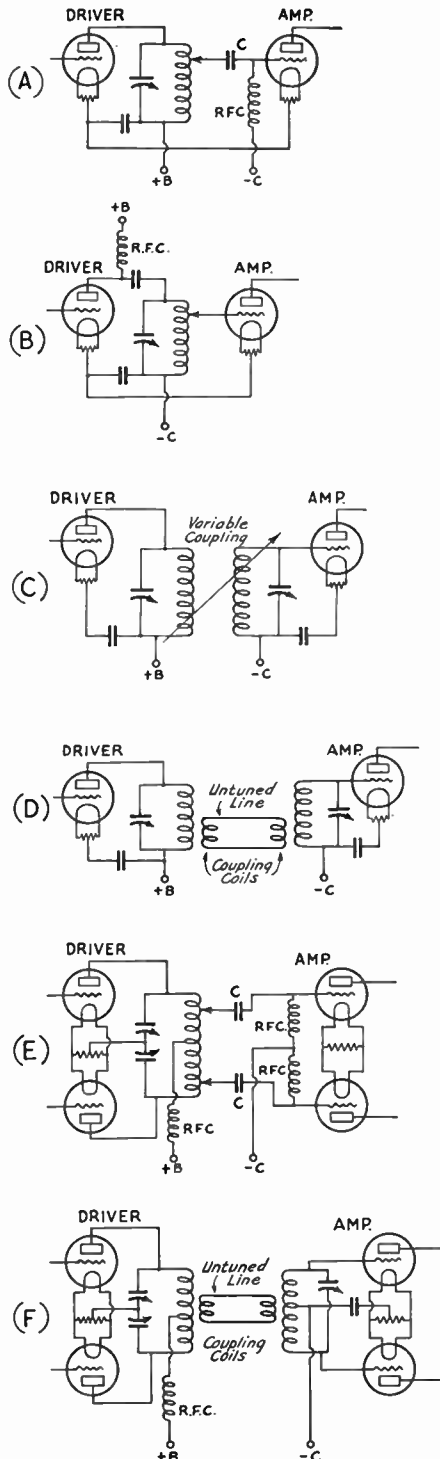


FIG. 714 — REPRESENTATIVE INTERSTAGE COUPLING CIRCUITS

taps of the two stages connected together, might be used but would tend to unbalance the push-pull circuit, so that inductively-coupled arrangements are to be preferred.

Neutralizing Circuits

▲ As we have already explained, a three-electrode tube used as a straight radio-frequency amplifier will oscillate because of radio-frequency feed-back through the grid-plate capacity of the tube unless that feed-back is nullified. The process of neutralization really amounts to taking some of the radio-frequency voltage from the output or input circuit of the amplifier and introducing it into the other circuit in such a way that it effectively "bucks" the voltage operating through the grid-plate capacity of the tube, thus rendering it impossible for the tube to supply its own excitation. There are several ways of doing this, the more common ones being shown in Fig. 717. Parts of the circuit which are not essential to the neutralizing scheme considered are not included in the diagrams.

In Circuits A and B the operation is the same; the choice between one or the other is simply a matter of preference or mechanical considerations. A point on the tank inductance (usually a third or half the way up toward the plate end) is made to assume the same r.f. potential as the filament by connecting it to the filament through a by-pass condenser. The voltage at the lower end of the coil is, therefore, opposite in phase to that at the plate end, and this voltage is fed back to the grid through a small condenser, C_n , to balance the

voltage which appears across grid and plate. Exact balance is obtained by properly proportioning the number of turns between X and Y and by adjusting the capacity of C_n . If parallel plate supply feed is used, the by-pass condenser between the point X and the filament is unnecessary, since there will be no d.c. voltage between the two points and a direct connection can be made.

In Circuit C the neutralizing or bucking voltage is obtained from the voltage drop across half the tuning condenser, which in this circuit must be a

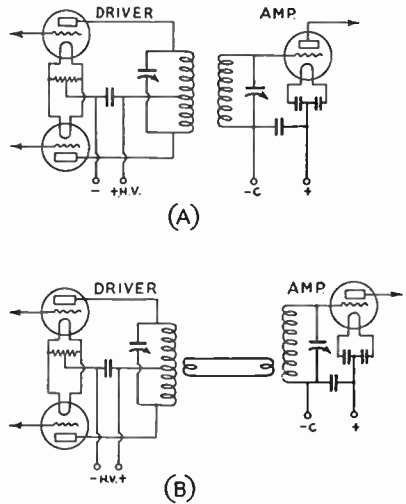


FIG. 716—THESE COUPLING ARRANGEMENTS ARE RECOMMENDED WHEN A PUSH-PULL STAGE IS TO EXCITE A SINGLE-ENDED AMPLIFIER

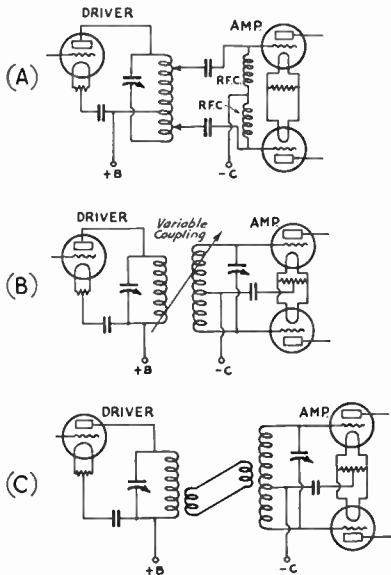


FIG. 715—TYPES OF COUPLING USED TO FEED A PUSH-PULL AMPLIFIER FROM A SINGLE-ENDED OSCILLATOR OR DRIVER

split-stator affair. Parallel plate feed is shown in this circuit, although series feed can be used by introducing the plate voltage at the center of the tank inductance through an r.f. choke. If series feed is used, the feed tap on the tank coil should not be connected to the filament through a by-pass condenser as is done in Circuits A and B; doing this places two grounds in the circuit and is likely to lead to circulating r.f. currents and undue losses. Circuit C is likely to be more stable at very high frequencies than Circuits A and B. Circuits D and E also are equivalent. In these circuits the neutralizing or bucking voltage is obtained from the tank circuit of the preceding tube and is fed to the plate of the amplifier through the neutralizing condenser. The tank tuning condenser may be connected across part of the coil or all of it, whichever seems most desirable.

Two push-pull neutralizing circuits are shown in F and G. One has a tapped plate tank coil and the other a split-stator tuning condenser with the rotor grounded. The neutralizing condensers are simply connected from the grid of one tube to the

plate of the other. Fig. 717-G is to be preferred for the higher frequencies, just as was the case with Circuit C. Both F and G will remain neutralized with different tank coils; in F, however, it is essential that the tap on the coil be placed accurately at the electrical center of the coil. Good balance between the two sections of the condenser in G will obviate this necessity.

In all these circuits, by-pass condensers and other parts not particularly a part of the neutralizing arrangement will have the usual values. In most cases the neutralizing voltage will be equal to the r.f. voltage between the plate and grid of the tube (using one of the circuits involving the use of a split-stator condenser, or a tapped-coil circuit having the tap at the center of the inductance) so that for perfect balance the required capacity in the neutralizing condenser theoretically will be equal to the grid-plate capacity of the tube being neutralized. If, in the circuits having tapped tank coils, the tap is more than half the total number of turns from the plate end of the coil, the required neutralizing capacity will increase approximately in proportion to the relative number of turns in the two sections of the coil. As a general rule, however, an even division between "plate" and "neutralizing" turns is desirable.

The paragraph above should make it clear that the neutralizing capacity required at C_n will depend upon the type of tube and the choice of circuit. In balanced circuits — those having the tap at the center of the coil or those using split-stator condensers — the neutralizing capacity is theoretically exactly the same as the grid-plate capacity of the tube. For those tubes having grid and plate connections brought out through the bulb, such as the 800, 825, 852 and a few others, this rule will hold good and a condenser having at about half scale a capacity equal to the grid-plate capacity of the tube should be chosen. Where the grid and plate leads are brought through a common base, the C_n capacity needed is greater because the tube socket and its associated wiring adds some capacity to the actual inter-element capacities. In such cases a slightly larger condenser should be used. For most small triodes, a condenser having a minimum of about 5 μmf . and a maximum of approximately 20 μmf . will suffice. Such condensers are readily obtainable in the midget sizes.

When two or more tubes are connected in parallel, the neutralizing capacity required will be in proportion to the number of tubes.

Neutralizing Adjustments

▲ The procedure in neutralizing is the same regardless of the tube or circuit used. To do the job satisfactorily it is essential that some form of fairly sensitive r.f. indicator be available; a flashlight lamp with its terminals connected to a loop of wire, a neon bulb, or a thermo-galvanometer connected to a wire loop are suitable.

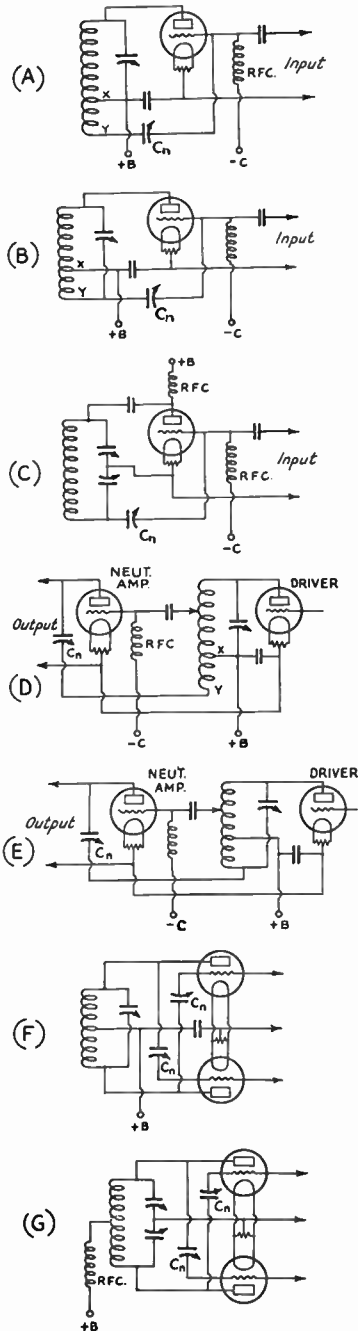


FIG. 717—METHODS OF NEUTRALIZING AMPLIFIERS

The first five are for neutralizing the grid-plate capacity of single tubes or tubes in parallel. The push-pull neutralizing arrangements shown at F and G are known as "cross-neutralized" circuits because the neutralizing condensers form a cross-connection from the grid of one tube to the plate of the other.

The first step in neutralizing is to disconnect the plate-voltage from the tube. Its filament should be lighted, however, and the excitation from the preceding stage should be fed to its grid circuit. Couple the r.f. indicator to the plate tank circuit (if a neon bulb is used, simply touch the metal base to the plate terminal) and tune the plate circuit to resonance, which will be indicated by a maximum reading of the r.f. indicator. Then, leaving the plate tank condenser alone, find the setting of the neutralizing condenser which makes the r.f. in the plate tank drop to zero. Turning the neutralizing condenser probably will throw off the tuning of the driver tank slightly, so the preceding stage should be retuned to resonance.

Now couple the r.f. indicator to the plate tank once more and again tune the plate circuit to resonance. Probably the resonance point will occur at a slightly different setting, and the second reading on the r.f. indicator will be lower than the first one. Retune the preceding stage once more and go through the whole procedure again. Continue until the r.f. indicator gives no reading when the plate tank circuit is tuned in the region of resonance. When this has been accomplished the tube is neutralized.

The aim of neutralizing adjustments is to find the setting of the neutralizing condenser which eliminates r.f. in the plate circuit when the plate circuit is tuned to resonance. It is not at all difficult to neutralize a tube after a few practice trials, provided the circuit is laid out properly and provided the neutralizing condenser has the right capacity range. It sometimes happens that while a setting of the neutralizing condenser can be found which gives a definite point of minimum r.f. in the plate circuit, the r.f. is not completely eliminated; in such a case stray coupling between the amplifier and driver tank coils, or stray capacities between various parts of the amplifier circuit tending to upset the voltage balance, probably will be found to be responsible. A better layout with short, widely-spaced leads, or with coils so placed that coupling between them is minimized — usually when the axes of the coils are at right angles — should be tried. Shielding of the amplifier often will eliminate troubles of this sort.

Fundamentally, neutralizing is used to prevent self-oscillation in an amplifier. After the adjustments have been completed, therefore, it is a good plan to apply plate voltage to the amplifier and reduce the grid bias until the tube draws a little plate current without r.f. excitation. If the tube does not oscillate under these conditions it can be assumed that the tube is properly neutralized. In case no fixed bias is used (operating bias secured through the flow of grid current through a grid leak), a suitable bias voltage can be temporarily introduced in series with the leak, or the plate voltage may be reduced to keep the plate current within reasonable limits.

Tuning an Amplifier

▲ Amplifier tuning is quite simple, and the adjustments are similar regardless of the type of circuit used. It is also immaterial whether the tube is a neutralized triode or a screen-grid tube requiring no neutralization. In describing the process, however, it will be assumed that the neutralizing, if required, has been carried through to a satisfactory conclusion. A tube which is not properly neutralized is likely to behave erratically when plate voltage is applied.

Before applying plate voltage to the amplifier, the plate circuit of the preceding stage should be tuned to give maximum output. Perhaps the most satisfactory indicator of the excitation power delivered by the driver stage is a d.c. milliammeter connected in series with the grid return circuit of the amplifier. The higher the rectified grid current indicated by such a meter, the greater is the excitation. The method of connecting the meter will depend upon the type of grid circuit used; Fig. 718 gives some examples. The connections at A would be used with amplifier grid circuits like those in Figs. 714-A and E; those at B with Fig. 714-B; and those at C with Fig. 714-C, D, and F. The plus and minus signs indicate the proper way to connect the meter in the circuit.

The first step is to adjust the driver stage tuning for maximum amplifier grid current. Then the coupling between the stages should be adjusted to give the same result. In the circuits shown in Fig. 714-A, B, and E, the coupling would be changed by changing the position of the taps on the driver tank coil. In the push-pull circuit at E both taps should be changed simultaneously, taking care that each is the same number of turns from the center of the coil. In Fig. 714-C the coupling can be changed by moving the two coils nearer together or farther apart. In transmission-line coupled systems such as those at Fig. 714-D and F, the coupling can be changed by changing the number of turns on one or both of the coupling coils in the untuned line, or by moving one of the coupling coils nearer to or farther away from the tank coil to which it is coupled. In any event, the driver circuit should be retuned to resonance every time the coupling is changed, no matter what the coupling system used, since a change in coupling is likely to throw the tank circuit slightly off tune. If there is a tank circuit in the grid of the amplifier, as in Fig. 714-C, D, and F, it too should be retuned for the same reason. A few minutes spent in changing the coupling and tuning should show quickly the optimum coupling for maximum grid current.

Once the proper grid-coupling adjustment has been found, the amplifier plate tank condenser should be set approximately at resonance. With the excitation connected, the plate voltage may then be applied and the plate tank circuit tuned to resonance, which will be indicated by a very pro-

nounced dip in plate current. This adjustment should be made quickly, since the tube filament will be damaged by continued application of plate voltage with the tank circuit tuned off resonance. The off-resonance plate current usually will be considerably higher than the rated plate current for the tube — sometimes several times as great — but at resonance should drop to ten or twenty percent of the rated value. The higher the excitation power, the greater will be the dip in plate current at resonance. If the dip in plate current is not very pronounced, the excitation may be low or the tube may not be properly neutralized, if a triode.

When the tuning process has been carried this far, the output load circuit may be connected to the amplifier. This load circuit may be the antenna itself, through the coupling apparatus, or the grid circuit of a following amplifier. When the load is connected on the amplifier plate current will rise. The plate tank circuit should be retuned for minimum plate current — this “minimum,” however, will no longer be the low value obtained at no load but a new value nearer the rated plate current of the tube — since connecting the load probably will detune the tank circuit to some extent. The coupling to the load circuit should be adjusted so that the new minimum plate current value is approximately the rated plate current of the tube. If the load is an antenna circuit, the methods outlined in Chapter Twelve should be followed; if another amplifier, the coupling may be adjusted by following the procedure given above for adjusting the amplifier grid circuit. In the preliminary tuning of an amplifier it is often desirable to use a dummy load such as the dummy antennas described in Chapter Twelve. These will give some indication of the actual power output of the amplifier.

If the amplifier has plenty of excitation it is often possible to use more coupling than that which gives rated tube plate current, thereby obtaining a further increase in power output. A slight increase in plate current — ten to twenty percent, for instance — will do no particular harm if the tube is operating efficiently. An extended overload, however, almost certainly will result in shortened tube life.

Amplifier Construction

▲ Typical examples of amplifier construction are shown, together with circuit diagrams and constants, in Figs. 719–725, inclusive. The 830 amplifier of Fig. 719 is a companion-piece, physically, to the crystal oscillator transmitter described earlier in the chapter. It may be used with that oscillator simply by making a connection from the plate of the 59 oscillator, Fig. 711, to the upper input terminal in Fig. 720, and from

the negative “B” terminal in Fig. 711 to the lower input terminal in Fig. 719. The coupling coil, L_3 in Fig. 711, will not be needed. This will be recognized as simple capacity coupling. It may be necessary to remove a few turns from the oscillator plate coil, L_2 in Fig. 711, to compensate for the capacity added by connecting the amplifier grid circuit across the coil, otherwise it may not be possible to tune the oscillator plate circuit to resonance.

The amplifier of Fig. 719 can also be used with Type 10, 801 or 841 tubes instead of the 830. No changes in circuit constants need be made except to apply the proper plate and filament voltages.

The amplifier of Fig. 722 illustrates the use of a tuned grid circuit with link coupling. This amplifier could be coupled to the oscillator of Fig. 711 by using L_3 as a link coupling coil. The output terminals in Fig. 711 would simply be connected to the input terminals in Fig. 722.

The high-power amplifier shown in Fig. 724 demonstrates the use of a pair of 852 tubes in push-pull. Such an amplifier is easily capable of an output of 250 or 300 watts with proper excitation.

Tuning, neutralizing and adjustment of these amplifiers is exactly as described in the preceding section.

Screen-grid Amplifiers

▲ Screen-grid power tubes are designed so that feedback from plate to grid cannot take place within the tube, so that neutralization is un-

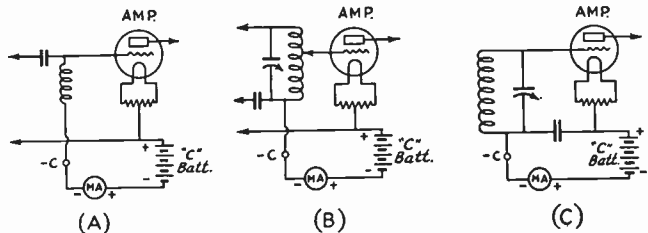


FIG. 718 — METHODS OF CONNECTING A MILLIAMMETER IN THE GRID RETURN LEAD TO MEASURE RECTIFIED GRID CURRENT

necessary when these tubes are used as straight amplifiers, provided the input and output circuits are isolated so that stray magnetic or capacitive coupling cannot take place between them. In many cases it is necessary, to secure the full benefit of the screen-grid tube and to prevent self-oscillation, to shield the input and output circuits. A typical screen-grid amplifier circuit is shown in Fig. 726. The second circuit is for use with screen-grid pentode power tubes such as the RK-20.

The screen-grid amplifier is tuned as described in the section on amplifier tuning.

Sources of Grid Bias for Amplifiers

▲ To get reasonable plate efficiency from a power amplifier it is necessary that the grid bias voltage

under operating conditions be of a value greater than that sufficient to cut off plate current when the amplifier is not receiving r.f. excitation. The "cut-off" bias depends upon the plate voltage and the type of tube, and in triodes is approximately equal to the plate voltage divided by the voltage amplification factor, or μ , of the tube. This rule does not apply to screen-grid or pentode tubes, however, because the voltage on the screen grids of such tubes has more effect on the plate current than does the plate voltage itself. The cut-off bias for such tubes must, in general, be determined from the tube characteristic curves.

Bias voltage may be supplied from a bank of batteries, from the drop in voltage caused by flow of rectified grid current through a grid leak, or from a combination of both. Bias also may be supplied by a power pack — transformer, rectifier and filter — provided a bleeder of suitable resistance is used across the output terminals. The requirements for bias power packs are discussed in Chapter Ten. All these methods will give satisfactory performance provided the bias voltage under operating conditions is the right value — approximately twice cut-off bias in the case of a straight amplifier intended to be operated at high efficiency.

Batteries have the advantage of giving practically constant voltage under all conditions of excitation or lack of it, although the grid current flow does have a charging effect which tends to raise the battery voltage. This effect increases as

the batteries age and their internal resistance increases.

Grid leak bias is economical, since no expenditure for batteries is necessary, and has the desirable feature that the bias regulates itself in accordance with the amount of excitation available and thereby tends to give optimum amplifier operation under varying conditions of excitation. When there is no excitation at all, however, there is also no grid bias, and in the case of tubes operating at fairly high voltages, especially those having low and medium values of amplification factor, a large plate current will flow if the excitation should for any reason fail or be removed while the plate voltage is connected to the tube. This may seriously damage the tube and possibly ruin it if not corrected in time.

The advantages of battery and grid-leak bias can be secured and their disadvantages eliminated by using a combination of both. Many amateurs use just enough battery bias to reduce the amplifier plate current to a safe value should excitation fail, and connect in series with the battery a grid leak to obtain the additional bias needed under operating conditions. In general, the leak values recommended in the tube table may be used without change when used in conjunction with a small amount of "safeguarding" battery bias. The bias power pack, when properly designed, offers the advantages of a battery-grid leak combination.

When grid-leak bias is used the bias under operating conditions may be calculated by multiplying the leak resistance by the grid current in amperes ($\text{ma.} \div 1000$). If a battery is in series with the leak, the battery voltage should be added to the voltage obtained by the calculation to give the actual operating bias.

Recently the cathode-biasing system, used universally in receivers, has been applied to transmitters, especially when low-power tubes having indirectly-heated cathodes are used. The 59 doubler circuits shown later in the chapter use this type of biasing, in part. In the cathode-bias system a resistor is connected between ground and the cathode of the tube; both plate and grid current flow through it. Its value can be determined approximately by dividing the required bias voltage by the normal plate current (expressed in amperes). Cathode-resistor bias tends to prevent excessive rise of plate current, since an increase in plate current automatically increases the grid bias. Its chief disadvan-

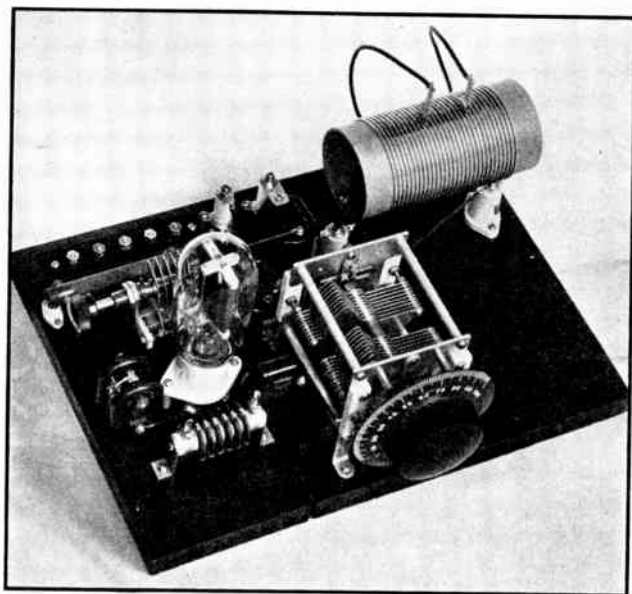


FIG. 719 — A NEUTRALIZED AMPLIFIER USING AN 830 TUBE.

It will give an output of approximately 50 watts with a driving power of about five watts. This same layout also is suitable for smaller tubes such as the 10, 801, and 842. The circuit diagram is given in Fig. 720.

tage is the fact that the bias voltage must come out of the available plate-supply voltage, therefore the plate supply must have higher voltage output than ordinarily needed or else some plate voltage must be sacrificed. If cathode bias is used with filament-type tubes, tubes so biased must have separate filament transformers for each stage.

Frequency Multipliers

▲ Since the most satisfactory crystals are those ground for the lower amateur frequencies — 1.75, 3.5 and 7 megacycles — it becomes necessary to resort to other means than straight amplification to obtain crystal-controlled output on the higher-frequency bands. Many amateurs make a practice of operating in three or more bands with only one crystal, usually one having a frequency toward the lower end of the 3.5-mc. band so that its harmonics will fall in the higher-frequency bands. To do this it is necessary to use harmonic generators or *frequency multipliers*. The frequency multiplier is simply a straight amplifier whose plate circuit is tuned to a multiple of the driving frequency, and operated under conditions which produce relatively high harmonic output. Since its input and output circuits are not tuned to the same frequency it cannot itself oscillate, hence a triode frequency multiplier does not need neutralization. The plate efficiency of a frequency multiplier is considerably less than that of a straight amplifier, and decreases rapidly when the plate circuit is tuned to a harmonic higher than the second. For this reason most frequency multipliers are designed to give output only on the second harmonic; since the frequency is doubled the tube is appropriately called a “doubler.”

To obtain maximum output and efficiency from the doubler it is necessary to use high negative grid bias on the tube — considerably more than double cut-off — and excite it with a correspondingly high radio-frequency voltage. A low-*C* tank in the plate circuit is also desirable. In general, a tube having a relatively large amplification factor is best as a doubler; tubes such as the 46 and 59 with Class-B connections, the 841, RK-18, 800, 825, 830-B and 203-A are most suitable. Other types, such as the 10, 801 and 830, will work satisfactorily but require higher bias and greater excitation voltage than the high- μ tubes. In practical work the bias may be supplied from the same sources previously recommended for amplifiers.

The efficiency and output of a doubler can be increased by feeding some of the energy in the plate circuit back to the grid to cause regeneration, provided the process is not carried so far that the tube breaks into self-oscillation. One of the most satisfactory ways of introducing regeneration is by neutralizing the frequency multiplier by one of the methods in which the neutralizing

voltage is fed from the plate circuit to the grid. Circuits A, B and C in Fig. 717 are examples of this type of circuit. When the tube is properly neutralized it cannot oscillate, yet the feedback is sufficient to increase the output and efficiency of the doubler to a worth-while extent.

Almost any single-ended amplifier — single tube, or tubes in parallel — will operate as a

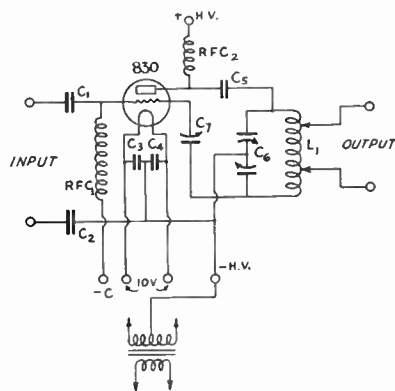


FIG. 720 — THE 830 AMPLIFIER CIRCUIT DIAGRAM

- C*₁ — 70- μ fd. mica grid coupling condenser.
 - C*₂ — 500- μ fd. mica blocking condenser.
 - C*₃, *C*₄ — .005- μ fd. mica filament bypass condensers.
 - C*₅ — 500- μ fd. mica plate blocking condenser, 2500-volt rating.
 - C*₆ — Split-stator variable tank condenser, 350- μ fd. each section (National).
 - RFC*₁ — Grid choke; 3-inch winding of No. 34 s.s.c. on half-inch bakelite form.
 - RFC*₂ — Plate r.f. choke (Hammarlund).
 - L*₁ — Plate tank coil 1.75 mc.: 45 turns No. 14 wire on 3-inch diameter form, winding length 4½ inches.
 - 3.5 mc.: 30 turns No. 14 wire on 2½-inch diameter form, winding length 3¾ inches.
 - 7 mc.: 15 turns No. 14 wire on 2½-inch diameter form, winding length 3¾ inches.
 - 14 mc.: 10 turns No. 14 wire on 2-inch diameter form, winding length 4 inches.
- (The coils shown are a manufactured product, made by Gross Radio Co.)

doubler if the plate circuit is tuned to the second harmonic of the driver frequency. The bias voltage should be raised either by adding more battery voltage or by using a higher resistance grid leak. The grid leak for a doubler may in general have a resistance from two to five times that recommended for a single tube. The driving power required for good doubling efficiency will be two or three times greater than that necessary for efficient straight amplification. A properly-operated doubler can give a power gain of about five, provided the tube is capable of handling the power. A small tube excited by one of similar ratings usually cannot give such a gain. At the higher frequencies — 14 and 28 mc. — small tubes used as doublers often do not give any power gain at all; the output on the second harmonic may be just about the same as the output

of the driver tube, or even less. This may be no particular disadvantage in some transmitter designs, as will be explained later.

Push-pull amplifiers cannot be used as doublers because the second and other even harmonics are cancelled in the output of such amplifiers. They can be used as triplers, however, the output circuit being tuned to the third harmonic. They are not very often used in this way because both

circuit is tuned to the harmonic. The circuit may not actually oscillate at the lower frequencies, but enough regeneration is supplied to increase both the output and efficiency of the doubler.

Tuning of Frequency Multipliers

▲ Frequency multipliers are tuned in much the same way as straight amplifiers. Once the bias or grid leak values are chosen, the input or grid circuit should be adjusted for maximum grid current just as with the straight amplifier. Then the plate voltage may be applied and the plate tank circuit tuned to the second harmonic, which will be indicated by the dip in plate current. The dip usually will not be as pronounced as with straight amplifiers, however. Once these adjustments have been made the load may be connected and adjusted for maximum output consistent with the plate current rating of the tube. Since the efficiency is lower, it may be necessary to use lower than rated plate current, especially if the plate of the tube shows color.

After the adjustments have been completed it is a good plan to change the bias voltage or the resistance of the grid leak to find which value gives greatest output. Since the optimum value will depend upon the type of tube used and the excitation available, it is not possible to give very definite specifications along these lines.

Locked Amplifiers

▲ If two oscillators operating on frequencies differing by only a small percentage are coupled together, they will tend to synchronize, or both oscillate at the same frequency. In such a case the less stable oscillator of the two will be pulled into step with the more stable one. This phenomenon is generally called "locking." Advantage can be taken of it to make a fairly powerful oscillator operate under the frequency control of a relatively weak crystal oscillator and thereby secure the stability of crystal control without having to build up the output of the crystal oscillator in successive stages of amplification. Since the locked oscillator or amplifier supplies its own grid losses, relatively little crystal-controlled power is needed for high output.

Instances of successful operation of medium-power tubes such as the 203-A or 852 from a low-power crystal oscillator are common. In some cases oscillators having power outputs as high as 250 watts have been similarly controlled. For equal power output from the same tubes as

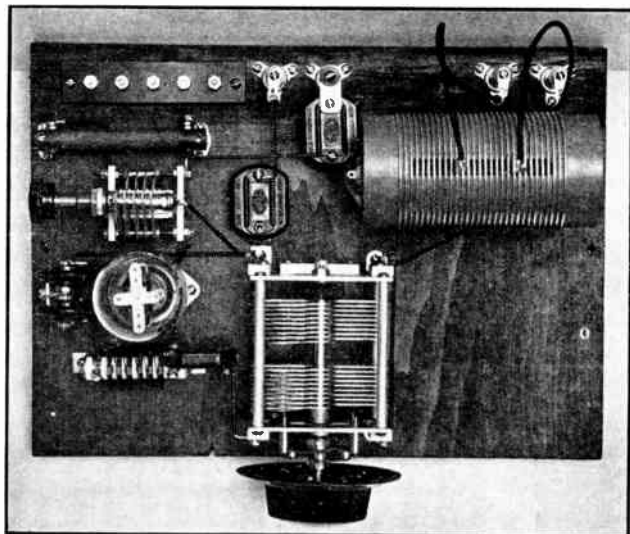


FIG. 721 — A PLAN VIEW OF THE 830 AMPLIFIER

The split-stator tank tuning condenser is centrally located on the baseboard; to its left are the plate blocking condenser, the plate r.f. choke, the tube socket, and the neutralizing condenser. Toward the rear are the grid r.f. choke and the two input coupling condensers. The plate tank coil and output terminals are in the upper right-hand corner. Connections for filament, plate and bias supplies are brought out to the terminal strip at the upper left, with wiring underneath the baseboard.

efficiency and output are low, and because the frequency relations of the amateur bands are such that even-harmonic output is necessary.

The simple doubler circuit is shown in Fig. 727-A. Neutralized circuits such as those in Fig. 717 also can be used. Special circuits for frequency doubling also have been employed. One which is often used is shown in Fig. 727-B. In this circuit two tubes are used; the excitation is fed to the grids in push-pull while the plates of the tubes are connected in parallel. Thus the tubes work alternately, and the output circuit receives two impulses for each r.f. cycle at the grids, resulting in all second-harmonic output. A regenerative circuit, especially suitable for indirectly-heated cathode tubes such as the 59, 2A5, etc., is shown at Fig. 727-C. It is really a controlled oscillator, its characteristics being such that it readily "locks in" with the frequency of the driving source when the plate

normal straight non-oscillating amplifiers, one or more intermediate stages would usually be required, so that the saving in apparatus may be appreciable. Very careful adjustment is required with the locked amplifier, however, since it will stay in step with the controlling oscillator over only a very small tuning range, and of course will lose the crystal stability as soon as it gets out of control. For this reason the locked amplifier has had relatively little application, most amateurs preferring to use straight amplification with its smaller likelihood of getting out of adjustment.

A typical locked amplifier circuit is shown in Fig. 728. The oscillating amplifier circuit will be recognized as the TNT, a circuit which is readily put to this use. The crystal oscillator may be any of the types previously described; the oscillator shown in Fig. 710 is especially suitable since it is capable of locking the amplifier on two bands with any one crystal. A short transmission line

turned on again, and the signal should take on the characteristics of the oscillator. Since the amplifier alone usually will be relatively unstable compared to the crystal oscillator, it is easy to tell when the two lock in.

A locked amplifier transmitter must be continuously monitored, since heating of the tube may cause enough of a change in the circuit constants to cause the amplifier to get out of step. Variations in antenna constants also can cause a like condition. If the amplifier becomes detuned sufficiently to get out of control, a whole series of beat notes usually will be heard in the monitor. A single, crystal-like signal in the monitor indicates proper operation.

The oscillator ordinarily is allowed to run continuously, keying being accomplished in the amplifier circuit. Since the amplifier is not neutralized, this often allows some energy from the oscillator to feed through to the antenna to cause a back-wave.

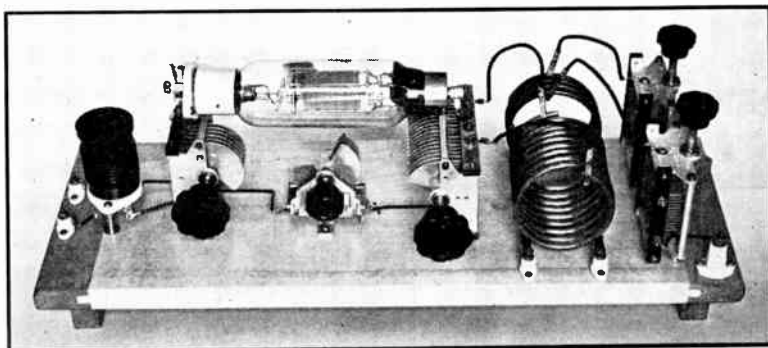


FIG. 722 — AN AMPLIFIER OF MODERATE POWER OUTPUT USING AN RK-18 TUBE

This amplifier is particularly suitable for the higher frequencies such as 14 and 28 megacycles. A grid driving power of three to five watts will produce a power output of about 50 watts with rated voltages on the tube. The circuit diagram is given in Fig. 723.

The physical layout almost exactly follows the circuit diagram. Input terminals are at the left. Beside them is the plug-in grid coil, wound on a receiving-coil form. The coupling coil, L_2 , is wound just below the grid coil on the form. The grid tuning condenser supports the tube socket. Underneath the tube is the neutralizing condenser. To its right is the plate tank condenser, followed by the plate and antenna-coupling coils, resting on bakelite rods for quick change of coupling, and finally, at the extreme right, the antenna tuning condensers.

Bypass condensers are underneath the baseboard, mounted close to their respective parts of the circuit so that short leads are possible. Plate, filament and bias supply leads are brought out to a terminal strip underneath the board at the rear.

(lampcord is satisfactory) with a turn or two at each end provides a simple and effective way of coupling the two oscillators.

A monitor is essential in the tuning of such a transmitter. With the amplifier plate voltage disconnected, the oscillator should be turned on and its signal tuned in on the monitor. Next, with the oscillator shut off, the oscillating amplifier should be started, and its plate tank circuit tuned to exactly the same frequency, as indicated by the monitor. Then the oscillator should be

Design of Complete Transmitters

▲ Up to this point consideration has chiefly been given to individual parts of the transmitter such as the oscillator, doubler and amplifier. A complete transmitter is simply a collection of one or more of such parts, or stages; the number of stages required depends upon the type of oscillator used, the power output required from the last stage, and the frequency or frequencies on which the transmitter is to work. Assuming

that the set is to be crystal-controlled, as are most modern amateur transmitters, the complexities will increase as the power output is increased, and also with the number of bands to be used.

Probably most amateurs who operate c.w. transmitters have their sets arranged to work in at least two and generally three amateur bands — 3.5, 7 and 14 mc. On the other hand, amateurs interested chiefly in 'phone transmission often work exclusively in a single band. A one-band

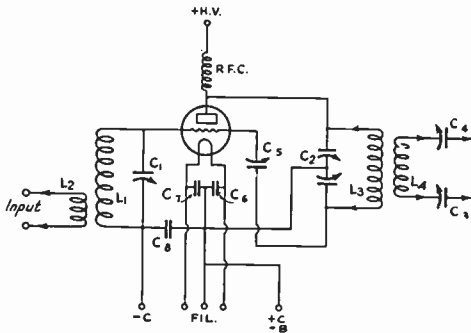


FIG. 723 — THE CIRCUIT OF THE HIGH-FREQUENCY AMPLIFIER

C_1 — 50- μ fd. variable grid tank condenser (Cardwell 410-B).

C_2 — Split-stator plate tank condenser; 75 μ fd. each section (Cardwell 413-B).

C_3, C_4 — 250- μ fd. antenna tuning condensers (Cardwell 406-B).

C_5 — 5- μ fd. neutralizing condenser (Cardwell 519).

C_6, C_7 — .005- μ fd. mica filament bypass condensers.

C_8 — .002- μ fd. mica grid bypass condenser.

RFC — High-frequency r.f. choke (National Type 100).

COIL DATA Grid Coils

	L_1	L_2
28 mc.	4 turns, coil length $\frac{5}{8}$ inch	2 turns
14 mc.	10 " " " 1 "	3 "
7 mc.	18 " " " 1 "	4 "
3.5 mc.	30 " " " $1\frac{1}{4}$ "	5 "
1.75 mc.	80 " " " $1\frac{1}{2}$ "	10 "

No. 20 or 22 wire may be used for the first four coils listed; the 1.75-mc. coil will require No. 28 d.s.c. In each case L_2 is close-wound at the bottom of the coil form, tightly coupled to L_1 . Diameter of all coils is $1\frac{1}{2}$ inches.

Plate Coils, L_2

28 mc. 4 turns 3/16-inch copper tubing, inside diameter $2\frac{1}{2}$ inches.

14 mc. 10 turns 3/16-inch copper tubing, inside diameter $2\frac{1}{2}$ inches.

7 mc. 24 turns No. 12 wire double-spaced, inside diameter $2\frac{1}{2}$ inches*.

3.5 mc. 45 turns No. 12 s.c.c. wire, no spacing, i.d. of coil $2\frac{1}{2}$ inches.

1.75 mc. 68 turns No. 16 d.c.c. wire, no spacing, i.d. of coil $3\frac{1}{2}$ inches.

Specifications for the 3.5- and 1.75-mc. bands call for plate coils of high inductance, since the plate tuning condenser has low maximum capacity. For 3.5- and 1.75-mc. work it may be more convenient to use a plate tank condenser, C_2 , of higher capacity, which will permit the use of smaller plate coils.

*No. 12 enamelled wire, double-spaced, will run six turns to the inch.

transmitter obviously will be somewhat easier to design than one which is to give approximately the same power output on several bands, since it is not necessary to provide for frequency changing.

Besides making certain that the power output will be adequate, consideration also should be given to convenience in operation — especially with reference to shifting the transmitter frequency from one band to another. For a given power output, too, there is usually a tube combination which will give greatest economy, tube and power-supply cost considered. For instance, if a power output of 100 to 150 watts is wanted, it can be obtained more cheaply by using tubes like the 203-A, 211, or 242-A than from the similarly-rated 852 or 860. Besides the lower cost of the first-named tubes, they give full output with a lower-voltage power supply, and the r.f. circuit parts need not have the high-voltage ratings required with the latter tubes. On the other hand, the 852 and 860 are designed especially for high-frequency work and ordinarily are capable of better operation than the others at the very high frequencies such as 14 and 28 megacycles.

Generally speaking, the most economical and conveniently-operated transmitter design will result when the largest possible power step-up is obtained in each stage and, consequently, the number of tubes and circuits is reduced to a minimum. With fewer stages, also, less trouble is likely to be encountered. This scheme works out very well for medium and high-power transmitters, especially when only two or three bands are to be covered. When more than three bands are to be used, however, recent practice has been to build the transmitter in two sections; one, an exciter unit, is designed simply to deliver a small amount of power on a great many bands, being equivalent in practice to having a crystal oscillator on each of the bands. The second section consists of one or more power amplifiers, the number required being determined by the power rating of the final stage. Both systems obviously have their advantages.

Before attempting to design a transmitter layout, it is urged that the foregoing sections on oscillators, amplifiers and frequency doublers be carefully studied, with particular attention being paid to the remarks on efficiency and required driving power. This information, together with the circuit data given, should enable any amateur to lay out a workable transmitter. It should be kept in mind, also, that it is better to err on the side of having too much excitation rather than too little, especially at the higher frequencies.

Very High Frequencies — LC Ratios

▲ The difficulties in getting a transmitter to function properly increase as the frequency is raised. A transmitter will "handle" about equally well on the 1.75-, 3.5- and 7-mc. bands, bands for

which, by coincidence, practical quartz crystals can be ground. Successful operation is fairly easy on these bands. On 14 and 28 megacycles, however, more care must be used in the construction and design of apparatus. For equally efficient operation on different bands, the *LC* ratios of the tank circuits used should be about constant, but since the tube and circuit capacities are approximately the same regardless of the band used, it becomes increasingly difficult to get "good" tank circuits at the higher frequencies. Besides this, the losses increase rapidly on these last two bands, making efficient operation even more difficult, while stray couplings which can be neglected on the lower frequencies often become sources of unstable operation. In practice, then, it is often found that tubes run hotter, efficiency is lower, and more excitation is required for the same output from a given type of tube operating at 14 and 28 mc.

For amplifiers, the optimum *LC* ratio is reached when the inductance is so por-

tioned that for tuning to the desired frequency a capacity of 250 $\mu\text{fd.}$ is needed on the 1.75- and 3.5-mc. bands, 100 $\mu\text{fd.}$ on the 7-mc. band, 50 $\mu\text{fd.}$ on 14 mc., and approximately 25 $\mu\text{fd.}$ on 28 mc. This does not mean that a different tuning condenser is required for each band,

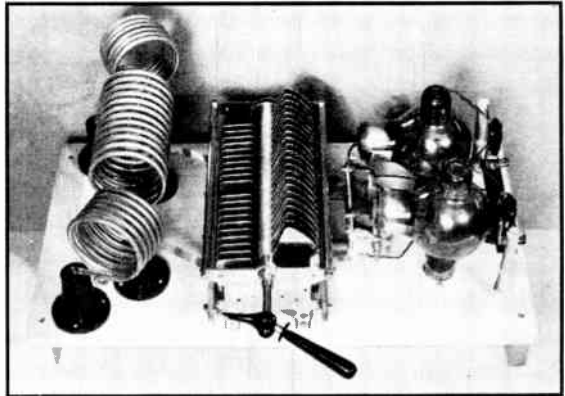


FIG. 724—A TYPICAL EXAMPLE OF THE USE OF 852 TUBES IN A PUSH-PULL AMPLIFIER

Grid chokes and coupling condensers can be seen at the right of the tubes, supported on a strip of bakelite. The tank and antenna coils are supported on large G.R. stand-off insulators — the coils being fitted with the large size G.R. plugs. Heavy copper strip furnishes the connection between the tank coil and condenser. The neutralizing condensers are underneath the projecting arms of the tubes.

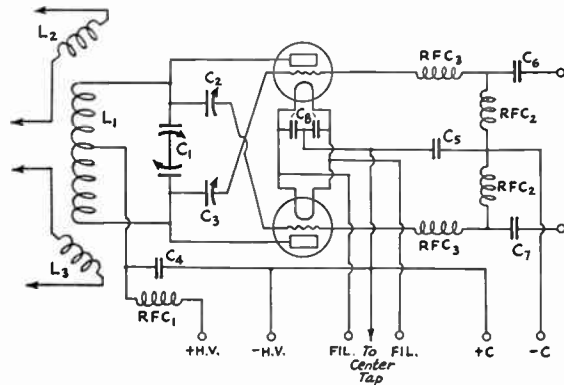


FIG. 725—CIRCUIT OF THE HIGH-POWER PUSH-PULL AMPLIFIER

- L*₁ — Plate tank coil; see coil table. The coil shown in the illustration is for 7000 kc. It has 12 turns of 1/4-inch tuning with 3-inch inside diameter turns.
- L*₂, *L*₃ — Antenna coupling coils. Six turns each, 3-inch diameter.
- C*₁ — Cardwell special type 16-B split-stator tank condenser, 100- $\mu\text{fd.}$ effective capacity, with neutralizing condensers attached.
- C*₂, *C*₃ — See above. Cardwell Type 519 condensers would serve as separate neutralizing condensers. The capacity required is approximately 5- $\mu\text{fd.}$ with about 1/4-inch spacing between plates.
- C*₄, *C*₅ — Plate and grid bypass condensers; .001 $\mu\text{fd.}$, 5000-volt rating.
- C*₆, *C*₇ — Grid coupling condensers; 100- $\mu\text{fd.}$, 5000-volt rating.
- C*₈ — .001- $\mu\text{fd.}$ filament bypass condensers.
- RFC*₁ — Plate r.f. choke; four-inch winding of No. 30 wire on a 1-inch tube.
- RFC*₂ — Grid r.f. chokes; three-inch winding of No. 36 wire on 1/2-inch wooden or bakelite rod.
- RFC*₃ — These are for the suppression of parasitic oscillations. They may not be found necessary. Ten turns of No. 14 wire wound on a pencil (the pencil being removed) will be suitable.

but simply that the actual capacity *in use* should be as recommended above. A single 250- $\mu\text{fd.}$ condenser might serve for all five bands, provided its minimum capacity is not more than 15 or 20 $\mu\text{fd.}$ The coil specifications given in the table are based on the actual capacity in use; for instance, with a 7-mc. coil of the size designed to resonate in the band with 100 $\mu\text{fd.}$ across it, a 250- $\mu\text{fd.}$ condenser would be set at about 1/3 full scale.

For 14- and 28-mc. work it is desirable that the tubes used be of the type designed for efficient operation at very high frequencies. Types such as the 10, 800, 801, 825, RK-18, and 852 are good examples of such tubes. Low-frequency tubes such as the 203-A, 211, 242-A, etc., work best at 7 mc. and lower, although they will give good results in proper circuits at 14 mc. Inductively coupled or transmission-line coupled circuits are best for these tubes at the very high frequencies, because the piling up of capacities which results when the output circuit of one tube and the input circuit of the next are both connected across the same tank coil — as in

capacity-coupled circuits — is avoided, and higher LC ratios are thereby made possible.

Some Practical Designs

▲ To illustrate a few of the ways in which transmitters may be designed, several types are shown, with circuit diagrams, in Figs. 729 to 738, inclusive. Although these are entirely practical sets, they are offered chiefly as examples, since space does not permit a detailed description of the construction and operation of each. For the benefit of those interested, a bibliography at the end of this chapter gives references to the issues of *QST* in which detailed information was presented.

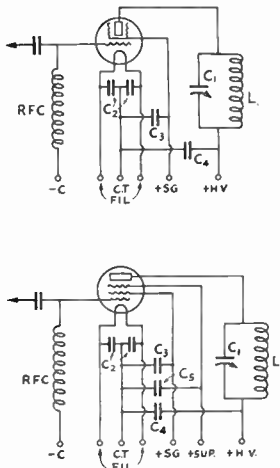


FIG. 726 — TYPICAL SCREEN-GRID AMPLIFIER CIRCUITS

The upper diagram is used with filament-type screen-grid power tubes such as the 865, 860, 282-A, 850, 254-A and 254-B. Important points to observe in the operation of the screen-grid amplifier are that the screen bypass condenser, C_3 , should have low impedance at the operating frequency (capacity of at least .002 μfd . for amateur transmitters) and that the output tank circuit L_1C_1 must be isolated from the input circuit, either by shielding or by physical spacing great enough to prevent feedback. Bypass condensers C_2 and C_4 may be the usual values used in power-tube circuits; .002 μfd . will be sufficient. Any type of input coupling shown in Fig. 714 may be used in place of the capacity coupling indicated.

For greatest efficiency the screen voltage should not be greater than the value recommended in the tube table for the type of tube used. Screen voltage is preferably supplied from a voltage divider across the plate supply.

The lower diagram is for use with r.f. screen-grid pentodes, in particular the Type RK-20 tube. It is essentially the same as the upper circuit except for the additional connections for the suppressor grid, which should be supplied a small positive voltage (about 50 volts) for maximum output. Values are the same for similarly-labelled components in both circuits. The RK-20 tube is characterized by high power sensitivity, resulting in an unusually high ratio of power amplification. A grid driving power of approximately two watts is sufficient to produce rated plate output of 50 watts with a plate voltage of 1000 and screen voltage of 300. C_5 should have the same value as C_3 .

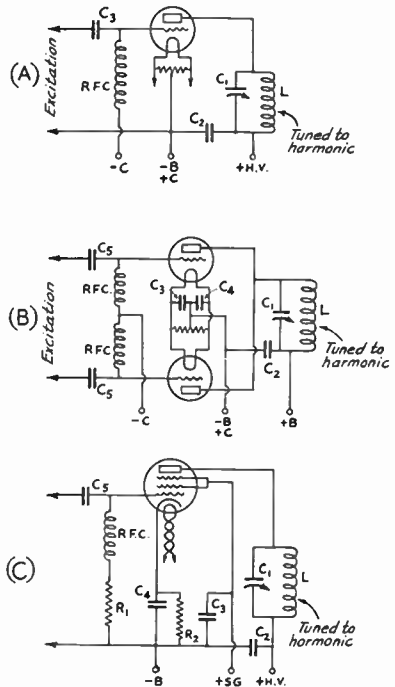


FIG. 727 — FREQUENCY MULTIPLYING CIRCUITS

The regular doubler circuit (A) is the simplest. The plate tuned circuit should be fairly low-C for best results; the capacity actually in use at C_1 should not exceed 100 μfd . at the lower amateur frequencies and 50 μfd . at 14 mc. and higher. C_2 is a plate bypass condenser having a capacity of about .002 μfd . The capacity C_3 , the grid coupling condenser, depends upon the type of tube; see the discussion on interstage coupling. Any of the recommended grid-coupling arrangements may be used instead of the simple capacity coupling shown.

Values in the "push-push" doubler (B) are in general identical with those in (A). This circuit requires push-pull input.

In the circuit at (C) tank circuit values should be the same as recommended above. C_2 and C_3 are the usual .002- μfd . bypass condensers. C_4 , which controls the regenerative effect, usually should be approximately 100 μfd .; so also should C_5 with the tubes most likely to be used in this circuit, the 59, 2A5, and their 6-volt equivalents. Grid leak, R_1 , should be 50,000 ohms and cathode resistor, R_2 , 1000 ohms.

Suitable coil specifications for the capacity in use at C_1 can be found by referring to the coil table.

An exciter unit capable of driving any type of amplifier requiring a few watts of grid excitation power is shown in Figs. 729 to 731. This unit uses two Type 59 tubes, one as an oscillator and the other as an amplifier or doubler. The oscillator is arranged to be used either as a tri-tet oscillator, tetrode oscillator, or as an electron-coupled oscillator when self-controlled operation is desired. The change between crystal- and electron-coupled operation is made simply by plugging the oscillator cathode coil into either of two sockets and using either a crystal or plug-in grid

condenser. Since the 59 is not a true screen-grid tube, the plate circuit of the oscillator must be tuned to the second harmonic when operating as an e.c. oscillator. For the same

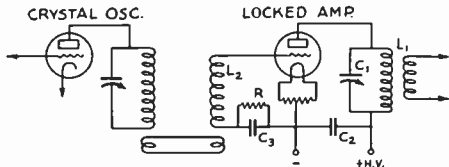


FIG. 728 — TYPICAL LOCKED AMPLIFIER CIRCUIT

The oscillating amplifier circuit is the TNT. Circuit constants will be the same as those recommended in the section on self-controlled oscillators. L_1 and C_1 are the usual tank inductance and capacity; fairly high-C is desirable, although not essential. C_2 and C_3 are the plate and grid condensers, respectively; L_2 is the untuned grid coil and R the grid leak. Adjustment of the circuit is described in the text.

reason, with crystal control the tube must be operated as a tetrode (practically speaking, the same thing as the pentode) oscillator when the output frequency is to be the same as that of the crystal. This is accomplished by connecting a short-circuiting link or jumper between the cathode of the tube and ground — or "B" negative — to complete the cathode circuit. The cathode coil sockets are left empty for this type of control.

The second 59 may be used either as a straight amplifier or as a doubler. Its circuit will be recognized as being that of Fig. 727-C. To avoid the necessity for neutralization when the tube is used as a straight amplifier, the oscillator plate coil, L_2 in Fig. 730, is not used, the coupling between oscillator and amplifier being accomplished by the r.f. choke shunted across C_2 . C_2 is set at minimum when L_2 is not used. Since the grid circuit of the amplifier is not tuned the tube will not oscillate, although this expedient reduces the coupling efficiency. The coil table gives the various coil combinations for operation on different bands. In the crystal-controlled table, a

3.5-mc. crystal is assumed except where specified otherwise.

Tuning of the oscillator and doubler is as described in the appropriate sections earlier in the chapter. At the plate voltages indicated in Fig. 730, the plate currents of the tubes will be approximately 20 to 30 milliamperes each when loaded.

Two Type 53 tubes are used in the exciter unit pictured in Fig. 729. Since a 53 actually is two tubes in one envelope, this particular arrangement gives the same effect as though four separate triodes had been used. An output of four or five watts, sufficient to excite the same types of amplifiers recommended for the 59 exciter unit, is obtainable on 1.75, 3.5, 7, 14 and 28 mc., using a crystal of the right frequency, and it is even possible to obtain small output on 56 mc. as well. Coils for the first three stages are plug-in; in the last stage, used only for 56 mc., the coil, L_1 , with the output coupling coil, L_2 , is permanently mounted on the tuning condenser, C_4 .

A plug-and-jack arrangement makes it possible to take the output of any one of the four stages and feed it through a twisted-pair transmission

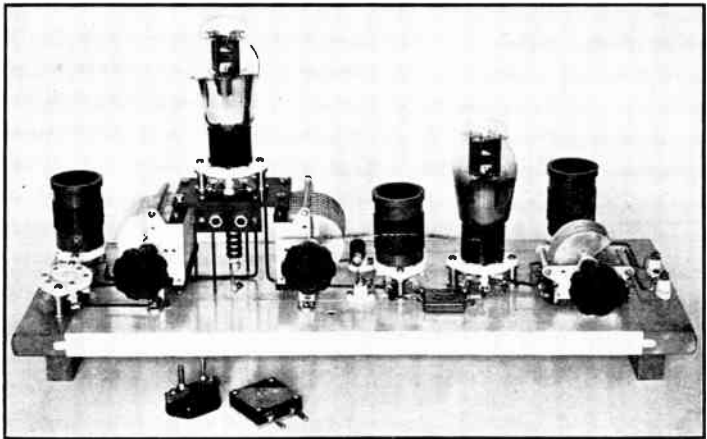


FIG. 729 — AN EXCITER UNIT USING TWO TYPE 59 TUBES, WHICH MAY BE OPERATED EITHER CRYSTAL- OR SELF-CONTROLLED

At the plate voltages recommended in the circuit diagram, Fig. 730, this exciter unit is capable of driving an RK-18 or 830 amplifier (such as the ones shown in Figs. 719 and 722) or a pair of 10's to rated output on four amateur bands. It would also provide sufficient excitation for a pair of RK-20's. The power output from the units is approximately 3.5 watts on 1.75 and 3.5 mc., 7 watts on 7 mc., and 5 watts on 14 mc.

In the photograph above, the two sockets at the left edge of the baseboard are for the oscillator coil; the one toward the front is used for crystal control, while that at the rear is for e.c. control. To the right of the coil sockets is the oscillator tuning condenser, C_1 , mounted edgewise so that the bakelite platform holding the oscillator tube socket can be bridged between the stator-plate terminals of this and the similarly-mounted plate tuning condenser, C_2 . Below the front edge of the platform is a bakelite strip equipped with two G.R. Type 274-J sockets for the plug-in crystal holder. To the right of C_2 is the socket for the oscillator plate coil, L_2 . Beside it is the r.f. choke which serves as a coupling impedance on the low-frequency bands. The doubler tube socket is on the other side, with the interstage coupling condenser, C_3 , between. The doubler plate tuning condenser, C_4 , the socket for L_3 , and the output terminals follow in order.

The remaining components are all mounted underneath the baseboard located in such fashion that short leads are possible.

line to an amplifier. Coupling coils, wound on the same form with the tank coils, are provided for this purpose. For operation on the crystal frequency, only the oscillator is used, all other coils being out of their sockets. When it is necessary to double once, both the oscillator and first doubler are used, the doubler being coupled via the transmission line to the amplifier. Three stages are used when it is necessary to double twice. Plug-in coils make possible the use of 1.75-, 3.5- and 7-mc. crystals in the oscillator.

In the exciter unit shown in Fig. 732 — which

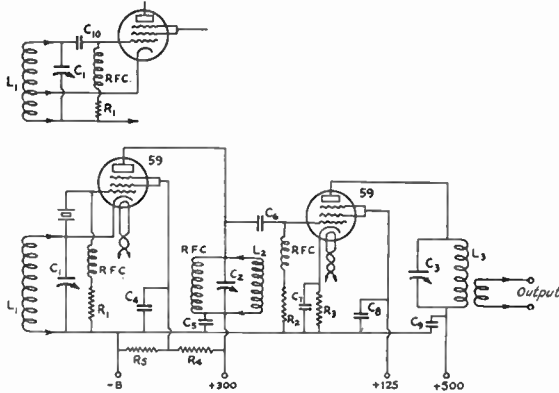


FIG. 730 — THE 59 EXCITER UNIT WIRING DIAGRAM

The alternative crystal and e.c. control circuits are shown as separate diagrams, although the choice actually is made in the unit by plugging L1 into either of two sockets and using a crystal or grid condenser as required. Wiring of the sockets is shown in Fig. 731.

- C₁ — Cathode tuning condenser, 350- μ fd. variable (Cardwell Midway Type 407-B).
- C₂ — Oscillator plate condenser, 100- μ fd. variable (Cardwell Type 412-B).
- C₃ — Doubler plate condenser, 50- μ fd. variable (Cardwell Type 410-B).
- C₄, C₅ — Oscillator screen and plate bypass condensers, .005- μ fd. (Dubilier Type 3).
- C₆ — Interstage coupling condenser, 100- μ fd. (Dubilier Type 4).
- C₇ — Doubler cathode condenser, 100- μ fd. (Dubilier Type 9).
- C₈, C₉ — Doubler screen and plate bypass condensers, .005- μ fd. (Dubilier Type 3).
- C₁₀ — Oscillator grid condenser, 250- μ fd. (Dubilier Type 9).
- R₁, R₂ — 50,000-ohm, 2-watt resistors (I.R.C.).
- R₃ — 1000-ohm, 5-watt wire-wound resistor (I.R.C.).
- R₄ — 10,000-ohm, 10-watt wire-wound resistor (Electrad).
- R₅ — 5000-ohm, 10-watt wire-wound resistor (Electrad).
- RFC — Universal-wound high-frequency chokes (National Type 100).

Coil data are given in the Table. All coils are wound on National six-prong receiving coil forms (diameter 1½ inches).

Coil and tube sockets are Isolantite, made by National. The knobs are G.R. Type 637-G.

The heaters of the two tubes are wired in parallel. No center-tap resistor is used in the exciter unit itself; a 20-ohm c.t. resistor should be connected across the heater winding at the power supply. The center-tap should be connected to -B.

is built for mounting on a rack — jacks are provided for reading the plate currents in each stage, the meter terminals being connected to a 'phone plug.

The circuits of the individual stages are the same as the simple triode crystal oscillator of Fig. 709 and triode doubler of Fig 727-A. The oscillator and doublers are tuned as described in previous sections. The coupling taps on the tank coils are used to avoid overloading the various stages, as previously described in the section on interstage coupling.

The exciter unit generally has an output of only a few watts at the most, which makes it impractical as a transmitter — except for very low-power work — unless it is used in conjunction with an amplifier. The same type and amount of apparatus — tuning condensers, coils, fixed condensers, etc. — can be used with somewhat larger tubes to make a transmitter having sufficient power output for ordinary communication, and which in turn can be used to excite a higher-power amplifier if at any time larger tubes are to be installed in the station. A transmitter of this type is shown in Fig. 734. It used a 47 crystal oscillator, operating on 3.5 mc., a 46 doubler which can be switched in or

COIL DATA FOR 59 EXCITER

Coil	Turns	Length of Winding	Tap*	Wire Size	Output Winding**
A	80		20	No. 28 d.s.c.	10
B	32	1¼"	8	No. 22 d.s.c.	5
C	15	1"	4	No. 22 d.s.c.	5
D	10	1"	3	No. 22 d.s.c.	3
E	7	1"		No. 22 d.s.c.	

Coil diameter is 1½ inches in all cases.
* Number of turns from ground end of coil.
** Turns close-wound.

Crystal Control

Output on	Coil at L ₁	Coil at L ₂	Coil at L ₃
1.75 mc.	B*	None	A
3.5 mc.	C	None	B
7 mc.	Jumper	B	C
14 mc.	C	C	D

E. C. Oscillator

Output on	Coil at L ₁	Coil at L ₂	Coil at L ₃
1.75 mc.	B	None	A
3.5 mc.	C	None	B
7 mc.	B	B	C
14 mc.	C	C	D

* 1.75-mc. crystal.

out of the circuit as needed, and a pair of 46's in parallel as a final amplifier on 3.5 and 7 mc. and as a doubler of 14 mc. This particular layout will give a crystal-controlled output of approximately 25 watts on either 3.5 or 7 mc., and 15 watts on 14 mc. at the voltages recommended in the circuit diagram, Fig. 735.

Band-switching complications are largely avoided by using the final amplifier as a doubler on 14 mc., but at some sacrifice of efficiency. The final stage is neutralized (regenerative) when doubling — as described in the section on doublers — so that the output is fairly good. All stages are adjusted in accordance with the instructions previously given. In normal operation the oscillator plate current will be approximately 20 to 30 ma., doubler plate current 40 to 50 ma., and amplifier plate current 100 to 120 ma. Plug-in coils are used only in the final stage. For 7- and 14-mc. work the switch *Sw*, Fig. 735, is thrown to the left, connecting the doubler in the circuit. For 3.5 mc. the doubler is cut out by throwing *Sw* to the right.

Actual neutralization of the amplifier on 14 mc. is difficult because the excitation is on 7 mc. A satisfactory setting of the neutralizing condenser can be reached by increasing its capacity until the amplifier self-oscillates, after which the capacity should be reduced slightly to prevent self-oscillation. This will give maximum safe regeneration and will result in improved efficiency and output over the non-regenerative state.

When the output tube of the transmitter is to be fairly large, the number of stages required can be reduced to a minimum by obtaining the larg-

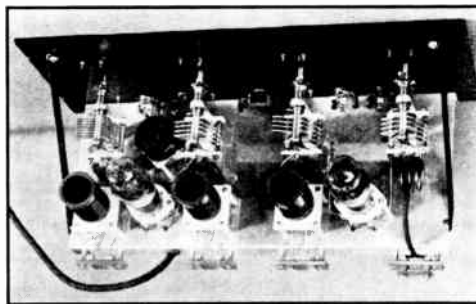


FIG. 732 — A PANEL-MOUNTED EXCITER UNIT USING TWO TYPE 53 TUBES

This unit, with appropriate crystals, will give sufficient output in five bands to excite a following low- or medium-power amplifier. Its circuit diagram is given in Fig. 733.

The tuned circuits run in regular order from left to right, starting with the crystal circuit at the left. A 56-mc. coil is shown mounted on the tuning condenser at the extreme right. Jarks for connecting the various stages to the transmission line are mounted on small insulating strips which project from the rear of the subpanel (at front in the photograph). The tuning condensers are insulated from the subpanel and are connected to the tuning dials by insulated couplings and extension shafts.

est possible power step-up in each stage. Reduction in the number of stages often is a desirable feature, not only because of economy but because the smaller the number of stages the less the chances for trouble. The transmitter shown in Figs. 736 and 738 illustrates this type of construction. Although only three tubes are used, considerable power output can be obtained on any of three bands with a single 3.5-mc. crystal. This set uses a 47 crystal oscillator, a 10 buffer amplifier or doubler, and a 203-A final amplifier. The buffer-doubler stage is arranged to cover both 3.5 and 7 mc. with a single coil and tank condenser, hence it is necessary to change coils only in the final stage of the transmitter to change bands.

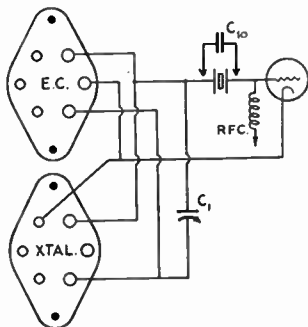
The 203-A is used as a straight amplifier on the 3.5- and 7-mc. bands, and as a doubler on 14 mc. just as was done in the case of the low-power transmitter described above. Operating convenience dictates this procedure, since another driving stage would be needed to operate the 203-A as a straight amplifier on 14 mc. The circuit is regenerative when doubling. At normal input to the tube (1000 volts, 150 ma.) the output is more than 100 watts on 3.5 and 7 mc., and 75 to 90 watts on 14 mc. Higher outputs can be secured by increasing the input. The oscillator normally operates at 350 volts and 30 ma., and the doubler at 500 volts and 60 ma. Tuning of the various stages should be done according to the directions given earlier in the chapter.

Other Circuit Combinations

▲ Tube and circuit combinations that can be worked out are numerous — so much so, in fact,



COIL CONNECTIONS



OSCILLATOR SOCKET CONNECTIONS

FIG. 731 — OSCILLATOR COIL AND SOCKET WIRING IN THE 59 EXCITER UNIT

The upper drawing shows the internal wiring of the coils, looking down into the coil form. The wiring of the two sockets into which L_1 may be plugged for either crystal or e.c. control is shown below.

that it is impossible in this chapter to do more than suggest a few. Some representative circuit diagrams are given in Fig. 739. They are offered chiefly as suggestions; parts of one circuit can be combined with parts of another, different oscillator circuits can be substituted for those shown for feeding one type of amplifier if the same or a similar-power driver tube is retained, or different interstage coupling and neutralizing arrangements can be substituted in the amplifiers, and so on. For example, in the circuit at (C) a pair of

Type 10 or 801 tubes could be substituted in the final amplifier; in fact any three-element tubes could be used. Similarly, an 841 or a 46 with Class-B triode connections could replace the 10 buffer-doubler. Plate and grid voltages suitable for the tube used should replace those indicated, of course. If more than one doubler stage is needed, a circuit identical with one of those shown could be placed between the existing doubler and amplifier diagrams. Simple changes in the filament wiring would make it possible to use tubes having indirectly-heated instead of directly-heated cathodes.

Circuit Values in Transmitters

▲ The practical circuit diagrams just given indicate the values of by-pass condensers and other circuit components in most general use. By-pass condenser values in particular are rarely critical. A by-pass is in the circuit simply to provide a low-impedance path for the flow of r.f. current, and so long as it does its intended job the value of capacity used does not matter. In the larger sizes, .01 μ fd. and up, however, condensers often will exhibit some inductance as well as capacity, so that there is a possibility that the condenser may be self-resonant at some high frequency. A condenser having such resonance will cause the circuit to work poorly at frequencies near the condenser's natural period. It is usually advisable to use mica condensers in high-frequency circuits, although non-inductively wound paper condensers often will give good service. In all purely by-pass applications, capacities of .002 μ fd. or larger will be satisfactory.

Condensers used for coupling two stages together may be more critical in value, as explained in the section on interstage coupling. In such cases the best value can be determined experimentally in case no definite specifications are at hand. In other coupling applications values between 100 μ fd. and 250 μ fd. will be satisfactory, although larger values sometimes are used.

Resistors which carry r.f. as well as direct current either should be non-inductive or should be bypassed by condensers of .002 μ fd.

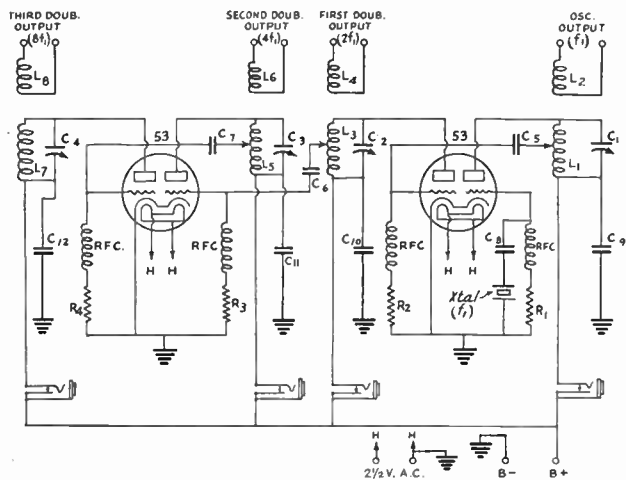


FIG. 733 — CIRCUIT DIAGRAM OF THE 53 EXCITER UNIT

In this circuit the number of stages in use is determined by the frequency at which output is desired and the frequency of the crystal. When both these frequencies are the same, only the oscillator is used. Other combinations readily can be worked out; for instance, if the crystal is on 3.5 mc. and 14-mc. output is wanted, a 3.5-mc. coil would be used at L₁, 7-mc. coil at L₃, and 14-mc. coil at L₅; if the crystal is on 7 mc. and output is wanted on 14 mc., a 7-mc. coil would be used for L₁ and a 14-mc. coil at L₃, etc.

- C₁ — Oscillator tuning condenser, 100 μ fd. (National Type SE-100).
- C₂, C₃, C₄ — Tuning condensers for first, second and third doublers, respectively; 20 μ fd. each (National Type SFU-20).
- C₅, C₆, C₇ — Interstage coupling condensers, .001 μ fd. each.
- C₈ — Insulating condenser, .001 μ fd.
- C₉, C₁₀, C₁₁, C₁₂ — Plate by-pass condensers, .01 μ fd. each.
- R₁ — Oscillator grid leak, 5000 ohms, 2-watt, non-inductive.
- R₂ — First doubler grid leak, 20,000 ohms, 2-watt, non-inductive.
- R₃ — Second doubler grid leak, 10,000 ohms, 2-watt, non-inductive.
- R₄ — Third doubler grid leak, 10,000 ohms, 2-watt, non-inductive.
- RFC — R.f. chokes (National Type 100).

Jacks are of the single-closed-circuit type.

Coil specifications are given in the table below. All are wound on 1 1/2-inch diameter receiving-coil forms with the exception of the 56-mc. coil. Link windings for output coupling (L₂, L₄, L₆, L₈) are each two turns of the same size wire as the main winding, and are wound between the turns of the latter at the ground end. Pin and socket connections should be the same for each coil and stage so that the coils will be interchangeable to give proper combinations with different crystals. The 56-mc. coil is a self-supporting winding of No. 10 wire, diameter of coil 1 1/4 inches.

Frequency	1.75 mc.	3.5 mc.	7 mc.	14 mc.	28 mc.	56 mc.
Total Turns	60	35	20	10	4	3
Tap Turns*	20	12	6	3	1 1/3	—
Length**	1 1/2"	1 1/2"	1 1/2"	1 1/4"	7/8"	1"
Wire Size	No. 28	No. 22	No. 16	No. 16	No. 14	No. 10

* Excitation tap turns are counted from ground end of coil.
 ** The turns are spaced to occupy the winding length given.



FIG. 734 — A CRYSTAL-CONTROLLED TRANSMITTER FOR OPERATION IN THREE AMATEUR BANDS

The circuit diagram is given in Fig. 735. The oscillator and doubler, using a 47 and 46 respectively, are mounted on the horizontal baseboard, with oscillator at the right. Tuning condensers and coils are located near the tubes with which they are associated. The switch for cutting the doubler in and out of the circuit is located between the two coils.

The final amplifier, two 46's in parallel, is mounted on the vertical baseboard. The tubes and neutralizing condenser are on a small shelf; above the tubes is the plate tank condenser. A bakelite strip with five G.R. jacks, mounted above the tank condenser, provides a plug-in socket for the amplifier plate tank and antenna-coupling coils, which are wound on the same form.

or more, otherwise the resistor will tend to act as an r.f. choke. Where the resistor need only carry one or two watts, non-inductive pigtail-type resistors are satisfactory and inexpensive.

Radio-frequency chokes may be home-wound or purchased. The manufactured sectional-wound chokes, using lattice or honey-comb type windings, are more satisfactory and work over a wider frequency range than home-made chokes. Home-wound chokes usually work best in a single amateur band, although a workable compromise often can be reached which will permit the choke to work well in two or three bands. Chokes are best wound with the smallest size wire which will carry the current in the circuit, and should be wound on a form of small diameter — one-half to one inch. Windings between two and three inches long, using No. 32 or 34 wire, will be found quite satisfactory as general-purpose chokes for moderate power.

Antenna Coupling

▲ In most of the circuit diagrams given in this chapter, a coil coupled to the tank coil of the os-

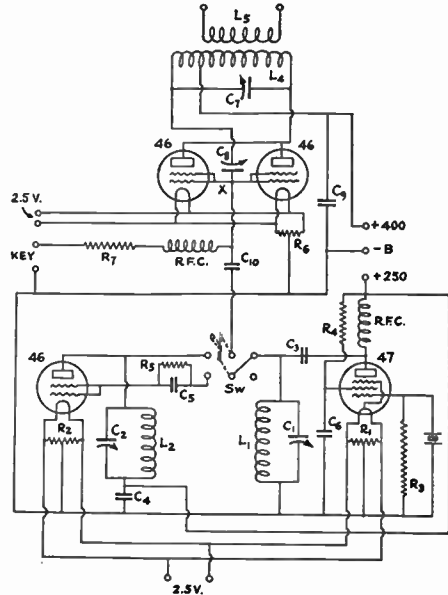


FIG. 735 — COMPLETE CIRCUIT DIAGRAM OF THE LOW-POWER CRYSTAL TRANSMITTER

- C₁ — Oscillator tuning condenser; 140- μ fd. midget condenser, Hammarlund.
- C₂ — Doubler tuning condenser; same as C₁.
- C₃ — Oscillator plate blocking condenser; 500- μ fd. mica condenser.
- C₄ — Doubler plate bypass condenser; same as C₃.
- C₅ — Coupling condenser; 100- μ fd. mica condenser.
- C₆ — Screen bypass condenser; .001- μ fd. mica condenser.
- C₇ — 150- μ fd. variable condenser (Cardwell 405-B).
- C₈ — 50- μ fd. midget condenser (Hammarlund MC-50-S).
- C₉ — .001- μ fd. mica condenser.
- C₁₀ — 40- μ fd. mica condenser (see text).
- R₁, R₂ — Filament center-tap resistors; 20 ohms, center tapped.
- R₃ — Oscillator grid leak; 5000 ohms, 2 watt.
- R₄ — Screen dropping resistor; 50,000 ohms, 5 watt.
- R₅ — Doubler grid leak; 20,000 ohms, 2 watt.
- R₆ — 20-ohm center-tapped resistor.
- R₇ — 1000 ohms, 2 watt.
- Sw — D.P.D.T. Porcelain-Base Switch.
- RFC — Short-wave choke (National Type 100).
- X — Ultra-high-frequency choke to be inserted here, if necessary, to prevent parasitic oscillation. A suitable coil can be made by winding 15 turns of No. 20 d.c.c. wire on a diameter of 1/4 inch.
- L₁ — Oscillator tank coil; 21 turns of No. 14 enamelled wire on 2" bakelite tube, spaced to occupy 2 inches.
- L₂ — Buffer tank coil; 11 turns same construction as L₁ but spaced to occupy 1 1/2 inches.

AMPLIFIER COIL DATA

Band	L ₄	L ₅
3500 kc.	20 turns tapped at 12th	8
7000 kc.	11 turns tapped at 7th	5
14,000 kc.	7 turns tapped at 4th	5

Taps are from plate ends of coils. L₄ turns are spaced to make length of 3500-kc. coil 2", 7000-kc. coil 1 1/2", 14,000-kc. coil 7/8". L₅ spacing between turns equal to approximately half the diameter of wire.

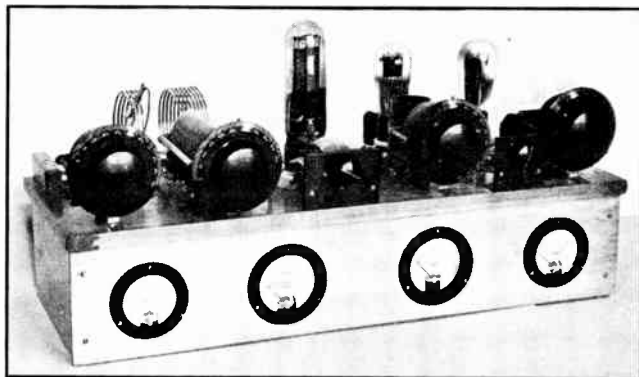


FIG. 736 — A THREE-TUBE CRYSTAL-CONTROLLED TRANSMITTER OF MEDIUM POWER OUTPUT

The circuit diagram is given in Fig. 737. The crystal oscillator is at the right, followed by the Type 10 buffer-doubler and the 203-A output tube. The variable condensers, going from right to left, are the oscillator tank condenser, buffer neutralizing condenser, buffer tank condenser, 203-A neutralizing condenser, 203-A tank condenser, and antenna tuning condenser. The two neutralizing condensers are mounted on small bakelite panels to insulate them from the baseboard. The final amplifier coils rest on glass rods. The filament by-pass condensers for the oscillator and doubler are mounted on short vertical pieces of copper tubing directly behind the tubes. The plate blocking condensers for the first two stages are located near the plate terminals on the sockets holding the tubes. All other fixed condensers and all r.f. chokes and bias resistors are mounted underneath the baseboard. Binding post strips at the back of the board furnish means of connecting to power and bias supplies. The rear view of the set, Fig. 738, will help give a clearer idea of the arrangements of the parts on the baseboard.

The narrow wooden panel below the baseboard holds an antenna ammeter, plate milliammeter for the final stage, filament voltmeter for the 203-A, and a plate milliammeter for the doubler.

illator or final amplifier is shown for transferring power from the transmitter to the antenna. The method of coupling the antenna to the set will not necessarily be by means of inductance coils, however; the type of antenna and feeder system used will often make a different type of coupling necessary. Coupling systems as a function of antenna and feeder design are treated in detail in the chapter on "Antenna Systems," to which the reader is referred for specific examples.

One type of antenna coupling arrangement, however, can be used to couple almost any type of transmitter to any type of antenna. Actually a low-pass radio-frequency filter, it provides a means of matching the load resistance represented by the antenna or feeders to the optimum load resistance for the oscillator or amplifier. Two types of filter are used, one for those antenna systems which involve bringing but a single wire into the station, and balanced or two-wire systems. The filters, with connections to a typical amplifier or oscillator, are shown in Fig. 740. In the unbalanced or single-ended system at A, the filter consists of the condensers C_1 and C_2 and the inductance coil L . In this case one side of the filter is grounded; on the other side the input terminal is tapped on the amplifier tank coil and the output terminal is connected to the antenna

or feeder. In the balanced system, two coils, L_1 and L_2 , are used; the input taps are equidistant from the ground point on the amplifier tank coil. Any type of amplifier or oscillator circuit can be substituted for that shown, although in the circuit at B the tank circuit should be balanced, i.e., the ground should come at the center of the tank. If the oscillator or amplifier is not parallel fed it is advisable to insert high-voltage blocking condensers of about .002 μ fd. capacity in series with the filter input leads, to insulate the antenna from the plate voltage.

Adjustment is as follows: With the filter disconnected, tune the amplifier or oscillator to resonance — the point of plate current minimum in the case of an amplifier or to the desired frequency in the case of an oscillator. Set the taps on L_1 (and L_2 , if used) approximately as indicated under the circuit diagram for the band in use. Connect the filter to the tank circuit, placing the taps about midway between ground and the "hot" end of the coil.

Apply plate voltage and rotate C_1 rapidly to find the point of plate current dip. This dip will not be to the no-load plate current value but probably will be to a value nearer the rated plate current of the tube. If the minimum plate current is too high, decrease the capacity of C_2 and retune C_1 to resonance; if the plate current is too low, reverse the procedure. The amplifier or oscillator tank condenser should not be touched during these adjustments.

Antenna current will be indicated by the ammeter A. The object of adjustment is to obtain the highest antenna current with the lowest plate current to the tube or tubes. Varying the inductance of L_1 and L_2 probably will help in attaining this result, although the inductance values usually are not critical.

Besides being universal in its application to transmitters and antenna systems, the antenna-coupling filter also will attenuate harmonic output, a highly-desirable feature.

Metering

▲ A certain number of meters is essential to the correct adjustment and operation of a transmitter. It will have been noticed particularly in all the foregoing discussion that frequent reference is made to the use of a plate-current milliammeter, without which adjustments become largely a matter of guesswork. It is not necessary, how-

ever, to have a separate plate meter for every tube or stage in the transmitter; by means of a plug and jack system such as was shown in Fig. 733 it is possible to read plate currents in any number of stages with but one milliammeter of suitable range.

The most suitable plate meter probably is one the full-scale reading of which is approximately twice the rated plate current of the tube (or tubes, if two are used in push-pull or parallel). Reference to the table of transmitting tubes will make it easy to select a meter of proper range if this rule is followed. For grid-current readings, a 0-100 milliammeter is satisfactory for practically all tubes except those of highest power. The method of connecting the meter for these readings has been given in Fig. 718.

With power tubes, especially those having thoriated tungsten filaments, a filament voltmeter represents an economy, since it will indicate whether the filament voltage is too high or too low, both conditions being detrimental to tube life. The voltage applied to a thoriated tungsten filament should never be more than 5% above or below the rated value. A filament voltmeter always should be connected near the tube socket, since there may be considerable voltage drop in the leads from the filament transformer to the socket, especially with tubes taking large filament currents.

Whenever possible, a meter should be located so that it is not in the field of a transmitting coil, since enough r.f. energy may be picked up to damage the movement. In parallel-fed circuits it is advisable to connect a by-pass condenser of about .002 $\mu\text{f}.$ capacity directly across the meter terminals so that any r.f. that escapes through the r.f. chokes in the transmitter will not have to flow through the meter itself.

The thermo-coupled antenna ammeter ranks next to the plate milliammeter in utility. Its range will be dependent upon the type of antenna system employed and the power output of the transmitter. For most low-power sets — up to 50 watts output — an ammeter having a 0-1.5 or 0-2 range will be satisfactory with current feed to the antenna or feeder system at the coupling point. When voltage feed is used the current is quite small and ammeters of ordinary range are not of much value. For outputs of 50 to 250 watts an ammeter of 0-4 or 0-5 amperes will be suitable.

Plate voltmeters are occasionally used by amateurs, but are not essential to the adjustment of the transmitter. They do afford a means of checking the actual voltage applied to the tube, however — the actual voltage often being considerably different from the power-supply transformer voltage — and make it possible to determine the power input with some exactness.

Harmonic Suppression

▲ Operating a power oscillator or amplifier at high efficiency results in a plate output having a greatly-distorted wave form; in other words, harmonics are present in considerable strength in the output. Since the output tank circuit is resonant only for the fundamental frequency the harmonics are filtered out to a large extent, but despite the filtering action of the tuned circuit there may be enough harmonic content in the

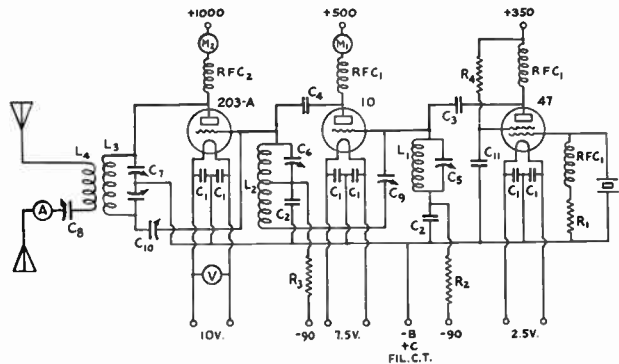


FIG. 737 — CIRCUIT DIAGRAM OF THE THREE-TUBE TRANSMITTER

- C_1 — Filament bypass condensers, 0.004 $\mu\text{f}.$ (not critical).
- C_2 — Grid bypass condensers, 0.002 $\mu\text{f}.$
- C_3 — Oscillator plate-blocking condenser, 100 $\mu\text{f}.$
- C_4 — Buffer plate-blocking condenser, 250 $\mu\text{f}.$
- C_5 — Oscillator tank condenser, 250- $\mu\text{f}.$ variable.
- C_6 — Buffer tank condenser, 350- $\mu\text{f}.$ variable.
- C_7 — Amplifier tank condenser, split-stator transmitting condenser; total capacity, sections in series, 100 $\mu\text{f}.$
- C_8 — Antenna tuning condenser, 500- $\mu\text{f}.$ variable.
- C_9 — Buffer neutralizing condenser, 50- $\mu\text{f}.$ midget variable.
- C_{10} — Amplifier neutralizing condenser, 50- $\mu\text{f}.$ transmitting variable (Cardwell 410-B).
- C_{11} — Oscillator screen bypass condenser, 0.002 $\mu\text{f}.$
- L_1 — 21 turns of No. 12 enamelled wire on 2-inch form, close-wound.
- L_2 — 10 turns of No. 12 enamelled wire on 2-inch form, spaced slightly less than diameter of wire. Neutralizing winding consists of 6 turns, close-wound, $\frac{1}{4}$ -inch from tank coil.
- L_3 — 3.5 mc.: 20 turns of $\frac{1}{8}$ -inch copper tubing, coil diameter $3\frac{1}{2}$ inches, spaced to make coil length 4 inches.
- 7 mc.: 9 turns of $\frac{1}{8}$ -inch copper tubing, coil diameter $3\frac{1}{2}$ inches, spaced to make coil length $1\frac{3}{4}$ inches.
- 14 mc.: 4 turns of $\frac{1}{8}$ -inch copper tubing, coil diameter $3\frac{1}{2}$ inches, spaced to make coil length 1 inch.
- L_4 — Antenna coupling coil, 4 turns, construction similar to L_3 .
- R_1 — Oscillator grid leak, 5000 ohms, 2-watt rating.
- R_2 — Buffer grid leak, 50,000 ohms, 2-watt rating.
- R_3 — Amplifier grid leak, 20,000 ohms, 10-watt rating.
- R_4 — Oscillator screen dropping resistor, 50,000 ohms, 2-watt rating.
- M_1 — 0-200 d.c. milliammeter.
- M_2 — 0-300 d.c. milliammeter.
- V — 0-15 a.c. voltmeter.
- A — 0-2.5 r.f. ammeter.

power delivered to the antenna to cause interference on the harmonic frequencies. Since harmonics often will fall outside the frequency bands assigned to amateurs, there is danger of off-frequency operation as well. The amateur regulations require that the transmissions shall be as free from harmonics as the state of the art permits.

utilizing a grounded-rotor split-stator tuning condenser — see Fig. 717-G — are more effective in eliminating harmonics than the type shown in 717-F.

Aside from those steps which can be taken to reduce harmonics in the plate circuit of the final amplifier stage, beneficial results can be secured

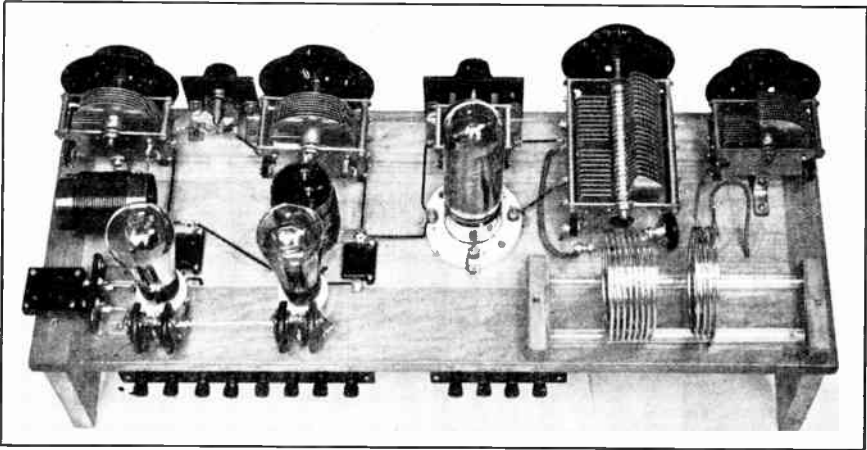


FIG. 738 — A REAR VIEW OF THE THREE-TUBE THREE-BAND TRANSMITTER

This photograph shows more clearly than the front view the way in which the parts are arranged on the baseboard. The crystal holder plugs into a mounting just to the left of the oscillator tube.

The use of an output tank circuit having a relatively large capacity-to-inductance ratio (high- C) will reduce harmonics. While this is quite usual practice in self-controlled transmitters, the use of low- C tank circuits in oscillator-amplifier transmitters is general because the efficiency is higher with low- C . Nevertheless, slightly lower efficiency with high- C is preferable to off-frequency operation. Loosening the antenna coupling also will reduce harmonic radiation.

In neutralized amplifier circuits, those neutralizing schemes in which the tube output is connected across a condenser — such as those in Fig. 717-C and 717-G — will discriminate against harmonics to a greater extent than the systems in which the grid and cathode are connected across part of a tapped coil, such as 717-B. This is because the condenser more effectively short-circuits the harmonics than the coil; in other words, the condenser impedance at the harmonic frequencies is smaller than the coil impedance at those same frequencies.

The push-pull amplifier possesses the characteristic of suppressing the even harmonics in its output circuit, although odd harmonics will be present to the same degree as in single-tube amplifiers of equivalent power output. Since the second harmonic is the most serious offender, however, the use of push-pull will do much to eliminate harmonic radiation. Those circuits

by using certain types of antenna coupling and feeder systems. Inductive coupling to the feeder is preferable to direct coupling, from the standpoint of harmonic elimination. Likewise, the coupling coil should be coupled to the tank at a point of low r.f. potential — at the filament end in output systems which are not balanced with respect to ground; at the center of the coil in balanced systems — to prevent electrostatic coupling between the tank and feeder circuits. Feeder systems having a current loop at the coupling apparatus will discriminate against even harmonics; a quarter-wave Zepp feeder is an example of this type of feeder system. Directly-coupled feeders will do little to prevent the radiation of harmonics; the directly-coupled single-wire fed antenna is practically as good a radiator at harmonics as at the fundamental frequency.

As for the antennas themselves, those systems which are center-fed through a low-impedance untuned transmission line will discriminate against even harmonics; an end-fed antenna or one fed through a high-impedance line such as the single-wire system and the doublet with fanned feeders will not, practically speaking. Grounded antennas (Marconi type) and center-fed antennas without transmission lines (sometimes called antenna and counterpoise) also are poor radiators of even harmonics.

The antenna-coupling filter previously described is effective in preventing harmonic radiation. Because of the properties of the filter, frequencies higher than the fundamental, to which the filter is resonant, are practically short-circuited and do not reach the antenna.

To check for harmonic radiation it is necessary to enlist the coöperation of another amateur station a few miles distant from the transmitter. Have the other operator listen for the harmonics to check their strength relative to that of the fundamental frequency. If a strong harmonic is detected, steps should be taken to reduce its strength. The discussion above should be of assistance.

If it is inconvenient to make major changes to the apparatus or antenna and feeder system, harmonics often can be brought to satisfactorily low strength by the use of tuned trap circuits. One method which has proved successful in a number of cases is shown in Fig. 741. The trap circuits are tuned to the frequency of the harmonic to be eliminated; a simple unilateral connection is used between the trap and the antenna or feeder. Best results will be secured by listening to the harmonic in the monitor while the trap condenser is slowly varied; the minimum point should be quite clearly defined. The tuning can be checked by having another station listen while the trap is tuned. A low-*C* trap seems to be most

FIG. 739 — SOME CRYSTAL-CONTROL TRANSMITTING LAYOUTS

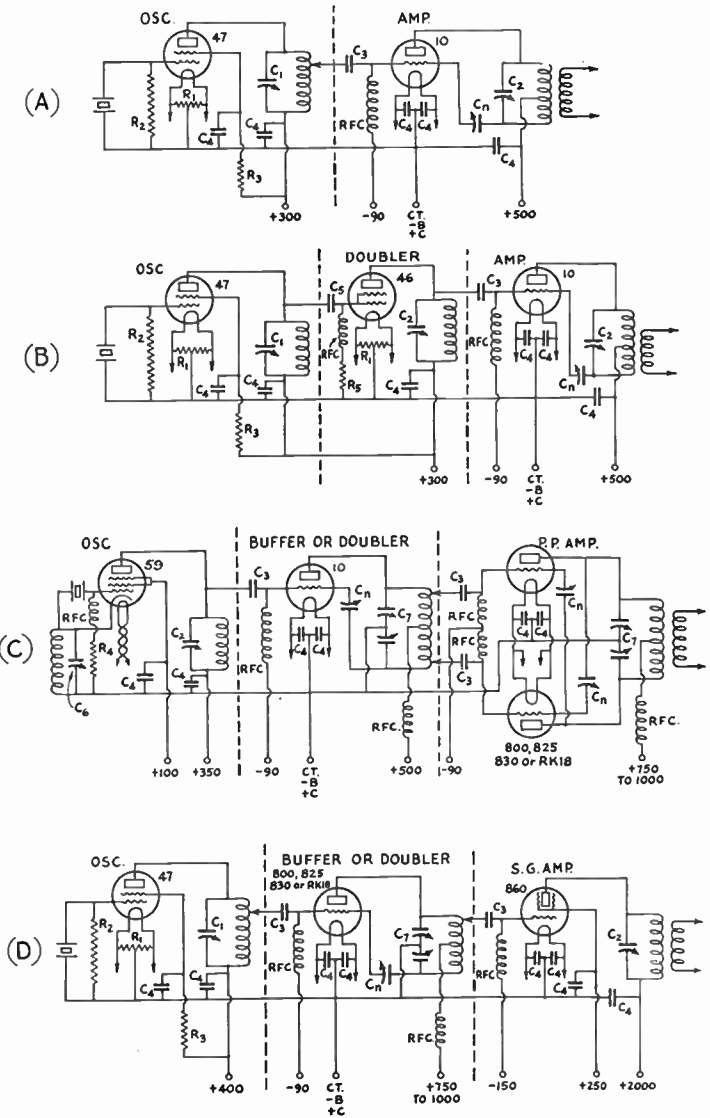
As with the self-controlled circuits of Fig. 733, substitutions or modifications can be made in any of these circuits.

The simple crystal oscillator and amplifier shown at A is good for operation in only one or at the most two bands with a single crystal; the amplifier can be used as a doubler for operation on the second harmonic of the crystal frequency. The arrangement at B will work on two bands. Circuit C illustrates the use of the Tri-tet oscillator, neutralized buffer or doubler, and changing from a single-ended stage to push-pull. In D the power step-up in each stage is greater than in the first three circuits; this transmitter could be used with good results on three bands.

Circuit values should be approximately as follows:

- C₁ — 250- μ fd. variable condenser.
- C₂ — 100- μ fd. variable condenser.
- C₃ — 100- μ fd. fixed mica condenser.
- C₄ — .002- μ fd. or larger fixed mica condenser.
- C₅ — 50- μ fd. fixed mica condenser.
- C₆ — 350- μ fd. variable condenser.
- C₇ — 100- μ fd. (both sections in series) split-stator condenser.
- C₈ — Neutralizing condenser; see Tube Table and section on "Neutralizing."
- R₁ — 20 ohms, center-tapped.
- R₂ — 10,000 ohms.
- R₃ — 50,000 ohms.
- R₄ — 100,000 ohms.
- R₅ — 5000 ohms.

Tank coil sizes will be found in the table of coil specifications; select a coil which will tune to the desired frequency in conjunction with the variable condenser recommended.



effective. The trap will not affect the fundamental output of the transmitter.

Parasitic Oscillations

▲ If the circuit conditions in an oscillator or amplifier are such that oscillations at some fre-

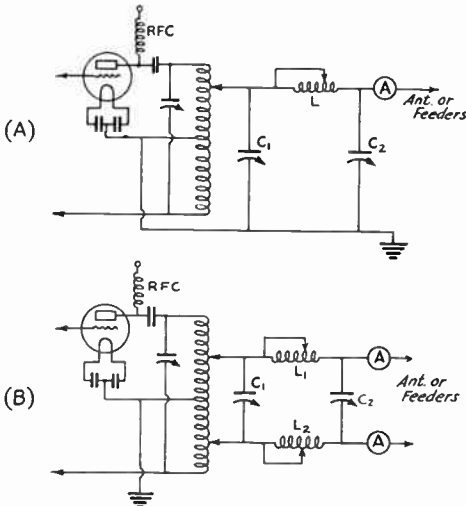


FIG. 740 — ANTENNA-COUPLING FILTERS

Their use and adjustment is explained in the text. Condensers C_1 and C_2 should have a maximum capacity of 250 $\mu\text{fd.}$ or more, with plate spacing sufficient to withstand the r.f. voltages developed by the transmitter. For powers up to 50 watts, receiving-condenser spacing will be satisfactory; for higher power, transmitting-type condensers should be used.

For operation from 1.75 to 14 mc., the inductances L_1 and L_2 should be 30 turns each wound to a 2½-inch diameter and 5½ inches long, tapped every five turns. Approximate settings on L_1 and L_2 are 30 turns for 1.75 mc., 15 turns for 3.5 mc., 10 turns for 7 mc., and 5 turns for 14 mc. The coils may be wound with No. 12 or No. 14 enamelled wire.

quency other than that desired can and do exist, such oscillations are appropriately termed "parasitic." The energy required to maintain a parasitic oscillation is wasted so far as useful output is concerned, hence an oscillator or amplifier afflicted with parasitics will have low efficiency and frequently will operate erratically. In addition, parasitic oscillations in the self-controlled oscillator can ruin the frequency stability and spoil completely the character of the note.

Parasitic oscillations may be higher or lower in frequency than the nominal frequency of the oscillator or amplifier. Low-frequency parasitics are relatively uncommon, but occasionally exist as the result of unfortunate choice of by-pass condenser and r.f. choke values. One way in which such a parasitic oscillation can be generated is shown in Fig. 742. A driver and neutralized amplifier are indicated, but this type of oscillation can exist in any circuit having r.f. chokes in both the plate and grid circuits. There is al-

ways some capacity shunting the chokes; if the inductances of the chokes and the shunting capacities happen to be such that both chokes are tuned to approximately the same frequency, a tuned-grid tuned-plate type of oscillation may be set up. The normal tank circuits will have but little effect on the oscillation. If oscillations of this type occur they can be avoided, usually, by changing the size of the plate by-pass condenser or by removing a choke in a series-feed circuit. In general, it is better to omit r.f. chokes with series feed and depend upon the by-pass condensers to keep the r.f. currents in the right path. If the by-pass condensers are large enough the chokes will not be necessary.

A type of parasitic oscillation peculiar to the neutralized amplifier is indicated in Fig. 743. It results from the use of a tapped plate tank coil for neutralizing and a similar tap on the driver tank coil for control of excitation. The parasitic circuit, again a t.p.t.g. type of oscillation, is through the shaded parts of the tank coils. This is a particularly vicious type of parasite; it is a persistent oscillator and usually requires a change in the design of the transmitter for its cure. A neutralizing circuit using a split-stator condenser (Fig. 715-C) will cure it; so also will discarding the tap on the driver tank, feeding the amplifier grid through a smaller coupling condenser connected directly to the plate end of the driver tank coil. The latter scheme does not result in particularly efficient coupling between driver and amplifier, however. A change to inductive or transmission-line interstage coupling also will be beneficial.

Fig. 744 shows one way in which ultra-high frequency parasitic oscillations can be set up in a neutralized amplifier; the same type of oscillation could exist in a Hartley oscillator with too-long leads. The leads to the tank circuit, if more than a few inches long, possess enough inductance to tune the shaded circuit in the three- to five-meter region; an ultraudion-type oscillation is set up. Changing the physical layout to shorten the leads should eliminate the parasitic.

Ultra-high frequency parasitic oscillations sometimes occur when tubes are connected in parallel because of the length of the leads connecting the grids and plates of the two tubes. The same type of oscillation can occur in push-pull circuits if the leads from the

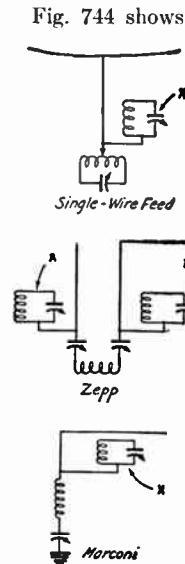


FIG. 741 — TUNED TRAP CIRCUITS TO REDUCE HARMONIC RADIATION

grids and plates of the two tubes to the tank circuits have approximately the same length. Such oscillations can be eliminated by putting small r.f. chokes in either the plate or grid leads, but not in both. The chokes can consist of a few turns of

shorted turns in the inductances. Different sizes of neutralizing condensers may also be tried, since circuit conditions vary considerably with different physical layouts. If a setting of the neutralizing condenser can be found which gives minimum r.f. in the plate tank circuit without completely eliminating it, the chances are that there is some magnetic or capacity coupling between the input and output circuits external to the tube itself. Short leads in neutralizing circuits are highly desirable, and the input and output inductances should be so placed with respect to each other that magnetic coupling is minimized. Usually this means that the axes of the coils should be at right angles to each other. In some cases it may be necessary to shield the input and output circuits from each other. Magnetic coupling can be checked for quite readily by removing the amplifier tube from its socket and testing for r.f. in the plate tank circuit as the tank condenser is swung through resonance.

Low output from an amplifier usually can be traced to one of the above causes or to lack of sufficient excitation. The rectified grid current gives a fairly good indication of the amount of excitation, although the meter reading does not mean a great deal unless the recommended bias is used on the tube. The bias may readily be calculated in case a grid leak is used, as explained previously. The grid current reading should be made with the plate voltage on the tube and with the load connected, since the grid current is higher with no plate voltage. The values given in the tube table refer to operating conditions, with the tube delivering power output at rated plate voltage and current. An amplifier cannot be considered to be fully excited until, with fixed plate voltage and load coupling, a further increase in excitation does not produce a corresponding in-

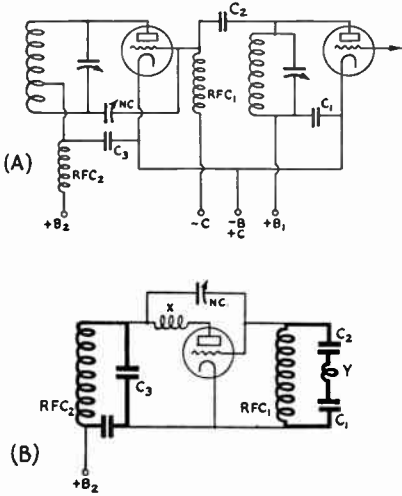


FIG. 742—HOW LOW-FREQUENCY PARASITIC OSCILLATIONS CAN BE GENERATED

fairly heavy wire (No. 18 or larger) wound in a coil having a diameter of about a quarter inch.

Other Transmitter Troubles

▲ The parasitic oscillations just discussed are one of the chief causes of inefficiency in oscillator-amplifier transmitters, although this is not always realized by the builder and operator. If an amplifier tube runs hot or behaves erratically for no apparent reason, it should be tested for self-oscillation by shutting off the excitation and reducing the bias on the tube until it draws some plate current. Under these conditions the parasitic oscillation usually will start and may be detected with the aid of a neon lamp touched to various parts of the circuit. If the plate current is found to vary as the tuning condensers are swung through their range or when the plate or grid of the tube is touched with the finger (needless to say, the finger test should not be used when the plate voltage is high enough to cause serious shock) the tube is almost certainly oscillating. An absorption wavemeter of wide range, such as the one described in Chapter Six, will be helpful in determining the oscillation frequency. Once the frequency is known, the circuit can be analyzed with the aid of the diagrams just given and the proper remedies applied.

Trouble is sometimes experienced in neutralizing amplifiers. In cases of this kind the circuit should be checked over carefully to make sure that all connections are good and that there are no

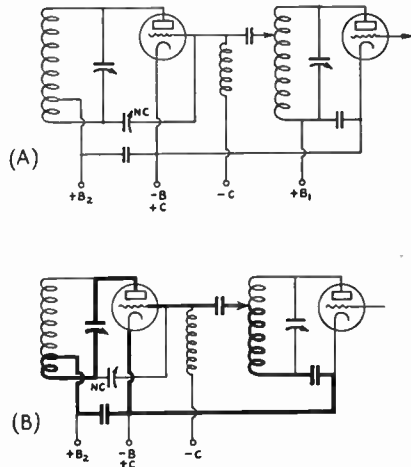


FIG. 743—A HIGH-FREQUENCY PARASITIC CIRCUIT RESULTING FROM THE USE OF A TAPPED EXCITATION COIL

crease in power output. An amplifier and driver which cannot stand this test is not operating at

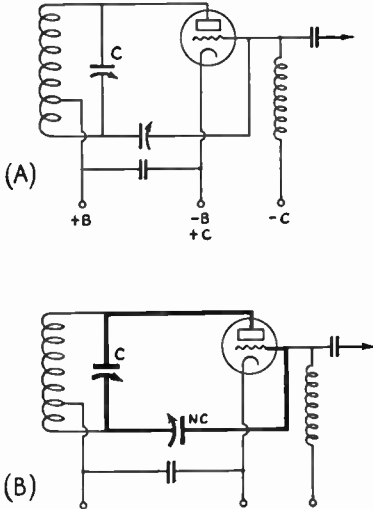


FIG. 744 — ULTRA-HIGH-FREQUENCY OSCILLATIONS CAN BE GENERATED IF THE LEADS FROM THE AMPLIFIER TUBE TO THE TANK CONDENSER ARE TOO LONG

the highest efficiency, and in radio-telephone transmitters will not be suitable for plate modulation.

Some of the receiving tubes used in low-power

transmitters, especially those having indirectly-heated cathodes or oxide-coated filaments, are prone to grid emission troubles which result when the temperature of the control grid becomes too high. Electron emission from the grid manifests itself by a gradual rise in the plate current of the tube after a short period of operation. Since the effect is cumulative, the plate current, once started climbing, will continue to rise until the tube is damaged unless the power is shut off. The most certain remedy for this condition is to reduce the power input to the point where the temperature of the grid stays at a low-enough value to prevent grid emission. This trouble is less frequently encountered in power tubes having thoriated tungsten filaments, and then rarely occurs unless the tube is greatly overloaded.

Bibliography

- ▲ The transmitters listed below have been described in detail in the following issues of *QST*:
 - Low-power crystal oscillator, Fig. 710: March, 1934.
 - Single-tube amplifier, Fig. 719: May, 1934.
 - Single-tube amplifier, Fig. 722: December, 1933.
 - Exciter unit, Fig. 729: November, 1933.
 - Exciter unit, Fig. 732: October, 1934.
 - Low-power transmitter, Fig. 734: November, 1932, and February, 1933.
 - Three-tube transmitter, Fig. 736: February, 1934.

SOME SUGGESTED COIL SPECIFICATIONS

Band →	1750				3500				7000				14,000			28,000		
	500	250	100		500	250	100	50	500	250	100	50	250	100	50	250	100	50
Max. condenser capacity— μ fds.	500	250	100		500	250	100	50	500	250	100	50	250	100	50	250	100	50
* $1/4$ " c.t., i.d. $1\frac{1}{2}$ "	—	—	—		—	—	—		9	17	—	—	5	11	—	2	4	6
$1/4$ " c.t., i.d. 2 "	—	—	—		18	—	—		6	10	22	—	4	7	12	—	3	5
$1/4$ " c.t., i.d. $2\frac{1}{2}$ "	—	—	—		12	—	—		5	7	15	—	3	6	9	—	2	4
$1/4$ " c.t., i.d. 3 "	—	—	—		10	17	—		4	6	12	—	—	5	7	—	—	3
$1/4$ " c.t., i.d. 4 "	20	—	—		7	11	24		—	—	8	15	—	—	5	—	—	—
$1/4$ " c.t., i.d. 6 "	12	20	—		—	—	24		—	—	10	—	—	—	—	—	—	—
* $3/16$ " c.t., i.d. $1\frac{1}{2}$ "	—	—	—		—	—	—		8	13	—	—	5	10	16	2	4	6
$3/16$ " c.t., i.d. 2 "	—	—	—		16	—	—		5	9	20	—	4	7	10	—	3	4
$3/16$ " c.t., i.d. $2\frac{1}{2}$ "	—	—	—		11	20	—		4	6	14	24	3	5	7	—	2	3
$3/16$ " c.t., i.d. 3 "	27	—	—		9	15	—		—	—	10	20	—	4	6	—	—	—
$3/16$ " c.t., i.d. 4 "	18	32	—		—	10	22	40	—	—	—	13	—	—	—	—	—	—
No. 12 wire, spaced $1\frac{1}{2}$ "	—	—	—		16	28	—		6	9	19	—	4	7	11	—	3	4
No. 12 wire, spaced 2 "	34	—	—		10	19	40		4	7	13	24	3	5	8	—	2	3
No. 12 wire, spaced $2\frac{1}{2}$ "	24	45	—		8	14	29	50	—	5	10	16	2	4	6	—	—	3
No. 12 wire, spaced 3 "	18	34	—		—	11	22	40	—	—	8	12	—	—	—	—	—	—
No. 12 wire, spaced $3\frac{1}{2}$ "	16	26	54		—	9	15	30	—	—	—	—	—	—	—	—	—	—
No. 14 wire, d.c.c. $1\frac{1}{2}$ "	30	53	—		10	17	35	—	—	7	11	22	3	6	8	—	2	4
No. 14 wire, d.c.c. 2 "	20	35	75		8	12	24	40	—	5	9	16	2	4	6	—	—	—
No. 14 wire, d.c.c. $2\frac{1}{2}$ "	16	25	53		7	10	19	32	—	4	8	12	—	3	5	—	—	—
No. 14 wire, d.c.c. 3 "	14	22	40		—	9	16	24	—	—	7	10	—	—	—	—	—	—

* Spacing between turns (not centers) is $1/8$ " for these coils. Abbreviations — Copper tubing, c.t.; inside diameter, i.d.
¹ Spacing between turns, in this case, equals wire diameter.
 Where blanks appear in the above table, coils of this construction are not recommended for that frequency and condenser capacity.

CHAPTER EIGHT

RADIOTELEPHONY

ALTHOUGH radiotelephony is closely akin to c.w. telegraphy and the 'phone transmitter might be considered as simply a c.w. set with additional equipment to give voice modulation to its output, 'phone not only is much more complex than c.w. in point of apparatus involved but also demands a sharply different and more rigorous technic; for the 'phone transmitter not only must have radio-frequency equipment typical of the good c.w. set and audio-frequency equipment to accomplish voice modulation, but also there must be proper coordination of the r.f. and audio units to insure that the outfit's performance meets modern requirements. The carrier frequency must be stable; the modulation capability must be high; and there must be no detrimental distortion. Fortunately the satisfaction of these requirements can be realized by following the well-defined rules subsequently outlined and without resort to hit-or-miss guessing. Actual experience gained from the construction and operation of the exemplary amateur transmitters described in this chapter has tried these principles; and their widespread application in modern commercial transmitters is a further recommendation. The amateur can profit by following them closely.

Modulation

▲ *Amplitude modulation is the process by which the amplitude of the transmitted radio-frequency wave is varied in accordance with the sound waves actuating the microphone. When the wave is detected or demodulated in the receiver, as explained in Chapter Four, there should result a true reproduction of the original modulating signal.*

By definition, *percentage modulation is the ratio of half the difference between the maximum and minimum amplitudes of a modulated wave to the average amplitude, expressed in percent.* When the variation in amplitude is symmetrical above and below the unmodulated carrier amplitude, as shown in "A" and "B" of Fig. 802, the average amplitude is the same as the carrier amplitude and the *percentage of modulation is the ratio of the difference between the maximum amplitude and the carrier amplitude to the carrier amplitude, multiplied by 100.* That is,

$$M = \frac{i_{\text{mod}} - i_{\text{car}}}{i_{\text{car}}} \times 100.$$

In case of unsymmetrical modulation (over-modulation) such as that suggested by "C," the average amplitude is no longer the same as the unmodulated amplitude and distortion results, even though the modulating signal is a pure tone. This effect is known as "carrier shift" because it is equivalent to a shift in average amplitude, sometimes being upward as in "C" and sometimes downward. The latter might occur in a transmitter which had less than 100-percent modulation capability. Either causes distortion, a broad signal and needless interference.

The process of modulation, involving combination of the carrier radio frequency and the modulating audio frequency, produces two additional frequencies coexistent in the output. These are the side-band frequencies, the carrier plus the modulating frequency (the upper side band) and the carrier minus the modulating frequency (the lower side band). At amateur-band frequencies, present technic requires the transmission of the carrier and both side bands although it is theoretically possible to communicate with the carrier and only one side band transmitted, or even with the carrier suppressed, since the carrier is only useful for beating with the side band frequencies to reproduce the original signal in the receiver's detector output. A locally

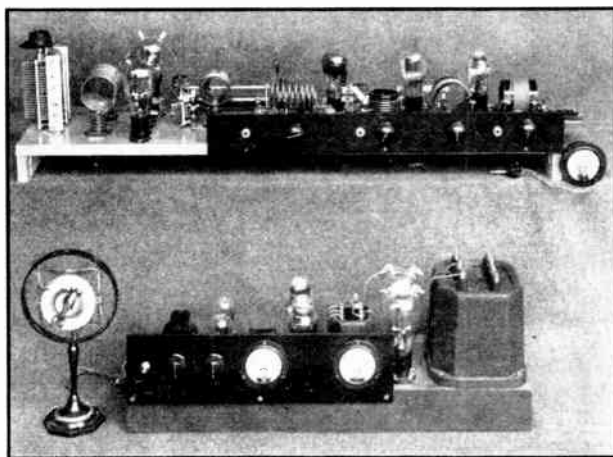


FIG. 801—THE R.F. UNIT (ABOVE) AND THE AUDIO UNIT (BELOW) OF A MODERN AMATEUR 100-WATT RADIOTELEPHONE TRANSMITTER DESIGNED AND CONSTRUCTED BY W2BRO

generated carrier might be used for this purpose.

The radiated power is considered to be divided between the carrier and the side bands. Considering the case of 100% modulation shown in A, Fig. 802, one-third of the total power is divided equally between the side bands, two-thirds being in the carrier. Since the maximum amplitude (peak current) is twice the carrier amplitude, the *instantaneous peak power* must be four times the carrier power because the antenna (load) resistance is constant and the power is therefore proportional to the square of the current. Using *effective current values*, the antenna power at 100% modulation, with a sustained sinusoidal signal, is 1.5 times the unmodulated carrier power. *The additional or side-band power in the antenna with 100% modulation is, therefore, 50% of the unmodulated carrier power.* The antenna current indicated by the r.f. ammeter will be the square root of 1.5 or 1.226 times the unmodulated value, *when the modulating signal is a pure tone (sinusoidal).*

It is apparent that the modulating system, whatever its type, must be able to effect a 50% increase in the transmitter's output power if the

set is to have a modulation capability of 100%. Since the effectiveness of a modulated wave as measured by receiver response depends on the *variation* in amplitude, it is desirable that the transmitter's modulation capability be high. As a specific instance, a 10-watt carrier modulated 100% (modulation factor 1.0) is practically as effective as a 40-watt carrier modulated 50% (modulation factor 0.5), the carrier power required for a given variation in wave amplitude being inversely proportional to the square of the modulation factor.

With transmitters of high-percentage modulation capability, particular care must be exercised to guard against frequency modulation as well as the over-modulation previously described. It has been shown that frequency "wobulation" is a serious defect in c.w. transmission and it must be realized that frequency modulation is far more objectionable in 'phone transmission. It not only causes unnecessary interference with other stations working on adjacent frequencies in the same band but also can cause interference with services operating on greatly different frequencies. An amateur 'phone working on the 3900-ke. band is even likely to cause interference on the broadcast band, as a result of frequency "wobulation" accompanying modulation and the consequent radiation of spurious frequencies over a band of hundreds of kilocycles. Frequency modulation is also a cause of distorted reception. Modulation of the oscillator in amateur transmitters is therefore prohibited except on the ultra-high frequency bands. Even when a radio-frequency amplifier following an oscillator is modulated, precautions are necessary to insure against affecting the oscillator's frequency. An extremely stable oscillator circuit is necessary, isolated from the modulated stage by at least one buffer amplifier.

Methods of Modulation

▲ The most widely used type of modulation system is that in which the modulating signal is applied in the plate circuit of a radio-frequency power amplifier (*plate modulation*). In a second type the audio signal is applied to the control-grid circuit (*grid-bias modulation*). A third system involves variation of the suppressor-grid voltage of a pentode-type power tube. Since tubes of this classification no doubt will become increasingly popular as new types are made available, the importance of suppressor-grid modulation is likely to increase. Other systems are occasionally used for special purposes but are not generally suitable for amateur work. Among these is screen-grid modulation in an amplifier using that type tube (limited to approximately 60 percent modulation capability). Practical arrangements illustrative of plate and grid-bias methods are diagrammed in Fig. 803. Suppressor-grid modulation is covered later in the chapter.

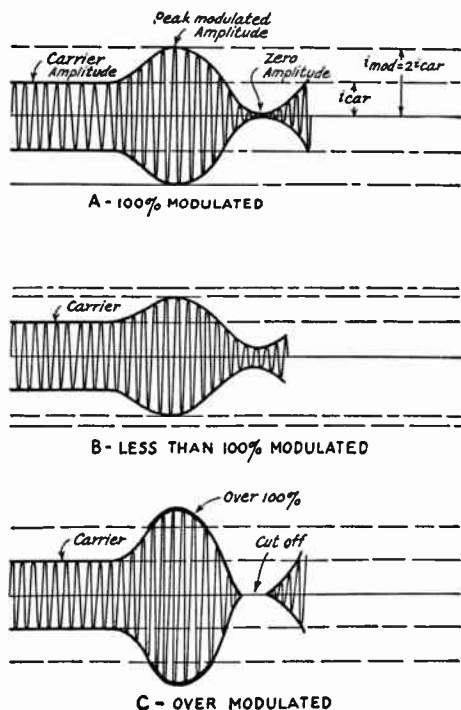


FIG. 802 — GRAPHICAL REPRESENTATION OF AN AMPLITUDE MODULATED WAVE

Illustrates the condition of overmodulation, the negative peak of the envelope being cut off. The outline of the r.f. peaks is called the envelope and should correspond to the wave shape of the modulating signal.

In A of Fig. 803 is shown the circuit of what is known as the Heising or constant-current system of plate modulation. The plate power for the modulator tube and modulated amplifier is furnished from a common source through the modulation choke, L , which has high impedance for audio frequencies. When the grid circuit of the modulator tube is excited at audio frequency, the modulator operates as a power amplifier with the plate circuit of the r.f. amplifier as its load, the audio output of the modulator being superimposed on the d.c. power supplied to the amplifier. The r.f. output of the amplifier is therefore identically modulated. For 100% modulation the modulator audio power output must be 50% as great as the d.c. power plate input of the r.f. stage and the audio voltage applied to the amplifier plate circuit across the choke, L , must have a peak value equal to the d.c. voltage on the modulated amplifier. To obtain this without distortion, the amplifier must be operated at a d.c. plate voltage less than the modulator plate voltage, the extent of the voltage difference being determined by the type of modulator tube used. The necessary drop in voltage is provided by the resistor R , which is by-passed for audio frequencies by the condenser C .

In Fig. 803B is shown another system of plate modulation in which a balanced (push-pull or Class-B) type modulator is transformer-coupled to the plate circuit of the modulated r.f. amplifier. When the grids of the modulator tubes are excited, the audio-frequency power generated in the plate circuit is combined with the d.c. power in the modulated-amplifier plate circuit by transfer through the coupling transformer, T . The power output of the modulated amplifier varies exactly with the power input to its plate, and the carrier power is therefore varied in accordance with the signal at the grids of the modulator tubes. For 100% modulation the audio-frequency power output of the modulator must be equal to 50% of the d.c. power input to the modulated amplifier, and the turns ratio of the coupling transformer must be such that the voltage at the plate of the modulated amplifier varies between zero and twice the d.c. operating plate voltage.

In C of the same figure is the diagram of a typical arrangement for grid-bias modulation. In this system of modulation, the secondary of an audio-frequency output transformer, whose primary is in the plate circuit of the modulator tube, is connected in series with the grid-bias supply for the modulated amplifier. When the grid bias and radio-frequency excitation to the modulated amplifier are properly adjusted, the power output will vary in accordance with the audio-frequency voltage variations set up in the grid circuit by the modulator tube. In this method of modulation the modulator tube furnishes little or no power to the modulated stage. The efficiency of the modulated stage is low because for 100% modulation it

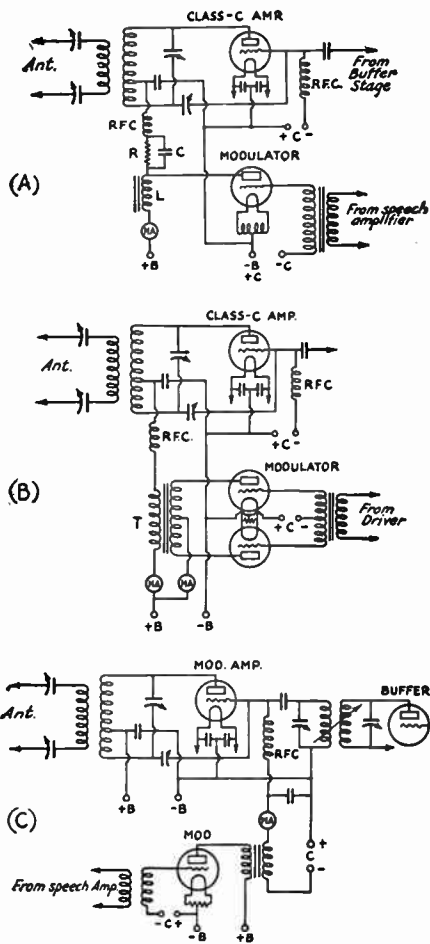


FIG. 803 — CIRCUITS FOR THREE METHODS OF MODULATION

A and B are for plate modulation, C for grid-bias modulation.

must have sufficient capacity to supply power peaks four times as great as the carrier power, and therefore is working far below its capabilities when no modulation is taking place.

Classes of Amplifiers and Modulators

▲ The modulator is simply an audio-frequency amplifier. In plate systems of modulation it must furnish power to the plate circuit of the modulated r.f. amplifier and, therefore, must be an audio-frequency power amplifier. The plate modulators generally used at the present time are of two types, Class-A and Class-B. The Class-A type may be coupled to the plate circuit of the modulated r.f. amplifier by the choke method shown in Fig. 803A or by the transformer method shown in B of the same figure. The choke method

is generally used with a single tube or tubes in parallel, the transformer coupling being used for push-pull modulator systems. The transformer coupling is always used with the Class-B type modulator, for the reasons given later.

The Class-A amplifier or modulator operates so that the plate output wave shapes are essentially the same as those of the exciting grid voltage, as shown in Fig. 804. It is operated with a negative grid bias such that the plate current is the same with and without excitation, the alternating grid excitation voltage and load resistance being such as to make its dynamic characteristic essentially linear. As generally used, the grid must not go positive on the excitation peaks and the plate current must not fall so low on the more negative half-cycles of the excitation voltage as to cause distortion due to the lower curvature of the characteristic. Since the grid is always negative with respect to the filament under these conditions, it draws negligible power and allows the use of a voltage amplifier for its excitation. Typical operating ratings for tubes popularly used as Class-A modulators in amateur transmitters are given in Table I. The tubes most suitable for use as Class-A power amplifiers or modulators are those having relatively low amplification factor (μ) and plate resistance, and are characterized by relatively high undistorted audio power output. Their plate efficiency at full output ranges from 20 to 35 percent. The method of determining Class-A modulator load conditions from audio power amplifier ratings is described further on.

A more economical and efficient type of modulator than the Class-A type has been recently developed. It is known as the Class-B type and uses two tubes in a push-pull or balanced circuit. With it much higher audio output can be obtained for a given plate dissipation and emission rating than with the Class-A modulator. The Class-B modulator operates so that the plate power input (and output) depends on the excitation. When there is no signal the plate current is nearly zero and when the excitation is maximum

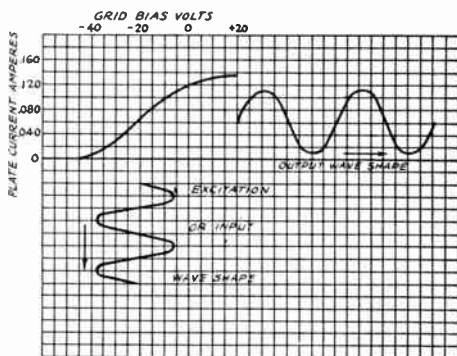


FIG. 804—INPUT AND OUTPUT WAVE SHAPES OF A CLASS A AMPLIFIER OR MODULATOR

the efficiency and output are high, comparatively large output being obtainable without exceeding the rated plate dissipation. The factors that limit the output are the excitation available, the filament emission and the plate dissipation on the output peaks. As shown in Fig. 805, plate current flows only during the positive half of the excitation cycle, the output wave shapes for each tube being essentially half cycles. It is necessary, therefore, to use two tubes in a balanced circuit with a special output transformer, the combined output wave shape being then the same as the excitation. The grids go positive on the excitation peaks, necessitating an exciting amplifier of the power type in contrast to the voltage amplifier used to excite the Class-A modulator. The operating conditions are determined from tube characteristic curves. The tubes should be supplied with negative bias sufficient to bring the no-signal plate current down near zero value. The approximate value of this "cut-off" bias is the d.c. plate voltage divided by the tube's rated amplification

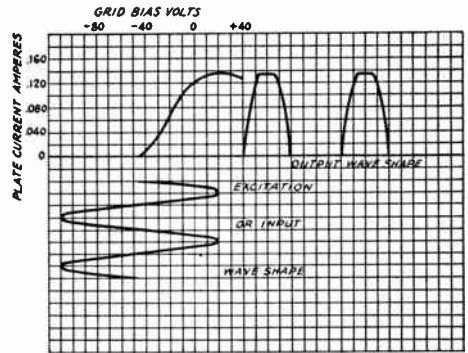


FIG. 805—INPUT AND OUTPUT WAVE SHAPES FOR ONE TUBE AS A CLASS-B AMPLIFIER

In a Class-B modulator the grid excitation would be less than that giving flattening of the peaks. In the Class-B r.f. amplifier the fly-wheel effect of the resonant tank circuit would restore the missing half-waves of the plate current.

factor (μ). Special Class-B tubes such as the 46 require no grid bias.

The tubes most suitable as Class-B audio power amplifiers or modulators are generally triodes having relatively high amplification factors, as contrasted to most types suitable as Class-A modulators. Class-B plate efficiencies at full output are considerably higher than in comparable Class-A modulators, running from 50 to 65 percent. Operating data for generally used Class-B modulator combinations are given in Table II, and the general method for determining modulating load conditions is described further on.

The Plate-Modulated R.F. Amplifier

▲ For distortionless or linear plate modulation with 100-percent modulation capability, the

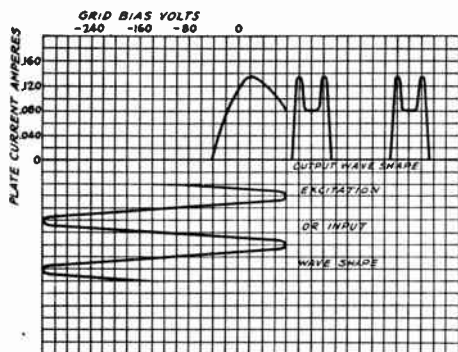


FIG. 806 — CLASS C AMPLIFIER INPUT AND OUTPUT WAVE SHAPES

modulated r.f. amplifier should operate with a steady d.c. power input equal to twice the modulator's maximum rated undistorted power output and should, simultaneously, present a load or *modulating impedance* to the modulator equal to the modulator's rated plate load impedance. To satisfy these conditions it is necessary that the modulated r.f. amplifier operate so that its plate circuit presents a constant resistance of proper value as viewed from the modulator's output, the value of this load resistance in ohms being the r.f. amplifier d.c. plate voltage (volts) divided by its d.c. plate current (amperes).

This condition obtains when the modulated stage operates as what is known as a Class-C amplifier; that is, so that its power output is proportional to its plate power input, the plate current and output current varying as the plate voltage between the limits of zero plate voltage and twice the mean plate voltage. This is accomplished by operating with a negative grid bias more than sufficient to reduce the plate current to zero with no excitation (usually twice "cut-off" bias) and by supplying the grid with r.f. excitation sufficiently ample to cause plate current saturation. Grid bias may be obtained from a fixed-voltage source (batteries), or by means of a grid leak, or by a combination of fixed and leak bias in series, or by a dropping resistor in the negative (cathode) circuit. A combination of automatic grid-leak bias and fixed bias is desirable for full-range linear modulation. As shown in the graphical representation of this operating condition, Fig. 806, large amplitudes of plate current flow during positive excitation peaks. The plate output wave shapes are quite distorted and "kick" the tank circuit on alternate half-cycles only. But the wave form in the output circuit is nearly sinusoidal because of the tank circuit's "flywheel" effect. This action is analogous to that of a single-cylinder two-cycle gas engine whose crank has nearly harmonic motion because of the smoothing effect of the flywheel, even though the impulses are delivered

to the mechanism during but a small part of each revolution. In a push-pull Class-C amplifier (or oscillator) the two plates alternate in supplying energy and the tank receives a "kick" on both halves of the cycle, this action being analogous to that of a two-cylinder two-cycle engine in which an explosion occurs at every half-revolution of the crank. The radio-frequency harmonic content in the output, including the antenna circuit, is less with a push-pull Class-C amplifier than with a single-ended one, the even harmonics canceling, and push-pull output amplifiers are therefore advisable where the final stage is modulated.

When the amplifier's operation is truly Class-C, its plate circuit input resistance, as viewed from the modulator output, will be equal to the mean plate voltage divided by the plate current. Also, the product of the plate voltage and current is the unmodulated power input, equal to twice the modulator's maximum audio power output for 100% modulation. Regardless of the type, size or number of tubes used in the Class-C amplifier, its mean plate voltage and plate current will be the same for a given modulator.

The tubes most suitable for use in modulated Class-C amplifiers are those designated for r.f. power amplifier use, such as are listed in the transmitting tube table of Chapter Seven. Triodes are preferable, in a neutralized circuit, because they are capable of giving more linear modulation while making best use of the modulator audio power output. Screen-grid tubes are seldom used because linear modulation requires simultaneous modulation of both plate and screen voltages, with consequent loss of audio power in the screen-grid voltage dropping resistor that is necessary. Tubes chosen for Class-C amplifier operation should have plate voltage and current ratings that will not be exceeded in modulated service. Excessive plate voltage or plate current will not only shorten the life of the tube but also may cause non-linear modulation, distortion and interfering spurious radiation. This applies particularly to receiving-type tubes (such as the 46) when operated as modulated Class-C r.f. amplifiers.

Determining Operating Conditions For Plate Modulation

▲ With a modulator of given power output and load resistance (or impedance) requirement (Tables I and II), calculation of the proper plate input to the Class-C amplifier and of coupling circuit values can be made quite easily. In the case of a Class-A modulator with choke coupling to the Class-C amplifier plate circuit, as shown in Fig. 803A, the procedure is as follows:

As has been stated, for 100 percent modulation the Class-C amplifier d.c. input power should be twice the modulator's rated maximum undistorted power output (u.p.o.). This input will be

equal to the product of the Class-C amplifier's mean (d.c.) plate voltage and plate current. At the same time, the mean plate voltage divided by the plate current gives the *modulating impedance*, which in this case should equal the modulator's rated load impedance. By Ohm's law,

$$I_b = \sqrt{\frac{P_o}{R_p}} \text{ and } E_b = \frac{P_o}{I_b}$$

where P_o = unmodulated d.c. power input to r.f. stage = *twice modulator power output, watts.*

R_p = optimum load resistance for modulator, ohms.

I_b = mean current to r.f. amplifier plate, amperes d.c.

E_b = r.f. amplifier mean plate voltage, d.c.

For the case of a Type 845 tube operating as a Class-A modulator with plate supply of 1000 volts at 75 ma. (grid bias—147 volts), the rated power output with negligible distortion is 23 watts for a load resistance of 7500 ohms. Substituting in the above equations,

$$I_b = \sqrt{\frac{2 \times 23}{7500}} = 0.078 \text{ amp.} = 78 \text{ ma.},$$

the Class-C amplifier d.c. plate current.

$$E_b = \frac{2 \times 23}{0.078} = 590 \text{ volts,}$$

the Class-C amplifier d.c. plate voltage.

The plate voltage drop for the Class-C amplifier is, therefore, $1000 - 590 = 410$ volts. The proper resistance value for the dropping resistor, R of Fig. 803-A, is this value divided by the Class-C amplifier plate current,

$$R = \frac{410}{0.078} = 5256 \text{ ohms (5250 ohms satisfactory).}$$

The dissipation rating of this resistor should equal the voltage drop multiplied by the current, or $410 \times 0.078 = 32$ watts. A 50-watt type resistor therefore would be satisfactory. It should be bypassed for audio frequencies by condenser C (2- μ fd. or larger). A coupling choke, L , of 30-henry effective inductance at 150-ma. d.c. will be suitable. Any one of several tubes capable of operating with 78 or 80 ma. input at 590 or 600 volts could be used in the Class-C amplifier; a Type 830, RK18 or 800 would be a likely choice.

In the case of transformer coupling between the modulator and Class-C amplifier, as shown in Fig. 803-B, the procedure is somewhat different. This method of calculation is generally applicable to any type of modulator, Class-A or Class-B, with transformer coupling. The purpose is to calculate the turns ratio of the transformer to match the modulating impedance of the Class-C amplifier to the required load impedance of the

modulator. For illustration, take the case of a modulator using a pair of Type 800 tubes in Class-B, operating at a plate voltage of 1000 volts (Table II). The rated power output with negligible distortion is 100 watts and the plate-to-plate load impedance is specified as 12,500 ohms. The Class-C amplifier using two similar tubes is to operate at the same plate voltage, 1000 volts, with a mean (d.c.) Power input of twice the modulator's rated maximum output, or 200 watts. The Class-C amplifier plate current is, therefore,

$$I_b = \frac{P_o}{E_b} = \frac{2 \times 100}{1000} = 0.2 \text{ amp.} = 200 \text{ ma.}$$

The modulating impedance of the Class-C amplifier is

$$Z_m = \frac{E_b}{I_b} = \frac{1000}{0.2} = 5000 \text{ ohms.}$$

The transformer therefore must match a 5000-ohm load to the modulator's 12,500-ohm load requirement. This calls for a step-down transformer having an impedance ratio of 12,500 to 5000. The turns ratio, *total primary to total secondary* will be the square root of the impedance ratio:

$$\text{Turns Ratio} = \sqrt{\frac{12,500}{5000}} = \sqrt{2.5} = 1.58 \text{ to } 1$$

(or 1 to 0.63).

In the case of Class-B output transformers it is customary to specify the turns ratio of $\frac{1}{2}$ *primary to total secondary*, which would be 1 to 1.26 in the example given. In the actual design of the transformer the secondary turns would be increased slightly over the theoretical calculated value, to allow for losses. Since the construction of such transformers is beyond the facilities of most amateurs it will not be described here. However, manufactured types having suitable characteristics for standard modulator combinations are widely available at reasonable prices. The transformer preferably should be designed to carry the Class-C amplifier d.c. plate current through its secondary without saturating the core. Otherwise it would be necessary to feed the amplifier plate d.c. through an audio-frequency choke and couple the transformer, across the choke, through a large condenser.

Speech Input Equipment — Microphones

▲ A microphone is the device used to convert the sound waves of speech into corresponding alternating currents or voltages which, after amplification, excite the modulator. Typical circuit arrangements of five types of microphones generally used in amateur transmitters are shown in Fig. 807. The arrangement of A is for a single-button carbon microphone; B is for a double-button carbon microphone; C is that of a condenser microphone; D is for a ribbon (velocity) type;

and E is for a piezo-electric (crystal) type microphone.

Carbon-grain microphones, both single- and double-button, convert sound waves into pulsating electrical current by the variation in the resistance with pressure between carbon granules in contact with a metal or graphite diaphragm which is caused to vibrate by the sound waves striking it. In the single-button microphone, M_1 of *A*, one connection is made to the diaphragm and the other is made to the cup containing the carbon granules, called a button. The microphone terminals are connected in series with a variable resistor (to adjust microphone current), which is connected across a battery, and the primary winding of a transformer. The current through the primary is a pulsating direct current which induces alternating voltage in the secondary winding. This voltage in turn is applied to the grid circuit of the speech-amplifier tube. In the double-button microphone, M_2 of *B*, there is a

carbon element on each side of the diaphragm. These "buttons" are connected to the two ends of the primary winding of the microphone transformer and the diaphragm is connected in series with a battery to the center of the winding, as shown in *B*. The granules in one button are compressed and their resistance is reduced while the granules on the other side loosen and their resistance is increased when the diaphragm is vibrated, with the result that there is an increase in current flow between one button and the diaphragm while there is a decrease in current flow between the other button and the diaphragm. The current flow through the common circuit and the battery will remain constant if the buttons have been properly adjusted. The diaphragm of the "high-quality" double-button microphone is "stretched" to make its natural resonant frequency well up in the audio-frequency range. This makes the microphone's sensitivity comparatively low but improves its frequency charac-

TABLE I—TYPICAL CLASS-A AMPLIFIER AND MODULATOR OPERATING DATA

Type Tube	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma., I_b	Neg. Grid Volts, ¹ E_c	Load Imp., ² Ohms	Audio Output, ³ Watts
50	7.5	500	50	100	7500	5.5
2A3 (P.P.) ⁴	2.5	300	80	62	3000	15.0
211, 242A, 276A	10.0	1000	65	52	7000	10.0
845	10.0	1000	75	150	7500	23.0
284A	10.0	1250	60	228	10,000	41.5
849	11.0	2000 2500 3000	125 110 100	75 104 132	12,000 12,000 20,000	42.5 81.0 100.0

With exception noted, ratings are for a single tube. For tubes in parallel multiply I_b and Output Watts by number used, and divide Load Impedance by number used. For 2 tubes in push-pull, multiply I_b , Load Impedance and Output Watts by 2, taking peak audio grid voltage twice bias value.

¹ Peak audio grid voltage equal to bias value for single tube or tubes in parallel.

², ³ To be used in determining Class-C amplifier operating conditions by method described in text.

⁴ Two tubes in push-pull. Peak audio grid voltage twice bias value.

TABLE II—TYPICAL CLASS-B MODULATOR OPERATING DATA

Class-B Tubes (2)	Fil. Volts, E_f	Plate Volts, E_b	Plate Ma. (Max.), I_b	Neg. Grid Volts, E_c	Load Imp., Ohms ¹	Tube Output, Watts	Input Trans. Turns Ratio (Pri.:Sec.)	Driver Tubes (P.P.)	Driver Plate Volts
46	2.5	400	108	0	7000	25	3:1	45	225
59	2.5	400	124	0	6000	28	3:1	45	225
841	7.5	500	108	13.5	8000	29	5:1	45	250
210*	7.5	600	153	67	8000	57.5	1.6:1	45	250
800	7.5	1000	164	55	12,500	100	1:1	2A3	250
RK18	7.5	1000	164	45	12,000	100	2:1	45	250
830-B*	10.0	1000	280	33	10,000	190	1:1.4	2A3	250
203-A*	10.0	1000	366	40	5800	240	1.6:1	2A3	250

Ratings are for 2 tubes, Class-B.

* Graphite anode types.

¹ Plate-to-plate. Use this load impedance and Output Watts for determining Class-C stage coupling and operating conditions by method described in text.

teristic. More sensitive double-button microphones have an "unstretched" carbon or graphite diaphragm.

The condenser microphone illustrated in C utilizes an entirely different principle — that the variation in electrostatic capacity between two plates causes a change in the potential difference between them. In the microphone one of the plates is thick and incapable of vibration but the other is of thin metal, tightly stretched, separated from the fixed plate by about a thousandth-inch. A high d.c. potential, which may be obtained from the amplifier "B" supply, is applied between the plates and the variation in the potential which results when the thin plate vibrates in response to a sound wave is applied across a high resistance (several megohms) in the grid circuit of an amplifying tube.

The velocity or ribbon-type microphone, M_4 ,

operates on the principle of the electric generator. A light corrugated ribbon of conductive material, such as dural, is suspended with slight tension between the poles of an electromagnet so that its motion will be transverse to the magnetic field. When vibrated by sound waves, the ribbon conductor cuts the magnetic lines of force and a corresponding alternating current flows through the ribbon and the primary of a transformer in its external circuit. The impedance of the ribbon is very small, a few ohms, permitting the use of a transformer with a small primary and large turns (voltage) step-up ratio for coupling to the grid of the first amplifier. The frequency response of this type microphone is very uniform over the audio range, since its inherent characteristics are such that the voltage generated is proportional to the amplitude of the sound wave and nearly independent of frequency, the velocity of the ribbon being proportional to the sound-wave particles. For this reason this type of dynamic microphone is also known as the "velocity" microphone. A somewhat different type of dynamic microphone has a low-impedance coil mechanically coupled to a diaphragm, the electrical current being induced in the coil by motion caused by sound waves. The moving-coil type microphone is relatively more complex and expensive than the ribbon type and is not so widely used for amateur work.

The input circuit for a piezo-electric or crystal type microphone is shown in Fig. 807-E. This type consists of a piece of piezo-active material, usually Rochelle salts crystal, mounted between metal electrodes. In the form diagrammed, the crystal is mechanically coupled to a diaphragm. Sound waves actuating the diaphragm cause the crystal to vibrate mechanically and, by piezo-electric action, to generate a corresponding alternating voltage between the electrodes, which are connected across the grid circuit of a vacuum tube amplifier as shown. This electro-mechanical action is the reverse of that utilized with the quartz crystals used in transmitters and described in Chapters Four and Seven. Unlike the other microphones described, the crystal type requires no separate source of current, polarizing voltage or magnetic field. The diaphragm type illustrated has frequency characteristics entirely adequate for speech transmission. Another type, which has no diaphragm and in which the crystal itself is actuated by sound waves, has more uniform response over a wider range of audio frequencies (up to 10,000 cycles or more) as is required for program transmission.

Wide-frequency response speech input equipment is not required for voice transmission, uniform frequency response up to 2800 or 3000 cycles being adequate. It is therefore satisfactory to choose a microphone intended particularly for speech transmission, rather than one designed primarily for broadcast program use. Since the

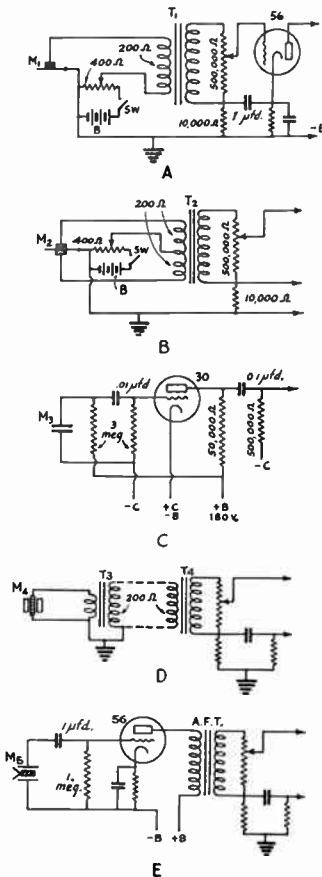


FIG. 807 — SPEECH INPUT CIRCUIT ARRANGEMENTS FOR FIVE GENERALLY USED TYPES OF MICROPHONES

M_1 , single-button carbon; M_2 , double-button carbon; M_3 condenser; M_4 , ribbon or velocity type; M_5 , crystal or piezo-electric type.

high r.f. selectivity of modern amateur 'phone receivers and the use of "tone controls" in receiver audio systems cut off the higher frequencies anyway, the modulation frequencies above 3000 cycles transmitted are largely wasted.

Microphone Output Levels

▲ The sensitivity of the microphone, or electrical output obtainable with speech input, governs the amount of amplification required between the microphone and modulator. Typical approximate values of electrical output, in terms of equivalent a.c. voltage across the microphone for speech at a distance of 6 inches or so, are as follows:

Standard single-button carbon microphones give outputs ranging from 0.3 volt across 50 ohms (W. E. Type 337), to 0.1 volt across 50 ohms (W. E. Type 395). An intermediate value for s.-b. types is 0.15 volt across 50 to 75 ohms (W. E. Types 323 and 615-A). With the usual microphone input transformer, designed to work with a single-button microphone, a peak voltage of between 2 and 3 volts across 100,000 ohms or so can be assumed available at the grid of the first tube. These microphones should be operated with a button current of about 100 ma.

A typical rating for a high-quality double-button microphone is approximately 0.025 volt across 200 ohms (32 db below 1 volt, W. E. Types 387-W and 600-A). With this type microphone, and the usual push-pull input transformer, a peak voltage of 0.4 to 0.5 volt across 100,000 ohms or so can be assumed available at the first speech amplifier grid. The button current with this type microphone may be 50 ma. per button (100 ma. total).

The output of condenser microphones varies widely from one type to another, the high-quality type being about one-hundredth to one two-hundredth as sensitive as the standard double-button carbon type. Usually an additional two-stage resistance-coupled amplifier having a gain of approximately 100 (40 db) is satisfactory as a "pre-amplifier" for adapting a double-button set-up to condenser mike input.

The sensitivity of the velocity or ribbon-type microphone is between that of the standard d.-b. carbon and condenser types. With a suitable microphone coupling transformer, about one stage of pre-amplification having a tube gain of 10 or so will bring the level up to that obtained at the grid of the first tube with a standard d.-b. microphone.

The sensitivity of piezo-electric microphones also varies from type to type. A typical value for the diaphragm type (Astatic Type D-104) obtained by experiment in a circuit of the type shown in Fig. 807-E, is approximately 0.1 volt across 1 megohm at the grid of the first tube. Since this particular microphone has a characteristic impedance of approximately 80,000 ohms, it might be used with transformer instead of re-

sistance input coupling, providing a sufficiently good transformer with a high-impedance primary was used — say a 1-to-3 step-up interstage-type audio transformer of high quality. This would give a proportionate voltage gain prior to amplification and bring the level up to approximately that obtained at the first amplifier grid with a standard d.-b. microphone.

A microphone of any type is a piece of apparatus deserving careful handling. The carbon types should never be moved or even touched while current is flowing through them because the slightest jar will give the diaphragm a jolt far greater than that caused by a loud sound. The carbon microphone should never be operated with excessive current through the buttons because the heat generated by high current may fuse the carbon granules together, causing "freezing." The current to each button of a double-button microphone should be of the same value and sometimes adjustment of the pressure on the buttons may be necessary to make it so. This adjustment must be made very carefully, preferably by an experienced microphone repairman.

If a carbon microphone should become "frozen" the granules may be loosened by lightly tapping the frame with one finger *after the microphone battery circuit has been opened*. The microphone should be suspended by springs in a frame or hung from the ceiling in preference to having it unprotected from shock and vibration on the operating table. A good shock-proof mounting will eliminate a lot of the "background" noise which afflicts many amateur outfits. A light cloth sack pulled over the microphone will keep out insects and dust as well as protect the diaphragm from corrosion by moisture condensed from the speaker's breath. An ordinary conversational tone should be used. Sometimes it is better to talk "across" rather than directly at the microphone because breath striking the diaphragm gives the speech a hissing characteristic.

Speech Amplifiers

▲ The speech amplifier of the 'phone transmitter includes the audio stages between the microphone and the grid circuit of a Class-A modulator or the grid circuit of the Class-A power driver stage for a Class-B modulator. The speech amplifier stages are operated as Class-A voltage amplifiers; that is, they are designed to give high undistorted voltage amplification and their output circuits are of high impedance, as contrasted with audio power amplifiers. The tubes used are the smaller receiving types having medium to high amplification factors, resistance or transformer coupling being generally used with the medium- μ types and resistance coupling with the high- μ types.

Knowing the approximate value of voltage output obtainable from the microphone and the voltage excitation requirement of the Class-A modulator or driver stage, the total voltage am-

plification necessary can be estimated. The voltage swing required by the Class-A power stage will be approximately equal to its grid bias in the case of a single tube or tubes in parallel, and approximately twice the bias value for tubes in push-pull. The approximate voltage gain required of the speech amplifier therefore will be the ratio of this maximum grid swing to the peak voltage across the microphone. This gain will include amplification of the tubes and step-up in coupling devices such as transformers. The method illustrated by the skeleton diagram of Fig. 808, which is for the 100-watt modulator unit is described later. The voltage step-up in a coupling transformer is assumed the same as its turns ratio while the approximate gain of a tube is taken as 75 or 80 percent of its rated amplification factor (μ) in the case of a triode, and about 10 percent in the case of a screen-grid tube. The combination chosen should show a calculated maximum gain of 50 to 100 percent greater than will actually be required, to allow for reserve, the excess being compensated for in operation by adjustment of the volume or gain control.

The diagram of Fig. 809 gives the circuit of a

to be troublesome and cause distortion because of feed-back troubles and instability, while one of insufficient gain will be forced and thereby cause distortion from overloading.

When two or more stages of speech amplification are used particular care must be taken to prevent "motor-boating" and distortion resulting from inter-stage feed-back. The coupling transformers should be isolated from each other and all supply circuits should be adequately bypassed. It is advisable to keep the modulation reactor or transformer well away from the other audio equipment when more than one stage of speech amplification is used since the strong magnetic field about the choke is quite likely to induce feed-back in nearby audio transformers. As a further precaution all transformer cases should be connected to the negative side of the plate supply and grounded. One lead of the microphone circuit should also be grounded and a shielded microphone cable is advantageous, particularly for eliminating radio-frequency pick-up in the microphone leads. R.f. overloading of the grid circuits of the speech amplifier and modulator is one common cause of "singing" and every precaution to eliminate it will prove worthwhile.

Liberal use of radio-frequency chokes in the power and bias supply leads, particularly the high-voltage leads between the modulator and Class-C amplifier, together with removal of the audio-frequency equipment from the vicinity of the radio-frequency units, helps

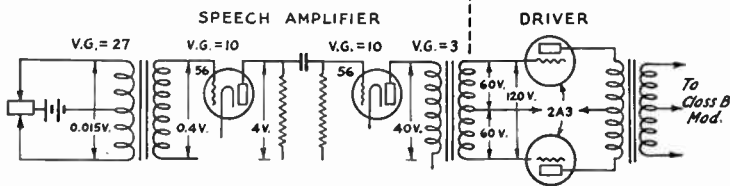


FIG. 808 — SKELETON DIAGRAM OF SPEECH-AMPLIFIER AND DRIVER STAGES, SHOWING APPROXIMATE VOLTAGE GAIN AND PEAK VOLTAGE PER STAGE

high-gain speech amplifier stage using a screen grid tube as an audio amplifier and having a voltage gain of approximately 100 (40 db) for the single stage. Fig. 811 gives the design of a typical three-stage resistance-coupled amplifier using triodes. This amplifier is intended to work from a 200-ohm velocity or ribbon microphone transformer secondary and into a 200-ohm output. Its rated overall voltage gain is approximately 1000 (60 db). There is an almost infinite number of speech amplifier arrangements that may be used, of course, using combinations of different tubes and coupling methods. The aim should be to design for the minimum number of stages adequate to give the necessary gain with negligible distortion. An amplifier with excessive gain is likely

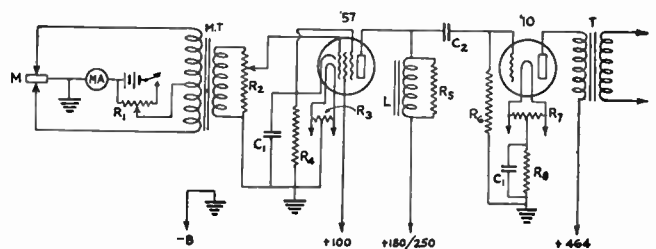


FIG. 809 — CIRCUIT USING A SCREEN-GRID TUBE AS A HIGH-GAIN SPEECH AMPLIFIER

- M — Double-button microphone.
- MA — 0-100 milliammeter.
- MT — Microphone input transformer.
- T — Output transformer for Type '10 tube.
- L — 300- to 500-henry choke.
- C₁ — 4- μ fd. 200-volt.
- C₂ — 0.1- μ fd. 500-volt.
- R₁ — 400-ohm potentiometer.
- R₂ — 100,000-ohm potentiometer.
- R₃ — 50-ohm center-tapped resistor.
- R₄ — 1000-ohm 1-watt resistor.
- R₅ — 250,000-ohm carbon resistor.
- R₆ — 0.5-megohm leak.
- R₇ — 100-ohm center-tapped resistor.
- R₈ — 2170-ohm 2-watt resistor.

Filament supply for the '10 should be separate from that used on other tubes. An additional secondary winding on the filament transformer will serve.

eliminate r.f. overloading. Complete shielding of the speech-amplifier unit is decidedly good practice.

D.c. plate and filament supply from batteries is recommended for the early stages in multistage high-gain amplifiers. A.c. filament supply and very well filtered rectified a.c. plate supply can be used, of course, provided precautions are taken to prevent hum from reaching grid circuits. Filtering or decoupling in individual plate and grid feed circuits should be employed in such amplifiers, as shown in the diagrams of Figs. 810 and 812. In the latter figure, the decoupling resistors are R_4 , R_6 and R_{10} .

Transmitter Assembly and Adjustment

▲ A typical example of speech-amplifier and modulator construction is illustrated in Fig. 811, and diagrammed in Fig. 812. It incorporates a speech amplifier suitable for double-button carbon microphone input, has an output rating of 100 watts and can be used to modulate the 200-watt plate input of a Class-C amplifier using 1000 or 2000-volt type tubes, the output transformer secondary being wound in two sections which can be connected in parallel for the former or in series for the latter. Fig. 801 shows this unit with a typical r.f. companion unit using a pair of Type 800 tubes in its Class-C final stage. The construction of the r.f. unit follows the design principles given in the previous chapter, while the audio circuits follow the design given in this chapter. This transmitter was described in detail in the

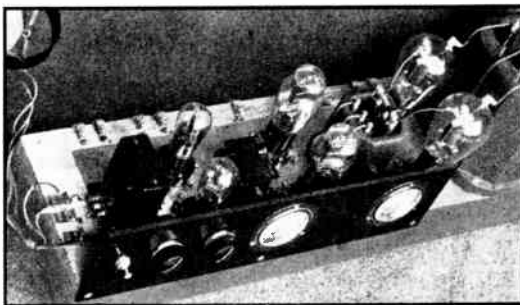


FIG. 811 — PLAN VIEW OF THE 100-WATT MODULATOR AND SPEECH-AMPLIFIER UNIT DIAGRAMMED IN FIG. 812

Mounted on the baseboard, from left to right, are the microphone transformer, speech amplifier tubes, the driver-stage input transformer, 2A3 driver tubes, Class-B input transformer, Type 800 Class-B modulator tubes and the output transformer. On the front panel, left to right, are the microphone switch, microphone button-current resistor, volume control potentiometer, microphone current milliammeter and Class-B plate current milliammeter. The parts are assembled on a copper sheet fastened to the baseboard. Common ground-side circuit connections are made to this sheet.

December, 1933, and January, 1934, issues of *QST*.

The diagram of a speech amplifier and Class-B modulator suitable for use with a low-power Class-C r.f. amplifier using a pair of Type 46 or 10 tubes is shown in Fig. 813. It is intended for double-button microphone input, but can be used with a single-button microphone by substitution of an appropriate microphone transformer. The audio output of the modulator is 20 to 25 watts, which will completely modulate an input of 40 or 50 watts to the Class-C stage.

In putting any 'phone transmitter into operation, the r.f. portion should be tuned up and adjusted as outlined in the previous chapter. For 'phone transmission it is especially important that the Class-C modulated stage and any subsequent r.f. amplifiers, be completely neutralized. Even slight regeneration in a stage handling modulated r.f. will cause non-linear modulation and distortion. The plate-modulated Class-C amplifier requires greater excitation than comparable amplifiers used for c.w. telegraph transmission. A conclusive test for adequacy of excitation would be to vary the d.c. plate voltage from zero to twice normal operating value while observ-

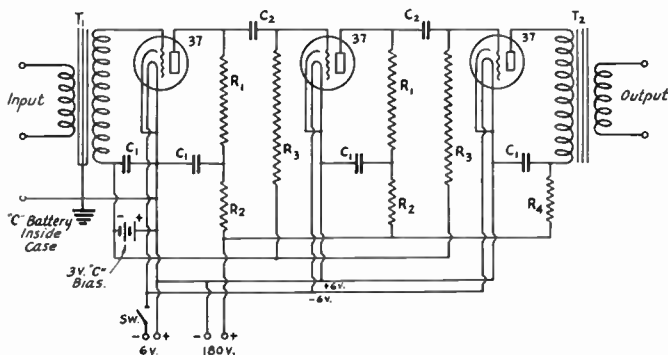


FIG. 810 — A THREE-STAGE RESISTANCE-COUPLED AMPLIFIER USING HEATER-TYPE TRIODES

- T_1 — 200- or 500-ohm line-to-grid input or microphone transformer.
- T_2 — Tube plate-to-line output transformer.
- C_1 — 1- μ fd. by-pass condensers.
- C_2 — 0.25- μ fd. coupling condensers.
- R_1 — 25,000-ohm 1-watt plate coupling resistors.
- R_2 — 9000-ohm 1-watt plate de-coupling resistors.
- R_3 — 1-megohm grid coupling resistors.
- R_4 — 25,000-ohm 1-watt plate de-coupling resistor.

Gain control is used in a subsequent amplifier, although it could be incorporated in the grid circuit of one of the three stages.

ing simultaneous values of plate current and r.f. load current, but this is usually impossible. A check on the d.c. grid current in the bias circuit is of more practical aid. When increase in excitation, which causes increase in grid current, is no longer accompanied by increase in r.f. am-

100 watts output. A pair of 'phones tapped across a hundred ohms or so of the load resistor may be used for listening checks. Electric phonograph input is convenient for testing; or microphone input may be used with an assistant doing the talking. If noticeable distortion or other defect is

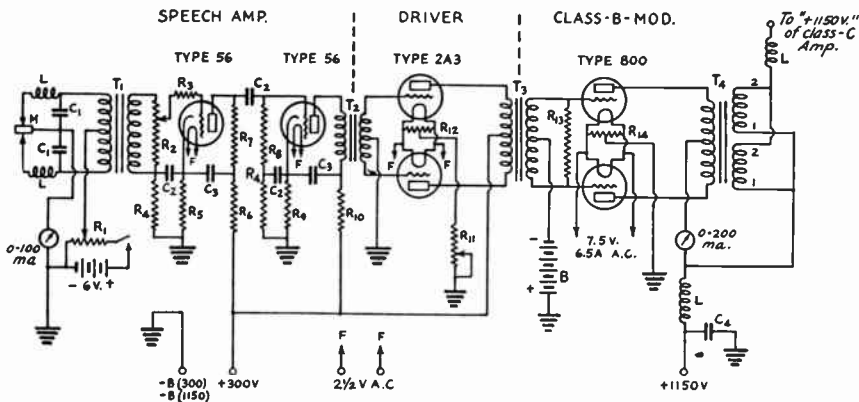


FIG. 812—CIRCUIT OF THE SPEECH AMPLIFIER AND MODULATOR UNIT

*T*₁—Double-button microphone transformer (Thoradson Type T-3180).
*T*₂—Push-pull input transformer.
*T*₃—Class-B input transformer (Hilet Type IB-100).
*T*₄—Class-B output transformer (Hilet Type OB-101).
M—Type 600-A double-button microphone.
B—Medium-size 6.3-volt "B" battery (45 and 18 volts in series).
L—8-mh. r.f. choke (General Radio Type 379-T).
*R*₁—400-ohm potentiometer, wire-wound.
*R*₂—500,000-ohm potentiometer, volume control.
*R*₃—75,000-ohm 1-watt resistor.
*R*₄—200,000-ohm 1-watt resistor.
*R*₅—2800-ohm 1-watt resistor.

*R*₆—25,000-ohm 1-watt resistor.
*R*₇—50,000-ohm 1-watt resistor.
*R*₈—500,000-ohm 1-watt resistor.
*R*₉—2700-ohm 1-watt resistor.
*R*₁₀—7500-ohm 1-watt resistor.
*R*₁₁—500-ohm 10-watt adjustable wire-wound resistor.
*R*₁₂—20-ohm center-tapped wire-wound resistor.
*R*₁₃—20,000-ohm 2-watt resistor.
*R*₁₄—50-ohm center-tapped wire-wound resistor.
*C*₁—0.002- μ fd. fixed mica.
*C*₂—0.1- μ fd. 300-volt.
*C*₃—2.0- μ fd. 400-volt.
*C*₄—0.002- μ fd. 5000-volt.

"Grounds" indicate connections soldered to copper base-sheet.

plifier output, the excitation may be considered adequate for Class-C operation. The excitation may be varied by adjusting the coupling to the preceding stage or by varying the plate voltage and grid bias of a preceding r.f. stage. Definite figures for grid current with different types of tubes cannot be specified because there are wide variations with different operating conditions, but the values given in the tube table in Chapter Seven will be helpful as a guide.

Checking Operation

▲ Before connecting the audio unit to the r.f. circuit it should be tested separately for proper operation. A resistor equal to the intended modulating impedance into which the modulator is to work should be connected across the modulator output circuit. In the case of the 100-watt unit described, whose output transformer secondary paralleled, a 5000-ohm 100-watt resistor should be used. A low-range thermo-couple meter in series with the resistor will show the a.c. load current, which will be approximately 0.14 amp. at

noticed, the preceding stages should be checked, the procedure being generally the same as described for receiver testing in Chapter Five. There should be no variation in plate current of Class-A speech amplifiers, of course, as indicated by a d.c. milliammeter. With the 100-watt Class-B modulator the plate current should "kick" to approximately 160 ma. at full output, while with the 46 unit it should kick to about 100 ma.

With the audio unit operation checked, it should be connected to the r.f. unit for modulation checks. The r.f. circuits should be tuned and neutralized as described in Chapter Seven. The testing should not be done with a radiating antenna connected to the transmitter. A dummy antenna should be used. The heating element of a 500-watt electric iron is convenient for this purpose. It can be clipped across a few turns of the plate tank circuit, or of an inductively coupled tank, the proper number of turns being that which causes the Class-C amplifier to draw the correct plate current (200 ma. at 1000 volts for the Type 800 modulator shown). Do not adjust for maximum antenna current. The Class-C

amplifier plate current value is the indicator of proper operating conditions, let antenna current be what it may. If the amplifier will not load up to the proper plate current, insufficient r.f. excitation is probable and the excitation should be increased as previously described.

The Class-C plate-current should remain practically constant with modulation. It should be possible to make it kick upward with modulation but the gain control should be backed off so that the greatest plate current variation does not exceed 5 percent of the unmodulated value. This applies to any amplifier handling modulated r.f. and with all systems of modulation. Variation, either upward or downward, indicates unsymmetrical modulation (overmodulation), distortion and generation of spurious frequencies which cause interference.

"Downward modulation," indicated by drop in plate current and even by drop in antenna current in extreme cases, is usually indicative of insufficient r.f. excitation or overloading of the r.f. stage, the latter calling for reducing the output coupling. R.f. circuits should not be detuned to vary loading because this also can cause distortion. All r.f. circuits should be tuned precisely to resonance.

A heterodyne monitor, of the type described in Chapter Six, should be used to check for frequency modulation. If the speech sounds "mushy" with the carrier tuned to zero beat but is clear without the heterodyne oscillation, frequency modulation is present. There should be no frequency modulation in the 'phone transmitter, of course, and its presence indicates reaction on the oscillator, with r.f. feed-back from the modulated stage, variation in oscillator plate voltage with modulation or ineffective buffer action as likely causes.

Grid-Bias Modulation

▲ Grid-bias modulation requires very little audio power of the modulator, hence making the modulating equipment relatively inexpensive, but has the disadvantage that the efficiency of the modulated r.f. amplifier is low as compared with plate modulation. For this reason grid-bias modulation is not very practicable with small tubes, although reasonable output can be obtained from tubes of 100 watts output rating or larger. The carrier output (and efficiency) that can be ob-

tained varies with the type of r.f. tube used, tubes having low amplification factors being best suited to this type of modulation.

Carrier efficiencies obtainable run between 10 and 20 percent, which means that the carrier to be expected from a tube having a safe plate dissipation of 100 watts will be between 10 and 25 watts. The output of a 100-watt tube with grid-bias modulation is therefore less than would be expected from a low-power transmitter using a modulator of the type shown in Fig. 813. As an initial installation, therefore, grid-bias modulation is uneconomical; for occasional 'phone work with a medium-power transmitter, however, it represents a fairly inexpensive method of obtaining modulation.

The circuit for grid-bias modulation is given in Fig. 803-C. Essentially the audio output of the modulator is connected in series with the grid bias source. Other types of interstage coupling between r.f. circuits than that shown can be used without affecting the operating conditions. The modulator can be a single 45 or a pair of 45's in push-pull; the diagram of Fig. 815 will serve for modulation of one or two tubes of the 203-A, 211 or 852 type. The coupling transformer between modulator and modulated-amplifier grid should have a turns ratio of approximately 1 to 1 and should preferably have a secondary of low d.c. resistance.

The method of adjustment is as follows:

The negative bias on the modulated r.f. amplifier is set at approximately 50% beyond cut-off value and the amplifier is neutralized. With normal plate voltage applied, the r.f. grid excitation is adjusted so that grid current just begins to flow, as indicated by the grid meter, and the an-

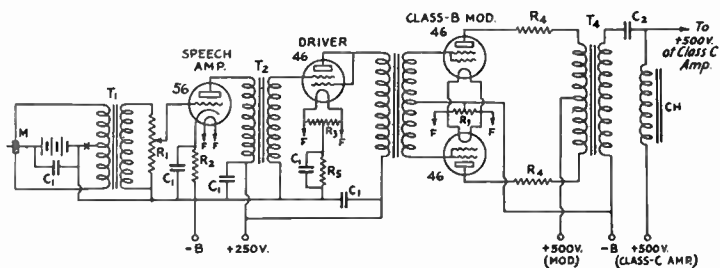


FIG. 813 — SPEECH AMPLIFIER AND CLASS-B MODULATOR FOR LOW-POWER TRANSMITTERS

M — Double-button microphone.

*C*₁ — 1- μ fd. 400-volt by-pass condensers.

*C*₂ — 2- μ fd. 1000-volt by-pass condenser.

*R*₁ — 500,000-ohm variable.

*R*₂ — 2,750-ohm 1-watt.

*R*₃ — 20-ohm center-tapped.

*R*₄ — 100-ohm 25-watt resistors (surge suppressors).

*R*₅ — 1500-ohm 2-watt.

*T*₁ — Microphone transformer.

*T*₂ — Audio transformer, about 3 to 1 ratio.

*T*₃ — Class-B input transformer.

*T*₄ — Class-B output transformer, 4000- or 5000-ohm secondary.

CH — 40-henry 400-mil choke.

tenna current is noted. The grid excitation is then reduced until the antenna current becomes one-half the value at which grid current began to flow. Finally, the audio input is adjusted so that grid current barely shows on the modulation peaks.

The criterion of proper operation with grid bias as with other types of modulation is unvarying plate current in the modulated r.f. stage. A change in r.f. plate current with speech indicates overmodulation, a broad signal, and impaired quality.

Suppressor-Grid Modulation

▲ Modulation of the suppressor grid of a pentode type power tube is akin to grid-bias modulation in that the modulator power required is negligible. The efficiency is somewhat higher, however, and the operating conditions not quite so rigorous. A carrier output of approximately 15 watts can be obtained from one Type RK-20 tube, using rated plate voltage. A diagram of a push-pull amplifier using a pair of RK-20's, capable of a carrier output of 30 watts 100% modulated, is given in Fig. 814. A modulator diagram for the pentode amplifier is shown in Fig. 815.

Adjustments for suppressor-grid modulation are quite simple. The amplifier is first tuned for

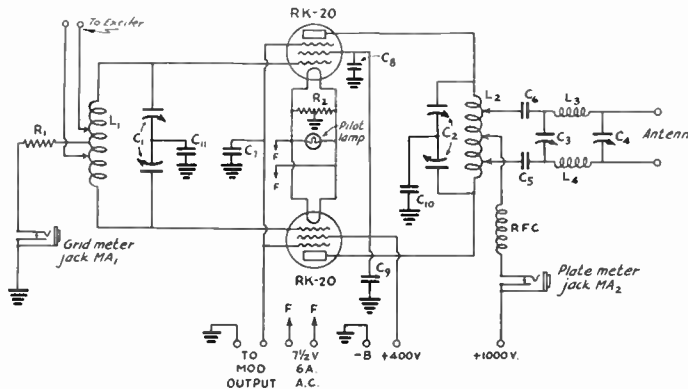


FIG. 814 — PUSH-PULL RK-20 CIRCUIT FOR SUPPRESSOR-GRID MODULATION

- L1 and L2* — Grid and plate coils. See coil table in Chapter Seven.
- L3 and L4* — Antenna coupler coils. See Chapter Seven.
- C1* — Split-stator midjet variable, 50- μ fd. per section.
- C2* — Split-stator transmitting condenser 100- μ fd. per section, 3000-volt.
- C3 and C4* — Receiving type variable condenser, 150- μ fd.
- C5, C6 and C7* — 0.001- μ fd. mica by-pass condensers.
- C8, C9, C10 and C11* — 0.01- μ fd. mica by-pass condensers.
- R1* — 12,000-ohm 25-watt grid leak.
- R2* — 50-ohm filament center-tap resistor.
- RFC* — Receiver-type r.f. choke.
- MA1, MA2* — Single-circuit closing jacks for 0-200 milliammeter.

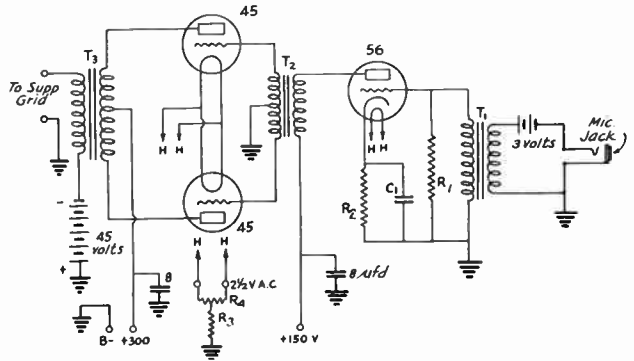


FIG. 815 — SPEECH AMPLIFIER AND MODULATOR CIRCUIT FOR SUPPRESSOR-GRID OR GRID-BIAS MODULATION

- T1* — Single button microphone transformer.
- T2* — Push-pull input transformer.
- T3* — Push-pull output transformer.
- R1* — 1/4-megohm metalized grid leak.
- R2* — 2000-ohm 5-watt biasing resistor.
- R3* — 750-ohm 10-watt biasing resistor.
- R4* — Filament center-tap resistor.
- C1* — 0.5- μ fd. low-voltage paper by-pass condenser.

maximum output, using the value of positive suppressor-grid bias beyond which no increase in output occurs (plus 45 volts in the case of the RK-20). The suppressor bias should then be set at the negative value which causes the antenna current to drop to 50 percent of the maximum value, and the amplifier is ready for modulation. The negative suppressor bias which meets this condition will be 45 volts or less with RK-20 tubes.

In making the initial adjustments care should be taken to make certain that the amplifier is not receiving too much excitation, since an excess will cause the output to decrease rather than increase.

Class B Linear R.F. Amplifiers

▲ The power output of a low-power 'phone transmitter may be increased by adding a suitable linear r.f. amplifier operating on the same frequency as the modulated amplifier. One suitable unit for operation with the low-power transmitter just described is the high-power push-pull amplifier described in Chapter Seven. There would be little gain in adding a linear amplifier of lower power because the carrier power output of a tube used as a linear amplifier is but quarter the

rated carrier power of the same tube used as a modulated Class-C amplifier.

The construction of a linear amplifier is much the same as that of any other power amplifier excepting the provisions for adjusting its grid excitation and for obtaining good r.f. grid voltage regulation. These are, respectively, adjustable input coupling and a resistor shunting the grids.

The Class-B linear amplifier operates so that its power output is proportional to the square of the grid excitation voltage, and with 100% modulation the unmodulated carrier output is one-fourth the peak or rated maximum output. The Class-B output rating of a push-pull amplifier using a pair of 852 tubes is 60 watts carrier and 240 watts peak for a plate voltage of 2000.

Fixed negative grid bias must be of cut-off value, approximately equal to the mean plate voltage divided by the amplification factor of the tube, or about 180 volts for the Type 852 at a plate voltage of 2000 volts d.c.

The procedure for putting a Class-B linear amplifier into operation is first to adjust its unmodulated excitation until the antenna current is the maximum obtainable and then to reduce the excitation until the antenna current becomes half that value. This adjustment is made by altering the coupling between its input circuit and the tank of the modulated amplifier (by means of a tap on the latter) or by varying the value of a resistor connected between the grids of the linear amplifier tubes, grid shunting resistance, or by varying both coupling and resistance. Since the primary function of the resistor is to stabilize the load across the output of the exciting amplifier, it is better as well as more convenient to keep the resistance fixed and make use of the coupling adjustment only. A variable resistor having a total resistance of 10,000 ohms will be satisfactory. It should be non-inductive and capable of dissipating 25 watts. Each change in coupling will necessitate retuning of the exciting amplifier's tank circuit and, possibly, the output tank and antenna circuits. *It is essential that all circuits be tuned to exact resonance.* If the carrier excitation is adequate, the total d.c. plate current at excitation coupling for maximum antenna current should be about 240 ma. (120 ma. per tube) and at half maximum antenna current the total d.c. plate current should be about 120 ma. (60 ma. per tube) with 2000 volts on the plates. The antenna current reading should increase with modulation of the carrier, but the plate current should remain constant.

Percentage Modulation Measurement

▲ A more accurate check on transmitter performance than that possible by the methods which have been described can be made with a simple adaptation of the peak vacuum-tube voltmeter which is known as the modulometer, the circuit

of which is shown in Fig. 817. The peak value of an a.c. voltage applied to the grid circuit of the tube is equal to the negative d.c. bias voltage required to balance it and bring the plate current milliammeter indication back to the same value as with no grid excitation. This reading of the plate milliammeter is known as the "false zero" and may be the first scale division above true zero. To obtain it the tube is operated at a set

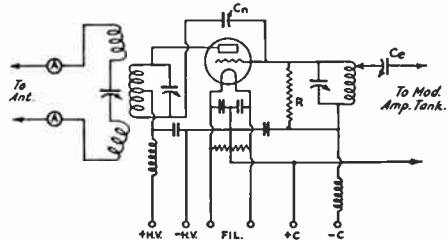


FIG. 816 — CIRCUIT OF A SINGLE-ENDED CLASS B LINEAR R.F. AMPLIFIER

The non-inductive grid-regulation resistor, R , should be capable of dissipating 50% of the exciting amplifier's power output. The excitation can be regulated by the coupling condenser, C_c or by adjustment of the regulating resistor or a tap on the exciting amplifier tank coil. The circuit values can be as usual for the frequency and power.

value of minimum bias determined by adjusting the potentiometer R_3 . The additional bias required to balance grid excitation voltage of 9-volt or less amplitude and bring the plate current back to false zero, is determined by adjustment of the potentiometer R_2 and is measured by the d.c. voltmeter V . Additional bias in series with that across R_2 is necessary for measurement of amplitudes of more than 9 volts. It is connected to the "Additional Bias" terminals shunted by the voltmeter V_1 . The sum of the readings of V and V_1 then gives the value of the peak voltage being measured. The "Additional Bias" terminals should be shorted when no battery is connected.

Percentage modulation measurements are made with S_2 thrown to the left. The coil L_2 is coupled to the output circuit of the transmitter and the r.f. current through the circuit causes a voltage drop across R_1 which is directly proportional to the current through the resistor. Variations in the amplitude of the r.f. current will therefore cause proportionate variations in the r.f. voltage across R_1 . The amplitude of the positive half cycles of this voltage is measured by the peak voltmeter.

The transmitting antenna should be replaced by a dummy antenna, of course. The coupling should be adjusted so that the modulated amplitude of the voltage across R_1 measures 5 or 6 volts. The gain control is then set at zero, leaving the carrier unmodulated, and a second measurement is made. The percentage of modulation is the difference

between the two voltages divided by the unmodulated carrier voltage, multiplied by 100:

$$M = \frac{E_{mod} - E_{car}}{E_{car}} \times 100$$

M is the percentage of modulation, E_{mod} is the voltage with modulation, and E_{car} is the voltage for the unmodulated carrier.

The gain of the speech amplifier is found by measuring the audio voltages on the grid of the first speech amplifier tube and on the grid of the

modulator, the ratio of modulator grid voltage to the speech-amplifier grid voltage being the voltage gain of the amplifier. A performance curve for the transmitter can be made by plotting the percentage of modulation for various values of speech-amplifier signal voltage against the signal voltage values.

Audio-frequency feed-back in the speech amplifier is detected by making measurements of the signal voltage on the grid of one of the amplifier tubes with the modulator plate voltage "on" and "off." If the signal amplitude is greater with the modulator "on," there is feed-back. Radio-frequency pick-up is similarly detected, the r.f. excitation (oscillator) being switched on and off, an increased amplitude with the carrier "on" indicating r.f. in the audio circuits. Audio- and radio-frequency feed-back can be eliminated by following the suggestions given in earlier parts of this chapter.

Transmitter Power Supply

▲ The filament supply for amateur transmitters is usually alternating current for the modulator and radio-frequency tubes, and either a.c. or d.c. for the speech amplifier tubes. The plate power for the speech amplifier may be from B batteries or a B substitute while that for the modulator and radio-frequency tubes is usually from d.c. generators or a.c. rectifiers. The power supply for the oscillator and buffer amplifier stages should be separate from that used for the modulator and Class-C amplifier, particularly with a Class-B modulator, unless the plate supply has exceptionally good voltage regulation. The plate supplies described in Chapter Ten will be satisfactory if the particular features pointed out therein as desirable for telephony are incorporated.

Fixed negative grid bias for low and medium power transmitters can be obtained from dry B batteries. Rectifiers are satisfactory for supplying grid bias to some r.f. and audio-frequency stages but, because of their poor regulation, are not so well suited to supplying bias for Class-B modulators.

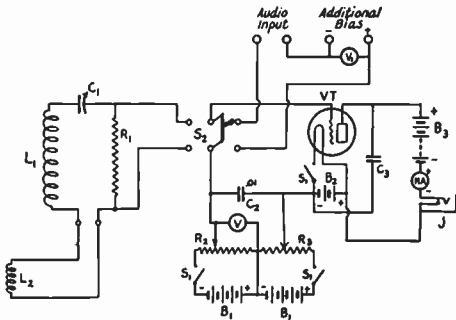


FIG. 817 — SCHEMATIC CIRCUIT OF THE MODULOMETER

- L_1 — For 3500 kc. use 40 turns of No. 28 d.c.c. wire on a $1\frac{1}{2}$ -inch diameter plug-in coil form.
- L_2 — Pick-up coil. 2 or 3 turns of lamp cord, any size convenient.
- C_1 — 100- μ fd. midget variable condenser. Any variable will do.
- C_2 — .01- μ fd. fixed condenser.
- C_3 — 1000- μ fd. fixed condenser.
- R_1 — 1500-ohm Ward-Leonard resistor No. 507-55. Any good non-inductive resistor of 1500 or 1600 ohms might be used.
- R_2 — 200-ohm wire-wound potentiometer.
- R_3 — 2000-ohm potentiometer.
- B_1 — 9- and 4.5-volt "C" batteries.
- B_2 — 2 dry cells in series (3 volts).
- B_3 — Small size 22.5-volt "B" battery.
- S_1 — Triple-pole single-throw switch.
- S_2 — Double-pole double-throw battery type switch.
- V — 0-10 d.c. voltmeter.
- V_1 — 0-120 d.c. voltmeter.
- MA — Weston Model 375 Student Type Galvanometer or 0-1 d.c. milliammeter.
- J — Closed-circuit phone jack.
- VT — Type '99 or '30 tube.

THE ULTRA-HIGH FREQUENCIES

A RELATIVELY tremendous amount of development work has been done on the lower frequency bands since the amateur first showed their effectiveness for medium and long-distance communication. So exhaustively have the characteristics of those bands been observed, that the experienced amateur of today knows fairly well, ahead of time, just what to expect in the way of performance with a given installation at a given time of the day, month or year. In this respect, the ultra-high frequencies are different. Amateur operation on frequencies of 56 mc. and above (wavelengths of about 5 meters and below) is something relatively new. Only during the last two or three years has there been appreciable amateur ultra-high frequency communication activity and only during the last year or so has this phase of amateur radio been generally recognized as one of the most fascinating of all.

Even at this stage, the full possibilities of ultra-high frequency working have by no means been explored. Widespread activity is to be found on the 56-mc. band but the higher frequency territory is still virtually unpopulated. Slowly, but very surely, amateurs are beginning to recognize that the territory below 5 meters contains the mystery bands of amateur radio — the bands about which very little is known and on which almost anything is likely to happen. It is not surprising, therefore, that these bands are gradually becoming populated by progressive amateurs determined to explore the possibilities and fondly hoping to be able to make some real contribution to the art.

Equipment Constantly Changing

▲ Because ultra-high frequency working is still very much in its infancy, it is subject to particularly rapid growth and change. Apparatus considered to be ideal today is quite likely to become antiquated tomorrow. It is therefore absurd to suggest that this chapter should be considered a complete survey of the field or that the equipment illustrated in it is the ultimate. Even as this is being written we can see developments on the horizon which are likely to result in many revisions of our present ideas. Our aim and our only hope is to present the details of well-tried ultra-high frequency equipment, together with the general principles of its operation, knowing that the sincere worker will keep himself abreast of the new developments as they are presented from month to month in *QST*.

What to Expect

▲ It is important that the amateur about to undertake ultra-high frequency work should realize that the very high frequency waves behave in a very different manner to those of lower frequency. On frequencies of 56 mc. and above, one does not find evidence of a bending of the waves in the Kennelly-Heaviside layer except under the most extraordinary conditions. Only the "ground wave" is considered to be of any value and communication is therefore restricted to relatively short distances. The lower frequency bands provide ample opportunity for long-distance working and the amateur interested only in DX might well restrict his activity to that territory. The particular practical value of the ultra-high frequencies, in contrast to the other bands, is in the very fact that they do not seem to allow communication over very long distances. It is this very characteristic of waves below 5 meters which allows groups of amateurs in various parts of the country to "rag-chew" with each other night after night without interfering in any way with the next group 50 or 60 miles away.

The actual range of communication possible on the ultra-high frequency bands is something on which it is not possible to offer a definite prediction. It is generally considered, however, that the range to be obtained reliably with a low-powered transmitter and a normal type of antenna system is about 10 per cent. greater than the visual range from the antenna. Recent work has shown, however, that this range can be increased to several times the visual range by the use of highly directive antenna systems for transmission and reception, though it is possible that the increased range so obtained is not absolutely reliable under all conditions. The advantages to be gained by using directive antenna systems have not been thoroughly examined as yet but it is already apparent that a tremendous field of possibilities is ready to be opened up — particularly on the frequencies higher than 110 mc. for which directive antennas are both simple and compact.

Suitable Equipment

▲ The same general principles of operation met with in apparatus for the lower-frequency bands hold good on the ultra-high frequencies. In many respects, however, the problems are quite different and, as a result, much of the ultra-high frequency gear differs greatly from that described

in the earlier chapters. Because the wavelengths are so short, it is natural that coils, condensers and radio frequency chokes will have to be much smaller than those used on other bands. It will be found, also, that greater attention will have to be paid to the length of connecting wires in the tuned circuits and to the presence of small "stray" capacities. Tubes which operate well on the low frequencies may not work at all below five meters. Radio frequency amplifiers which work so effectively at, say, 7 mc. may be found to be entirely useless at 56 mc.

This very problem of obtaining radio-frequency amplification in either the transmitter or receiver on the ultra-high frequencies has led to the rather general use of self-controlled oscillators for transmission and broad-tuning but highly sensitive super-regenerative receivers for reception. The combination provides a completely practical and very effective solution to a whole group of technical problems. In congested areas, of course, it is probable that such "modulated-oscillator" transmitters and broad-tuning receivers might result in severe interference. In such cases, a more complex but more stable oscillator-amplifier transmitter is very much to be desired and is, indeed, becoming widely used on the 56-mc. band — the only ultra-high frequency band on which interference is likely to be a problem at this juncture and the only one on which the oscillator-amplifier transmitter is likely to be really practical.

For reception, the super-regenerative receiver is still by far the most popular type. Its simplicity, reliability and extreme sensitivity, combined with its broad tuning, make it almost ideal for ultra-high frequency work. For the very high frequencies (110 mc. and above) it is virtually indispensable. For 56-mc. work, the super-heterodyne is becoming increasingly popular but opinion on its value is still very much divided.

Finding the Bands

▲ On the ultra-high frequencies the amateur has available the territory between 56 and 60 mc. and also all the frequencies higher than 110 mc. In order to facilitate contact and communication in the enormously extensive territory higher than 110 mc., however, it has been suggested that the amateur endeavor to operate in bands related harmonically with the 56-mc. band. The

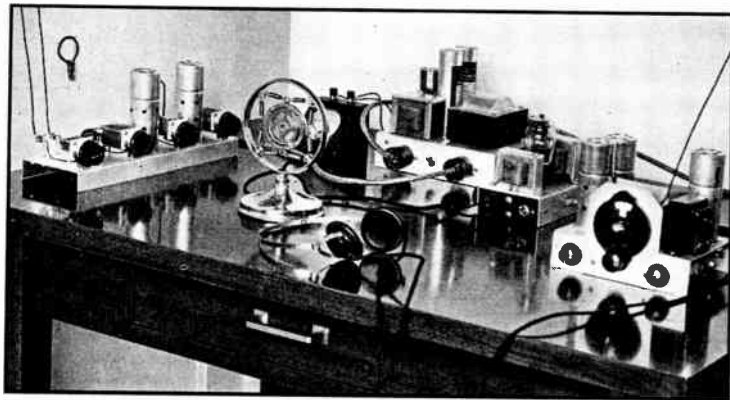
so-called ultra-ultra high frequency bands to which particular attention is being given are therefore 112 to 120 mc.; 224 to 240 mc. and 448 to 480 mc.

In mentioning these bands we have so far adhered to the usual practice of stating the frequencies involved. This practice, however, is prone to be very inconvenient when speaking of and working with the ultra-high frequencies. Antennas, linear tuning rods, reflectors and directors are all to be measured in terms of wavelength and it is most inconvenient to be obliged to convert frequency to wavelength before proceeding with such measurements. Then, the most practical means of frequency determination on the ultra-high frequencies is by actually measuring the wavelength directly from a standing wave on wires. It is obviously a handicap to be obliged to convert direct measurements so obtained back to frequency.

For these reasons we will find it desirable to make use of wavelength very frequently in this chapter and can only hope that the reader will find it reasonably simple to acquire the habit of thinking in terms of frequency and wavelength simultaneously.

The 56-mc. band covers from 5.357 to 5 meters. This means that the harmonically related 112-mc. band will be from 2.678 to 2.5 meters while the next band down — the 224-mc. band — will be from 1.339 to 1.25 meters.

The future will certainly see amateur activity on the frequencies higher than these but, at the



A MODERN 56-MC. AMATEUR STATION

Fitted out with an oscillator-amplifier transmitter and a non-radiating receiver, this station is capable of producing excellent signals and of operating with a minimum of unnecessary interference. This particular equipment was given comprehensive description in August, 1934, QST.

moment, most of the interest is concentrated in exploring the wide "wastes" between 5 and 1.25 meters.

The methods of frequency measurement and checking described in Chapter Six are, generally speaking, unsuited for the ultra-high frequencies.

Fortunately, simpler (though probably less accurate) methods are available.

The simplest method is merely to cut the antenna wire to 95 per cent. of the actual wavelength desired, then tuning the transmitter until the antenna is operating most effectively. This scheme is, of course, extremely approximate and would serve only as a preliminary measure.

The next simple scheme is to compare the frequency of one's own transmitter by tuning

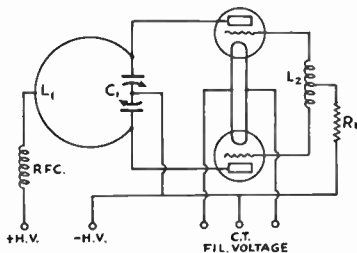


FIG. 901 — A TYPICAL 56-MC. OSCILLATOR CIRCUIT

L1 — Single turn of 1/4-inch copper tubing, 4 inches in diameter, mounted on stator terminals of tank condenser.

L2 — 4 turns No. 14 enamelled antenna wire, 1" in diameter, and about 2" in length. Turns are squeezed together or separated until set oscillates with minimum plate current at the desired frequency of operation.

C1 — National split-stator condenser, Type TMP-100. Net maximum capacity (sections in series) 100 μfd.

RFC — 18 turns of No. 24 d.c.c. on 1/2-inch wooden dowel, 1/16-inch spacing between turns.

R1 — 10,000-ohm non-inductive grid-leak 5-watt size or larger.

These constants are for Type 10 tubes. Slight modification of L2 may be necessary when Type 15, 71-A or 801 tubes are used. A tank tuning condenser of lower voltage rating would be satisfactory for the smaller tubes. A receiver type condenser may be used when the plate voltage does not exceed 250 or 300 volts.

it on the receiver and comparing the setting with other stations of known wavelength. This is readily possible in districts where plenty of signals are available for the purpose but at present would be impractical on the 2 1/2 or 1 1/4-meter bands. On the latter bands, or even on 5 meters, the problem is readily solved if a linear type oscillator is used. With this type of oscillator (to be described later) the wavelength can be measured directly from the rods which constitute the tuning circuit.

For the very short waves, probably the most practical method involves the use of two parallel wires — known as Lecher wires — on which standing waves may be measured directly. Such a Lecher system may be set up readily and forms a valuable addition to the ultra-high frequency worker's equipment.

A typical Lecher system consists of two No. 18 bare copper wires spaced about two inches and mounted on stand-off insulators on a length of

board. The wires should be at least eight feet long. The wires are left free at one end while at the other they are connected to a one- or two-turn coupling coil of about the diameter of the tank coil of the transmitter. This coupling coil is placed near the transmitter coil. In operation, a sliding bridge — consisting of a piece of stiff bare wire on the end of a two-foot wooden dowel — is run slowly down the length of the wires until a point is reached where the oscillator plate current makes a sudden fluctuation. The point is marked. The bridge is then moved farther down the wires until a second node is located. This also is marked. The same procedure is then followed to locate a third node. At this stage, the distance between each pair of marks is measured. If the Lecher system is operating correctly and if it is mounted well clear of surrounding objects, the distances will all be the same and will represent quite accurately one half of the wave-length being measured. An alternative sliding bridge — useful when the oscillator has plenty of output — is a flashlamp bulb with wires soldered to its contacts. These wires are hooked over the wires of the Lecher system and the lamp moved along until the various points are located at which the lamp lights brightest. The points will be extremely critical.

The same general procedure may be used to calibrate a receiver — the indication in this case being obtained by the receiver going out of oscillation as the bridge passes over the various nodes.

Once the approximate calibration has been obtained in this way, it can be readily checked by comparing harmonics produced by oscillators on harmonically related lower frequency bands.

Transmitters for 56 mc.

▲ The circuit of Fig. 901 will serve to illustrate what is probably the simplest arrangement of a 56-mc. transmitter. Built into a "bread-board" lay-out, it will resemble the transmitter shown



FIG. 902 — A 56-MC. EXPERIMENTAL OSCILLATOR
The various components can be located by reference to the circuit of Fig. 901. The antenna coil is a half turn mounted over the plate coil.

in Fig. 902. The tuning and adjustment of such a unit will be carried out in the manner suggested for the lower frequencies with the difference that it will hardly be practical to make use of a monitor for checking the signal emitted. This type of oscillator, when modulated, will produce a frequency-modulated signal occupying a wide slice of the band. For this reason, we cannot recommend its use in large cities or in other localities where many 56-mc. transmitters are in operation.

The constants given under Fig. 901 are suited for use with a pair of Type 10 tubes. The circuit itself, of course, is entirely effective with other tubes. Type 45 tubes, for example, are widely used in lower powered transmitters, while 800's could serve to provide a high-powered installation in locations where interference is not a serious problem. Slight modifications of the coils L_1 and L_2 may be necessary with these other tubes. An appropriate tank tuning condenser also would be desirable.

Another widely used type of oscillator circuit is that shown in Fig. 903. It has the advantage of operating well over a wide variety of frequencies without the need for adjustment of anything except the tuning condenser. While the use of a split-stator condenser (as shown in the diagram) is advised, a normal single-ended condenser can

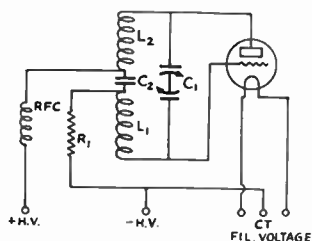


FIG. 903 — ANOTHER OSCILLATOR CIRCUIT FOR 56 MC.

L_1, L_2 — each 5 turns of No. 14 enamelled wire $\frac{5}{8}$ -inch inside diameter.

C_1 — Tank tuning condenser with plate spacing to suit the voltage used. A receiver type condenser with 25- μ fd. total capacity would be satisfactory at 200 to 300 volts. A single three-plate midjet is often used in this type of circuit with small tubes such as the 37 or 76.

C_2 — 100- μ fd. fixed condenser.

R_1 — 10,000 to 25,000 ohm grid-leak.

RFC — National Type 100 choke or similar unit to that given under Fig. 901.

be employed if it is supported well away from any metal base and provided with an insulated shaft coupling.

Transmitters for the Higher Frequencies

▲ The circuits just described, and many similar to them, are satisfactory on the 5-meter band. However, they are not altogether suitable for the $2\frac{1}{2}$ and $1\frac{1}{4}$ -meter bands. By the time the inductances have been cut down to tune even to

$2\frac{1}{2}$ meters, there is nothing much left. Another type of circuit, admirably suited for all the bands mentioned, is that given in Fig. 904. It is one of a large group of so-called "linear" oscillators. In Fig. 904, the conductors L_1 and L_2 are made of such dimensions that the entire length of each conductor — including the elements and leads within the tube — correspond to a half wavelength. The plate and grid feeds are then connected at the nodal point in the electrical center of the system. The conductors may be made of No. 14 wire but it is considered that a great

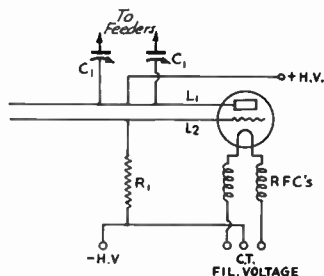


FIG. 904 — AN OSCILLATOR CIRCUIT SUITED FOR THE VERY HIGH FREQUENCIES

L_1, L_2 — Copper rods or tubes slightly less than a half-wave long. Tubing $\frac{1}{2}$ -inch outside diameter spaced 1 inch between centers is suggested though smaller or larger conductors will serve.

C_1 — Feeder tuning condensers. Three-plate midjets would be satisfactory for $2\frac{1}{2}$ meters or below. Condensers several times this capacity would serve for 5 meters.

R_1 — Grid-leak of resistance and power rating to suit oscillator tube. 25,000 ohms is a good average value.

RFC's — About 25 turns of No. 14 wire $\frac{5}{8}$ -inch diameter with turns spaced the diameter of the wire. These chokes are absolutely essential.

Almost any of the usual triodes will operate in this circuit down to at least $2\frac{1}{4}$ meters. The Type 800 or W.E. 301A are suggested for satisfactory performance at $1\frac{1}{4}$ meters.

improvement in performance is made possible by using large diameter copper tubing — the two conductors being spaced approximately the diameter of the tubing.

Several methods of coupling the feeder system are possible. That indicated in Fig. 904 is one possibility. In this case, the tuned feeders of a Zepp system are clipped on the plate rod, one on each side of the nodal point. Variation of the spacing of the two clips then permits variation of the coupling to the feeder. Untuned feeders may be attached in the same manner, the spacing of the clips being varied to give the necessary impedance match.

In this type of oscillator, the adjustment of the length of the rods is the one very important matter. It is probably a good scheme to start out with rods a full half-wave long, then cutting them down until the desired wavelength is reached. The actual length of the rods will

depend upon the type of oscillator tube used.

The mounting of the rods is another important matter. Probably the simplest method is to support them between two stand-off insulators on a strip of good insulating material. The support should preferably be at the nodal point.

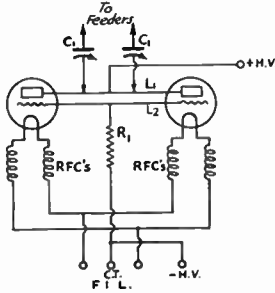


FIG. 905 — A PUSH-PULL VERSION OF THE LINEAR OSCILLATOR

The same values may be used as given under Fig. 904. The length of the rods must be reduced, however, to allow for the loading effect of the second tube.

A Push-Pull Linear Oscillator

The circuit of Fig. 905 shows how the linear oscillator may be adapted for push-pull working. Instead of having one end of the half-wave lines open, they are connected to the grid and plate of a second tube. This means, of course, that the actual length of the rods will be decreased to allow for the loading provided by the second tube. The full length of each rod will be twice the distance from the node to the tube terminals in Fig. 904. The nodal point, where plate and grid feeds are attached, will now be in the center of the system. The antenna feed methods may be the same as those previously mentioned.

Setting up a Linear Oscillator

The construction and tuning of transmitters of the type just mentioned is delightfully simple. The only essential need is to develop the habit of visualizing the voltage distribution along

the rods so that the actual operating conditions in the circuit can be determined rapidly. The most suitable tubes for these circuits, and for the $2\frac{1}{2}$ and $1\frac{1}{4}$ meter bands, are probably the 800 and the W.E. 304A. Other tubes such as the 45, 10 or 37 have been shown to be effective but a little more difficulty may be had in obtaining stable operation and reasonably long tube life.

The use of a plate current meter is, of course, essential. If the circuit is oscillating, this meter will show current fluctuations when the rods are touched with a pencil or screw-driver at points other than the voltage nodes. This very method, indeed, is probably the best one to reveal the actual location of the nodes. Another practical way of locating the best position for the plate and grid feed clips is to move the clips until the plate current drops to a minimum value.

A Three-band Transmitter

Fig. 906 illustrates a transmitter of this general type suited for operation on the 5, $2\frac{1}{2}$ and $1\frac{1}{4}$ -meter bands. It is similar to the arrangement of Fig. 904, being identical, in fact, when the set is operated on $2\frac{1}{2}$ meters. The plate and grid conductors are made a full-wave long at $1\frac{1}{4}$ meters and the circuit will oscillate at that wave-

length when the plate and grid-feed clips are connected three-quarter waves (at $1\frac{1}{4}$ meters) from the tube elements. Sliding the feed clips out near the center of the rods will put them one-quarter wave (at $2\frac{1}{2}$ meters) from the open end and the system will then operate at $2\frac{1}{2}$ meters. For 5-meter operation, the feed clips are run down to the ends of the rods and a by-pass condenser is clipped across them. Since the entire rod length is one-quarter wave at 5 meters the node will be at the far end and the system will oscillate at 5 meters. It will be necessary, of course, to change the location of the antenna feeder clips when changing from one band to another. On the $2\frac{1}{2}$ and $1\frac{1}{4}$ meter bands they may be on either side of the plate feed connection. On 5 meters, one feeder may be

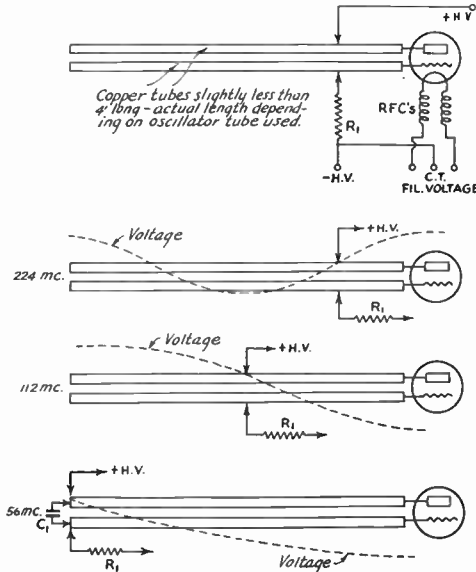


FIG. 906 — A THREE-BAND ULTRA-HIGH FREQUENCY TRANSMITTER

The rods are of $\frac{1}{2}$ -inch copper tubing spaced 1 inch center to center. Their length is slightly less than a full wave at $1\frac{1}{4}$ meters. The actual length is determined by the type of tube used. With a W.E. 304A, the rods are 113 centimeters (about 46 inches) long. They would be slightly shorter for the 800 and most of the smaller tubes. An adjustable bridging condenser of about 25 μ fd. between the grid and plate feed points may be found desirable on 112 and 224 mc.

clipped on the plate rod near the feed end, the other feeder opposite it on the grid rod.

A Low-powered Transmitter for Three Bands

▲ The conventional circuits used on the lower frequencies may be put to work on the ultra-high frequencies providing the special "acorn" ultra-high frequency tube is used. This tube will readily permit operation on wavelengths of $1\frac{1}{4}$ meters and lower. Fig. 907 shows one typical circuit for this tube while Fig. 908 illustrated one possible layout of the apparatus. The transmitter as illustrated is fitted with a $1\frac{1}{4}$ -meter band coil.

An important feature of the transmitter is a heavy copper plate on which the apparatus is mounted and which serves to establish a good "ground" for the system. The tube is mounted over a hole cut in this plate to keep the connecting leads as short as possible. The plate and grid lugs are mounted on a strip of "Vietron" bridging this hole, leads running directly to the coil on one side and the grid condenser on the other. The special split-stator tuning condenser is used with the idea of keeping the minimum capacity of the circuit low and to keep the path through the condenser short. The condenser itself is mounted on a block of hard rubber attached to the copper base. The methods of coupling a feeder system to this transmitter may be exactly similar to those used on the lower frequencies.

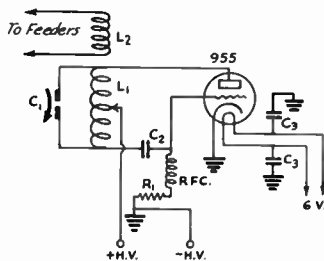


FIG. 907 — CIRCUIT OF THE "ACORN" TRANSMITTER

- L_1 — Five turns of No. 14 wire $\frac{1}{4}$ -inch inside diameter, with turns spaced diameter of wire, for $1\frac{1}{4}$ meters. Five similar turns $\frac{1}{2}$ -inch diameter for $2\frac{1}{2}$ meters. Fourteen turns of same diameter for 5 meters.
- C_1 — Two plate midget condenser with stator cut in half.
- C_2 — Two pieces of sheet brass $\frac{3}{8}$ by $\frac{3}{4}$ -inches cemented with Duco cement to a thin piece of mica. A very small size fixed condenser of about 50 $\mu\text{fds.}$ is required.
- C_3 — 100- $\mu\text{f.}$ midget fixed condensers running as directly as possible to the metal base plate.
- R_1 — 25,000 ohm half-watt resistor.
- RFC — About twenty turns of No. 20 wire $\frac{1}{4}$ -inch diameter.

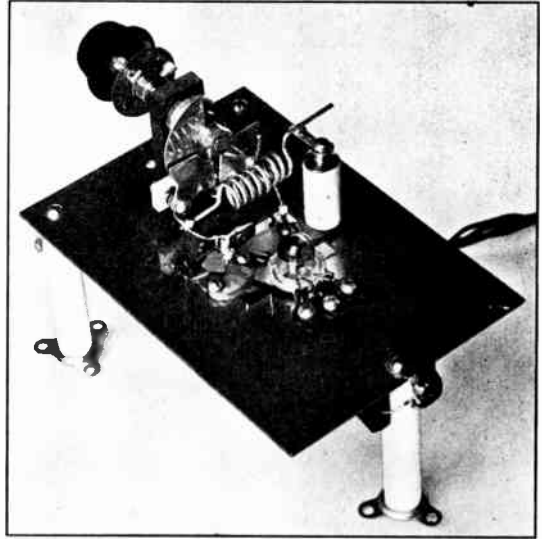


FIG. 908 — THE "ACORN" TRANSMITTER

While this oscillator is built up as a separate unit, there is no reason why it should not be incorporated as part of the complete transmitter and mounted alongside the modulator. It is suggested, though, that the copper base plate should be retained.

An Oscillator-Amplifier Set for 56 mc.

▲ The reader who has studied Chapter Seven will readily understand the advantages to be gained by replacing a simple oscillator, feeding the antenna, with an oscillator-amplifier transmitter. Unfortunately, the process is much more difficult on the ultra-high frequency bands than on those of lower frequency. Not only must the amplifier be excited from a much more powerful oscillator but the entire procedure of tuning and neutralizing is much more difficult to perform. The 56-mc. band is the only ultra-high frequency territory on which oscillator-amplifiers have been shown to be practical.

Fig. 909 is the circuit of a typical medium-powered oscillator using Type 10 tubes. Two important features distinguish it from the oscillator-amplifier circuits used on the lower frequencies: the use of an oscillator having comparable output to the amplifier and the employment of inductive coupling between oscillator and amplifier. Both of these are made desirable by the relatively poor efficiency of amplifiers on the very high frequencies and the consequent difficulty in providing sufficient excitation with the conventional low-powered oscillator and the conventional circuits. It will be seen that the oscillator circuit is similar to that of Fig. 901 and that its tank circuit is inductively coupled to the tuned grid circuit of the amplifier. In practice, this coupling is adjusted to the lowest possible value consistent with full excitation of

the amplifier. The amplifier is neutralized in the normal fashion. Its adjustment in every respect will be similar to the process outlined for similar transmitters in Chapter Seven.

It should be remembered that while the signals from this type of transmitter will be more stable than those from the straight oscillator type of set and less subject to frequency modulation, the arrangement is still far from perfect. Advanced 56-mc. workers anxious to obtain the greatest possible freedom from frequency modulation will find it practical to excite a unit such as that shown in Fig. 909 from the output of the "Tri-tet" exciter described in Chapter Seven.

A Low-Powered Oscillator-Amplifier

▲ The use of suitable screen-grid tubes in an oscillator-amplifier transmitter make it possible to avoid neutralization and to provide a highly

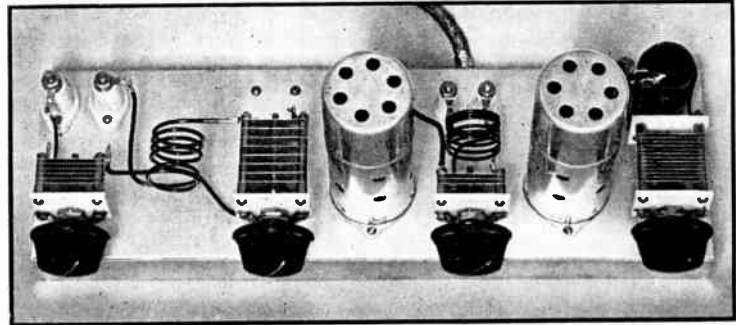


FIG. 910 — A SIMPLIFIED HIGH-STABILITY 56-MC. TRANSMITTER
Type 58 receiving tubes show their splendid capabilities as transmitters in this rig. An unusually high order of stability under modulation is attained by the circuit design and layout.

stable electron-coupled oscillator. Unfortunately, transmitting tubes of that type, effective in ultra-high frequency circuits, are not readily available. On the other hand, receiving tubes of the 58 or 6D6 types have proved to be entirely practical for the small 56-mc. transmitter. Such tubes are put to good use in the transmitter illustrated in Figs. 910, 911 and 912.

Two Type 58 or 6D6 tubes are used in the transmitter proper, one as an electron-coupled oscillator-doubler and the second as the 56-mc. amplifier. The latter tube is, of course, the tube modulated.

A top view of the transmitter is given in Fig. 910. The physical layout, it will be observed, almost exactly follows the circuit diagram of Fig. 911. The metal chassis is made of aluminum and measures 13 by 4 inches, with 3/4-inch vertical sides.

The tuning condensers are mounted on brackets supplied for the purpose. The oscillator tuning condenser C_4 is provided with mounting brackets at both ends so that this condenser will be quite

solidly mounted. The double mounting helps to prevent frequency changes arising as the result of vibration. For the same reason the oscillator coil L_6 , which is just behind C_4 , is wound on a form instead of "on air" as are the other coils.

The oscillator plate-coupling coil L_4 is mounted on two feed-through stand-off insulators at the rear edge of the chassis behind C_3 . This coil is placed so that its axis coincides with that of L_2 , and is about 1/4-inch away from it. Its connections run down through the insulators to the under side of the chassis.

The bottom view of the transmitter will be helpful should there be any doubt about the way in which the parts under the chassis are placed and wired.

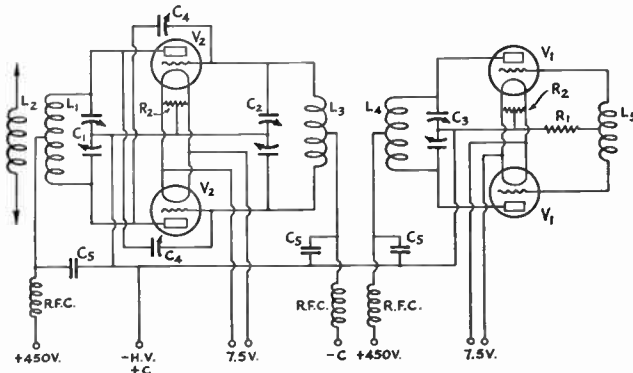


FIG. 909 — THE CIRCUIT OF A SIMPLE OSCILLATOR-AMPLIFIER TRANSMITTER

- L_1 — 2 turns 2 inches inside diameter.
- L_2 — One turn at each end of L_1 , same diameter.
- L_3, L_4 — 2 turns 1-inch diameter.
- All above coils wound with 3/16-inch copper tubing.
- L_5 — See L_2 of Fig. 901.
- C_1 — Double-section midget condenser, 35 μ fd. per section, double spaced.
- C_2 — Double-section midget condenser, 100 μ fd. per section.
- C_3 — Same, 110 μ fd. per section.
- C_4 — Single 35 μ fd. midget condensers double spaced.
- C_5 — R.f. by-pass condensers, about 100 μ fd.
- R_1 — 10,000-ohm 5-watt resistor.
- R_2 — 75-ohm center-tapped resistors.
- RFC — See ditto of Fig. 901. Any other r.f. chokes suitable for 56 mc. may obviously be used.
- V_1, V_2 — Type 10 tubes. Other UX-type tubes may be used with reduced voltages.

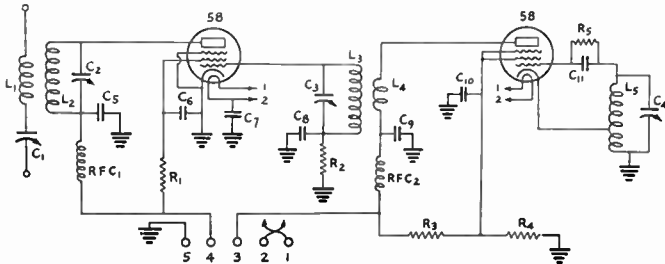


FIG. 911 — CIRCUIT DIAGRAM OF THE OSCILLATOR-AMPLIFIER TRANSMITTER

Ground symbols indicate connections to the metal chassis.

- C*₁ — 50- μ fd. midget variable condenser (Cardwell Trim-Air Type RT-50).
*C*₂ — 30- μ fd. midget variable condenser (Cardwell Trim-Air Type XT-30).
*C*₃ — 25- μ fd. midget variable condenser (Cardwell Trim-Air Type RT-25).
*C*₄ — 140- μ fd. midget variable condenser (Cardwell Trim-Air Type RT-140).
*C*₅ to *C*₁₀ incl. — 250- μ fd. midget mica condensers.
*C*₁₁ — 100- μ fd. mica condenser.
*R*₁ — 50,000-ohm 1-watt resistor.
*R*₂ — 25,000-ohm 1-watt resistor.
*R*₃ — 50,000-ohm 20-watt resistor.
*R*₄ — 50,000-ohm 2-watt resistor.
*R*₅ — 25,000-ohm 1-watt resistor.
*RFC*₁, *RFC*₂ — Sectional-wound short-wave chokes (National Type 100).
*L*₁ — 2 turns No. 12 enamelled wire, coil diameter $\frac{7}{8}$ inch.
*L*₂ — 4 turns No. 12 enamelled wire, coil diameter $\frac{7}{8}$ inch, length $\frac{1}{2}$ inch.
*L*₃ — 3½ turns No. 12 enamelled wire, coil diameter $\frac{7}{8}$ inch, length $\frac{1}{2}$ inch.
*L*₄ — 3 turns No. 12 enamelled wire, coil diameter $\frac{7}{8}$ inch, length $\frac{3}{8}$ inch.
*L*₅ — 5½ turns No. 12 enamelled wire, on 1-inch diameter (National) coil form, length $\frac{7}{8}$ inch; tapped 1½ turns from ground end.

The following additional components will be required:

- 2 6-prong Steatite tube sockets (National).
 2 tube shields (Hammarlund Type TS-50).
 2 feed-through stand-off insulators (Birnbach Type 458).
 2 small porcelain stand-off insulators (Birnbach Type 366).
 2 midget porcelain stand-off insulators.
 4 feet of 5-wire shielded cable.
 5 mounting brackets for Trim-Air condensers (Cardwell).
 1 5-prong plug or old tube base.

Terminals 1 and 2 connect to the heater voltage supply. Terminal 3 is supplied with 250 volts for the oscillator supply while terminal 4 connects to the modulator and high voltage positive. A maximum plate voltage of 300 is suggested. Terminal 5 is connected to the negative high-voltage. A complete installation which included this transmitter was detailed in the August, 1934, QST.

Long Lines Control

▲ The problems that present themselves when one builds an oscillator-amplifier transmitter even for the 56-mc. band provide an indication of the impracticability of employing the same principle of frequency stabilization to the still higher frequencies. Quite possibly it could be accomplished if one had the necessary tubes, patience and enthusiasm but there is obvious need for some entirely different approach to the subject. Linear oscillators of the type already described show decided promise of improved

stability and they represent a field in which there will undoubtedly be great progress made in the early future. Another excellent general method of gaining improved stability is by the use of so-called "long lines." The scheme, in one of its simpler variations, involves the use of a long tuned line attached to the grid circuit of what otherwise would be a conventional circuit.

Fig. 913 illustrates the circuit used in one successful transmitter designed for 1¼ meter operation. The arrangement of the plate and filament circuits will be seen to be similar to those of Fig. 905. The latter circuit, as a matter of fact, represents a stage in the setting up of the transmitter under discussion. It has been found desirable first to build the transmitter as a push-pull oscillator similar to Fig. 905 or Fig. 901 (depending on the frequency) then replacing the grid circuit with the long line after all other adjustments have been made. The line itself may conveniently consist of a pair of No. 14 or 16 bare copper wires spaced about 2 inches and strung across the room. One suitable line for 1¼ meters is about eleven feet six inches long stretched directly across the ceiling of the room in which the transmitter is located. These wires at one end are connected to the two grids and are jumped by a sliding wire bridge, to the center of which the grid return

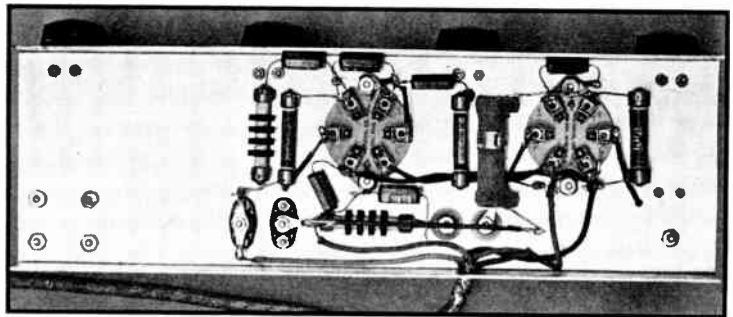


FIG. 912 — A SUB-BASE VIEW OF THE OSCILLATOR-AMPLIFIER TRANSMITTER

By-pass condensers, resistors and chokes are located near the tube sockets with which they are associated in the circuit diagram.

is connected. In tuning, the bridge is moved along the wire until the transmitter oscillates on the frequency desired. The usual meter in the feeder circuit might well be used to indicate

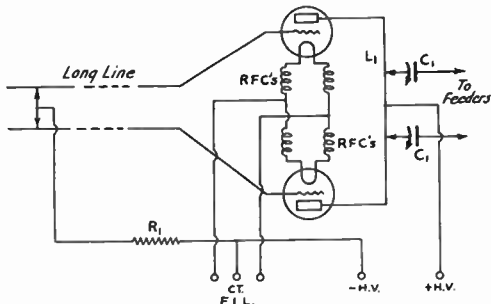


FIG. 913 — A STABILIZED 1/4-METER TRANSMITTER EMPLOYING LONG-LINES CONTROL

The components of this circuit correspond exactly with those of Fig. 905 with the exception of the grid circuit. This is described in the text.

oscillation while a receiver functioning as a monitor might be used to indicate the approximate frequency. It will be found that the transmitter will oscillate whenever the bridge is at a voltage node and after a few of these nodes have been located, the bridge should be moved out to the most distant one from the transmitter. The frequency stability will be improved as the length of the line is increased and on the 5 or 2 1/2 meter bands it might be found desirable to zig-zag the line across the ceiling in order to get a reasonably large number of quarter waves on the line. Should it be inconvenient to run a third wire to the end of the line for the grid return, it may be connected instead at any voltage node (on one wire only) nearer the transmitter.

Choosing Suitable Modulators

▲ Before planning and building any complete transmitter for ultra-high frequency work, the amateur should become familiar with the principles outlined in Chapter Eight. The type of modulator used or the manner in which it is operated are matters not influenced in any way by the frequency on which the transmitter is set.

Much of the ultra-high frequency work is done with transmitters of very low power. In such cases, it is obviously unnecessary to provide elaborate modulators with speech amplifiers. Usually a single pentode tube operated Class A will serve the purpose. A 2A5, for example, makes a suitable modulator for the transmitter of Fig. 911 while a 41 might well be used with the oscillator of Fig. 907. Transmitters using a single 800 or a W.E. 304A are usually operated at a

plate voltage of 600 or 700 at 70 or 80 m.a. Class B 10's or even 46's would serve in the modulator. The possible tube combinations are so numerous that we can only suggest study of Chapter Nine and a choice of tube combinations based on the fundamental requirements.

Receivers for Ultra-High Frequency Work

▲ Of the possible types of receivers, the super-regenerative is by far the most popular. Though possibly more sensitive than the super-regenerative receiver, the super-heterodyne has not yet been widely accepted. The probable reason is that its complexity and cost appear to be out of all proportion with its performance. The autodyne type of set, sometimes fitted with a radio frequency amplifier, has been used successfully by some workers. Like the super-heterodyne, it is of value in the reception of stable signals in instances where high selectivity is called for. The super-regenerator, however, remains the ideal for most work. It is simple, inexpensive, sensitive, and reliable.

Since super-regeneration plays such an im-

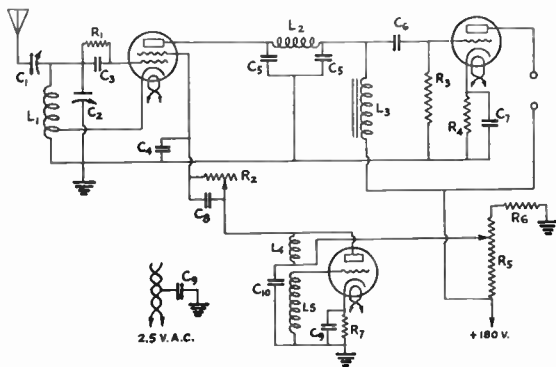


FIG. 914 — A THREE-TUBE 56-MC. RECEIVER

- C₁ — Very small compression type mica trimmer condenser.
- C₂ — 12-μfd. variable condenser.
- C₃ — .0001-μfd. condenser.
- C₄ — .001- to .002-μfd. condenser.
- C₅ — .001-μfd. condenser.
- C₇ — .5-μfd. or more.
- C₆ — .5-μfd. or more.
- C₀ — .01-μfd. or more.
- C₁₀ — .5-μfd. or more.
- R₁ — 1/2-watt, 5 megohm.
- R₂ — 50,000 ohm rheostat.
- R₄ — 2,000 ohm, 1 watt.
- R₅ — 12,000-ohm voltage divider.
- R₆ — 50,000-ohm 2-watt resistor.
- R₇ — 2,000-ohm, 1 watt.
- L₁ — Detector coil. Two turns, 1-inch diameter. Tap one-quarter turn from grounded end.
- L₂ — 250 millihenry r.f. choke.
- L₃, C₆, R₃ — Parts of National S101 coupling unit.
- L₄, L₅ — National or Sickles interruption oscillator coils.

The 57, 36 or 77 would suit for the detector, 45's or 37's being used for the other tubes. A 2A5 or 41 audio tube would be useful for speaker operation.

portant part in this work, it might be well to outline its principle of operation. We all know that the sensitivity of a regenerative receiver increases very rapidly as the point of oscillation is approached, but that the point of oscillation constitutes the limit to which this amplification may be carried in the usual receiver. In the super-regenerative system the application of an auxiliary super-audible frequency voltage on the grid or plate of the regenerative tube allows relatively terrific regeneration without the paralyzing self-oscillation which would ordinarily occur. In the first receiver to be described, the regenerative detector is "plate modulated" by the long-wave oscillator and the detector plate voltage is therefore swinging back and forth at the frequency of that oscillator. On the positive peaks the voltage is of an order which would ordinarily make the detector oscillate violently. Such oscillation has no time to develop, however, before the plate voltage swings down on the next half-cycle of the auxiliary oscillator. Strictly speaking, an oscillation may develop during the positive half cycles but its amplitude is of such a low order as to be of little consequence. Operated in this condition, a regenerative detector may provide amplification many million times greater than that of the simple regenerative detector operated just below oscillation.

In other receivers described, the low interruption frequency is generated by the same tube that does the regenerating and detecting on the signal frequency. This arrangement is particularly desirable in small receivers where weight, size and battery consumption are important factors.

A Three-Tube Set for A.C. Operation

▲ A typical a.c. operated receiver for the 5-meter band is illustrated in Figs. 914 and 915. It will be seen from the circuit diagram that the detector is arranged in the electron-coupled circuit already

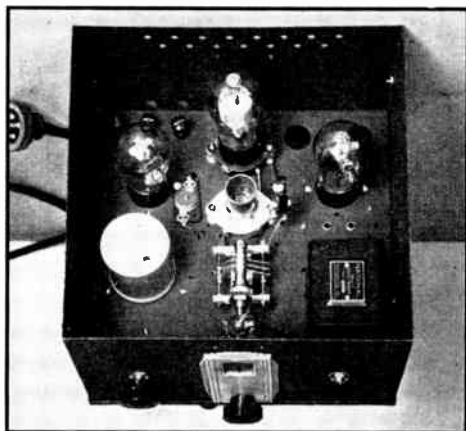


FIG. 915 — THE THREE-TUBE 56-MC. RECEIVER

discussed in Chapters Five and Seven. The screen grid acts as the plate of the r.f. oscillator while the audio is taken out in the plate circuit. The long-wave modulator is connected into the screen grid, thereby modulating the r.f. oscillator by varying the screen-grid voltage. It would appear that both the coils comprising the long-wave oscillator transformer are untuned. However, they are arranged in a tuned-plate circuit with the grid coil acting as a tickler. The condenser C_4 acts not only as a ground for the screen grid but also as the tuning condenser across the long-wave plate coil L_4 . If the grid coil is not large enough, a small condenser may be required to tune it also. L_2 must be a good long-wave choke but care must be taken that C_5 is not of such a value as to tune the filter to the frequency of the long-wave oscillator.

In other respects, the circuit of this set follows the usual practice.

The mechanical arrangement of the parts is made clear in Fig. 915. The interruption frequency oscillator tube is at the left. Its associated coils are in the shield can immediately in front of it. The detector, its coils and condenser occupy the center of the base while the audio tube and coupling choke are at the right. Needless to say, a quiet plate supply system is needed for a.c. operation of the set.

A Single-Tube Receiver

▲ Fig. 916 is the circuit of a midget single-tube receiver which has proved very effective for portable work. Examination will show that the signal-frequency portion of the circuit is similar to that shown in Fig. 903. The interruption-frequency coils L_4 and L_5 , instead of being connected to a separate interruption-frequency oscillator tube, are inserted in the plate and grid circuits of the detector tube, so permitting it to do the double job of oscillating at the interruption frequency and super-regenerating at the signal frequency.

The receiver in its final form is illustrated in Figs. 917 and 918. In its planning, consideration was given not only to size but to the accessibility of every component and connection; hence the "U" shaped frame. Measuring $3\frac{1}{4}$ by $4\frac{1}{4}$ by $1\frac{1}{16}$ inches, this frame is bent from a strip of $\frac{1}{16}$ -inch aluminum. In Fig. 917, the Type 30 tube can be seen at the top. Immediately below the tube socket are to be seen the inductances L_1 , L_2 , L_3 and the condensers C_1 , C_2 , C_3 . The tuning condenser is mounted to and insulated from the frame by a small piece of bakelite. It is placed at the end of the set opposite the knob so as to allow space for the essential insulated coupling. Straddling the $\frac{1}{4}$ -inch bakelite shaft is the interruption frequency coil unit. Under the latter, and under the drive shaft, are the two 0.002- μ f. midget fixed condensers connected in parallel to form C_4 . The two "tip-jacks" for connection of

the 'phones can be seen close under the knob. They are mounted in a strip of bakelite bolted to the frame.

The cover for the set is bent from $\frac{1}{16}$ -inch thick aluminum. The inside of the cover is protected against electrical contact with the components of the set by having its surfaces covered with ordinary writing paper and lacquered.

The operation of the receiver should present no problem other than the adjustment of coils to give the desired band coverage. The lack of the characteristic rushing noise which accompanies

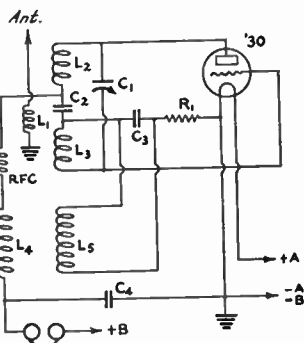


FIG. 916 — THE CIRCUIT OF THE MIDGET RECEIVER

- C_1 — Five-plate Cardwell Balancer.
- C_2 — 100- μ fd. midget fixed condenser.
- C_3 — 0.002- μ fd. midget fixed condenser.
- C_4 — 0.004- μ fd. midget fixed condenser (two 0.002's in parallel).
- R_1 — .1-megohm half-watt fixed resistor.
- L_1 — Two turns of No. 22 wire $\frac{1}{4}$ " diameter mounted between L_2 and L_3 .
- L_2, L_3 — Five turns each of No. 20 wire $\frac{3}{8}$ " diameter and spaced to occupy $\frac{1}{2}$ " for 56 mc. Ten turns of No. 24 wire same diameter and unspaced for 28 mc. The coils are made solid with "dope" in the latter case.
- L_4, L_5 — Sickles interruption-frequency coil unit.
- RFC — No. 30 gauge wire wound unspaced for a length of $\frac{3}{4}$ " on $\frac{5}{16}$ " bakelite rod.

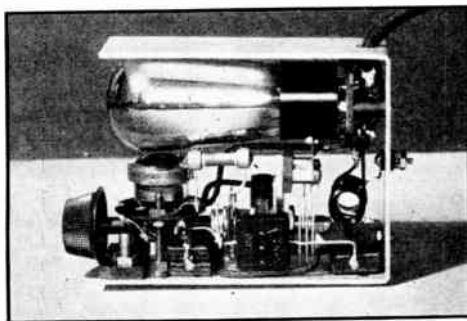


FIG. 917 — UPON SLIPPING THE COVER OFF THE MIDGET RECEIVER, ALL COMPONENTS AND WIRES ARE IMMEDIATELY REVEALED

This type of construction is therefore particularly valuable when service and adjustment become necessary — and when is it that they don't?

normal functioning will indicate either a faulty component or incorrect wiring. This particular circuit operates satisfactorily with just 45 volts of plate supply. For filament supply, two ordinary flashlight cells are used with a 16-ohm fixed resistor in series.

A Two-Tube 56-mc. Receiver

▲ Fig. 919 illustrates a typical two-tube super-regenerative circuit which has been very widely adopted. The left-hand tube in the circuit is the detector. In the plate circuit of the tube we have the usual radio frequency choke and the 'phones (by-passed by a large fixed condenser). The regeneration control resistor R_2 usually will not be noisy if connected in the manner shown. It is possible, however, that with some type of resistors a by-pass condenser of 1 μ fd. will be required to prevent noisy operation.

Receiving on the higher frequencies

▲ The normal types of detector tubes have not proved very effective on the bands higher in frequency than 56-mc. For this work, the "acorn" tube is so superior as to be almost indispensable. Fig. 920 shows the circuit for a receiver employing this tube — a circuit suited for use on the three ultra-high frequency bands under discussion.

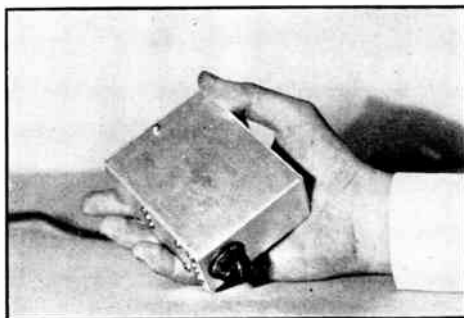


FIG. 918 — THE SMALL SUPER-REGENERATIVE RECEIVER

Containing but one tube, the set is, nevertheless, capable of producing strong 'phone signals.

The key unit in the receiver is the detector assembly. It is built on a heavy copper plate, measuring two inches by four inches. The assembly includes the tube socket and the tuned circuit components. The detector is of the self-quenching type. It could be mounted in the manner shown in Fig. 922 or could be arranged in similar fashion to that of Fig. 908.

As Fig. 922 shows, the tube in this case is mounted on two "Victron" strips supported above the copper plate. The grid condenser may be similar to C_2 of Fig. 907.

A suitable plate voltage for the receiver is something between 135 and 200. Should the higher voltages be used, it would be well to bring

out a separate lead for the audio amplifier plate voltage so that the supply to the potentiometer R_3 could be obtained from a lower voltage tap (say, 90 volts).

Experience has shown that a simple receiver of this type is admirably suited for work on the $2\frac{1}{2}$ and $1\frac{1}{4}$ -meter bands, giving high sensitivity and ease of tuning.

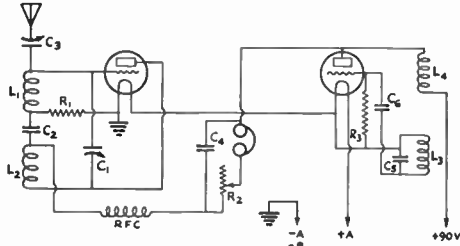


FIG. 919 — THE WIRING OF THE TWO-TUBE 56-MC. RECEIVER

- C_1 — 20- μ fd. three-plate Hammarlund midget variable.
 C_2 — 150- μ fd. fixed condenser.
 C_3 — Trimmer condenser (Mica dielectric) set near zero.
 C_4 — .001- μ fd. fixed condenser.
 C_5 — .002- μ fd. fixed condenser.
 C_6 — .0005- μ fd. fixed condenser.
 R_1 — 1-megohm fixed resistor.
 R_2 — 50,000-ohm variable resistor.
 R_3 — 50,000-ohm fixed resistor.
 RFC — 30 turns of No. 26 wire on $\frac{1}{4}$ " rod.
 L_1, L_2 — Each three turns of No. 16 enamelled antenna wire $\frac{1}{2}$ " inside diameter.
 L_3, L_4 — 1400 and 900 turns, respectively, of No. 34 silk-covered wire wound on a $\frac{3}{8}$ " dowel between cardboard disks spaced $\frac{1}{4}$ ". A "Sickles" interruption-frequency coil unit may be used instead.

The tubes are Type 30 with a 4-volt "C" battery serving as filament supply.

An insulating coupling between the dial and tuning condenser is essential if "hand-capacity" effects are to be avoided.

Transceivers for 56-mc. Operation

▲ Amateurs who have had any experience with 56-mc. recognize as one of its advantages the possibility of completely effective 'phone operation with extraordinarily simple equipment. It is no wonder that for portable work the transceiver is popular. In such a unit the same tubes, power supply and other components are used both for transmission and reception, with the obvious result of a still greater reduction in the cost, size and weight of the apparatus required.

Of the many possible circuit arrangements for the transceiver, that shown in Fig. 924 is probably the most popular. In it, the first tube is operated as a self-quenching detector for reception and a normal oscillator for transmission. The second tube serves as an audio frequency amplifier for reception and a modulator

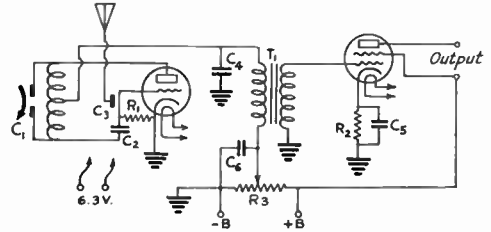


FIG. 920 — CIRCUIT OF THE SIMPLE THREE-BAND RECEIVER

C_1 — Special split-stator tuning condenser — two rotor and one stator plate — the latter saved in two.

C_2 — Very small grid condenser (see C_2 of Fig. 907).
 C_3 — Brass strip $\frac{3}{16}$ inch wide mounted close to the exposed surface of C_2 (see Fig. 922).

C_4 — .002 μ fd. fixed condenser.

C_5 — 2 μ fd. or more.

C_6 — 1 μ fd.

R_1 — 1.5 megohm, half-watt resistor.

R_2 — 1200 ohm, one-watt resistor.

R_3 — 100,000 ohm potentiometer. Note that this resistor is across plate supply and that, if batteries are used, the supply should therefore be disconnected when switching off set.

A 41 tube is used as the audio amplifier and allows speaker operation. A transformer or choke-condenser coupling unit must be used with this tube. For head-phone work, a 37 audio tube would probably be more appropriate.

The coils may be exactly similar to those given for Fig. 907.

Quieter operation may be obtained by putting a .5 megohm resistor across the transformer secondary.

for transmission. The two transformers of the circuit likewise do double duty. T_1 serves as both inter-tube audio transformer and microphone transformer. T_2 operates as output transformer and as the modulation choke. Switching from receiver to transmitter is accomplished by a four-pole double-throw switch indicated on the diagram as four separate switches. The first changes the receiver gridlead to one suitable for

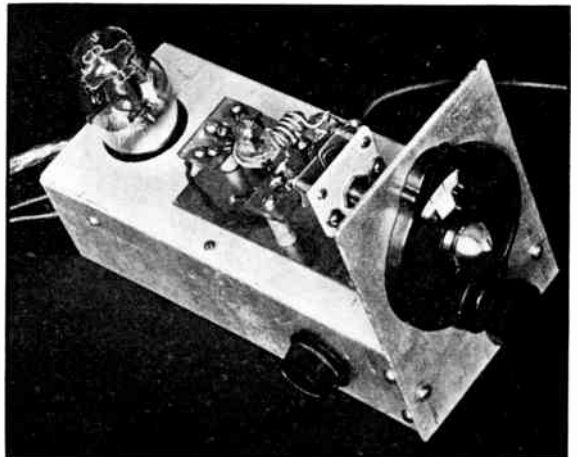


FIG. 921 — THE THREE-BAND "ACORN" RECEIVER

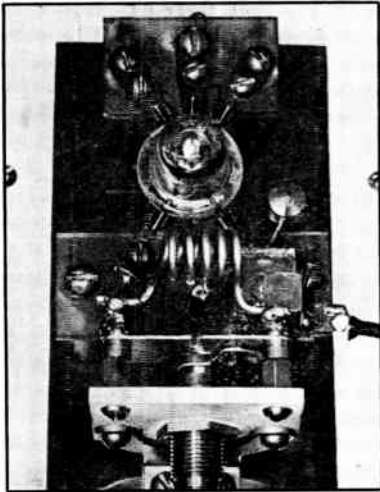


FIG. 922 — THE "ACORN" DETECTOR TUBE AND ITS TUNING EQUIPMENT

The grid condenser may be seen immediately to the right of the coil. The brass strip of the antenna coupling condenser can be seen apparently touching the right-hand coil connection.

transmission. The second switches the plate lead of the detector from the audio transformer to the modulator plate. The third connects the microphone to the transformer primary for transmission while the fourth simultaneously disconnects the head 'phone.

The transformers can be purchased, or adapted in the following manner: T_1 is any ordinary interstage audio transformer with the addition of a 300-turn microphone winding; T_2 is a 7000-ohm-to-15-ohm speaker output transformer (for use with the low-resistance telephone receiver). It should be a high-resistance output type, of course, if high-resistance 'phones are to be used. Alternatively, a conventional choke-condenser output circuit could be used for the operation of high-resistance 'phones.

Suitable Antenna Systems

▲ The same principles are involved in planning antennas for 56-mc. work

FIG. 924 — CIRCUIT AND SPECIFICATIONS OF THE TRANSCIEVER

- C_2 — 3-plate mica condenser, two stator and one rotor, double-spaced (National STN-6).
- C_3 — 100- μ fd. midget mica condenser.
- C_4 — .004- μ fd. mica.
- C_5, C_6 — .002- μ fd. mica.
- R_1 — 10,000-ohm 1-watt (transmitting gridleak).
- R_2 — 100,000-ohm 1-watt (receiving gridleak may require variation).
- R_4 — 2-ohm filament supply resistor.

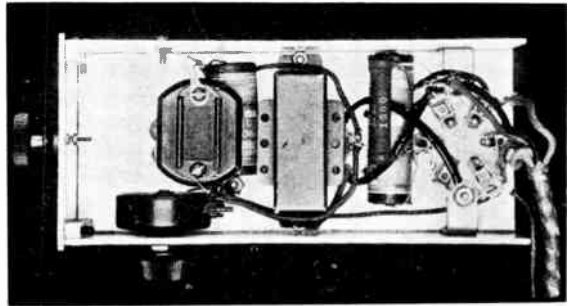
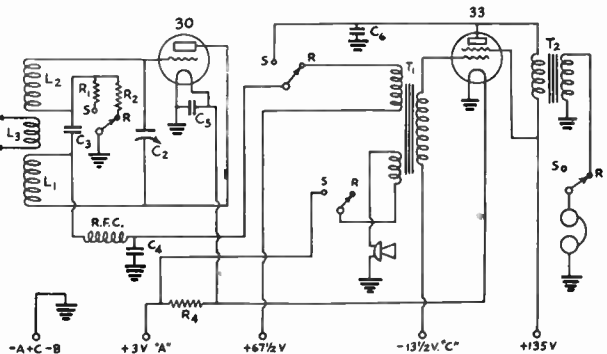


FIG. 923 — UNDERNEATH THE "ACORN" RECEIVER
All the items not above the chassis channel can be seen in this photograph. The location of the detector voltage control potentiometer is unconventional but convenient.

as for operation on the lower frequency bands. For this reason, the ultra-high frequency enthusiast should be quite familiar with the contents of Chapter Twelve.

Since radiators for the ultra-high frequencies are relatively small, it is possible for the amateur to install a directive array and so reap the enormous benefits to be derived from the general procedure of concentrating the radiation from the transmitter in one or two directions. Practice has shown that a good directive array will probably double the range normally had with a single radiator.

Of course, not all 56-mc. workers have the facilities for erecting a directive antenna. Then, the portable or mobile 56-mc. station can rarely be fitted with anything but a simple antenna. In these cases, conventional vertical half-wave



- L_1, L_2 — each 5 turns about $\frac{3}{8}$ -inch diameter, No. 14 enamelled wire (adjust to cover the band).
- L_3 — 2 or 3 turns, same diameter (coupling should be adjustable).
- RFC — Radio-frequency choke (National R-100).
- T_1 — Audio transformer with extra winding for microphone (see text).
- T_2 — Output transformer (to match telephone receiver).

It will be noted that the detector plate voltage is reduced in the receiving position, thus reducing the severity of the radiation.

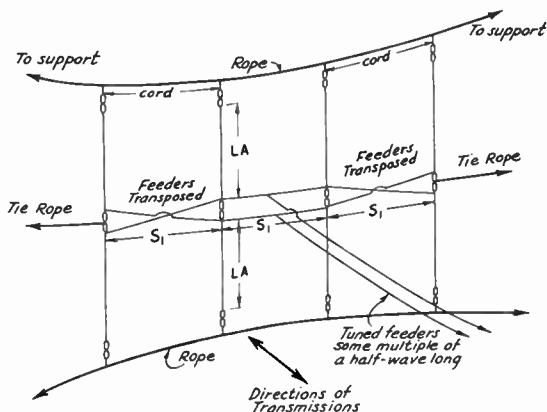


FIG. 925 — AN ARRAY WHICH TRANSMITS EQUALLY WELL IN TWO DIRECTIONS

Consisting of two rows of half-wave antennas, one above the other, this system is capable of a high order of power gain in two directions. Antenna and feeder dimensions from the table should be followed.

antennas are satisfactory, the method of feeding them being any of those described in Chapter Twelve. The simple antennas used for receiving should preferably be tuned. In receivers having a small condenser for coupling between the antenna and input circuit, it is invariably advantageous to make the total length of the antenna (including lead-in) one or more half-waves long (8 feet or some multiple of 8 feet). When inductive coupling is employed, it is possible to use a half-wave doublet with a twisted-pair feeder (see Chapter Twelve), or merely two quarter-wave (4-foot) wires or rods. Alternatively, one side of the antenna coil may be grounded and the other connected to a long vertical wire having a length equal to some odd multiple of four feet. A still further possibility is merely to ground one side of the antenna coil, attaching the other to some well elevated antenna (such as that used for transmission on the lower frequencies), then tuning the system, with a five- or seven-plate midget condenser across the antenna coil.

Directive Arrays for 56-mc.

▲ On the lower frequency amateur bands, space rarely allows the erection of a directive array. Few amateurs do not have enough space for an ultra-high frequency array, however — even for 56-mc.

The directive antenna illustrated

in Fig. 925 is one which is both simple to build and highly effective in practice. It transmits effectively in the two directions at right angles to the plane of the wires. The array consists of eight half-wave antennas all operating in phase and under average conditions is capable of greatly extending the range of the transmitter or receiver. The array occupies a space about 25 feet wide and 16 feet high and should be suspended just as high above ground as possible. It should also be placed well clear of large trees, power wires or buildings. The dimensions of the system are given in the table. They should be adhered to with great care and all wires should be stretched before being cut. While No. 14 antenna wire is suitable for such an antenna, it will be found that No. 18 will hang in place much more effectively.

Fig. 926 illustrates an alternative type of array suited for transmission in only one direction. In this case, four antennas operating in phase are backed by four reflector wires. The whole assembly is supported on light wooden spreaders suspended from two main ropes running

Frequency Mc.	Wave length Meters	Ant. Length LA	Ref. Length LR	Ant. Spacing S1	Ant. to Ref. S2
56	5.357	8' 1"	8' 7"	8' 9"	4' 4 1/2"
57	5.263	8' 2 3/4"	8' 5 1/2"	8' 7 1/2"	4' 3 3/4"
58	5.172	8' 0 1/2"	8' 3 3/4"	8' 5 3/4"	4' 2 3/8"
59	5.085	7' 10 3/4"	8' 2"	8' 4"	4' 2"
60	5.0	7' 9"	8' 0 1/2"	8' 2 1/2"	4' 1 1/4"

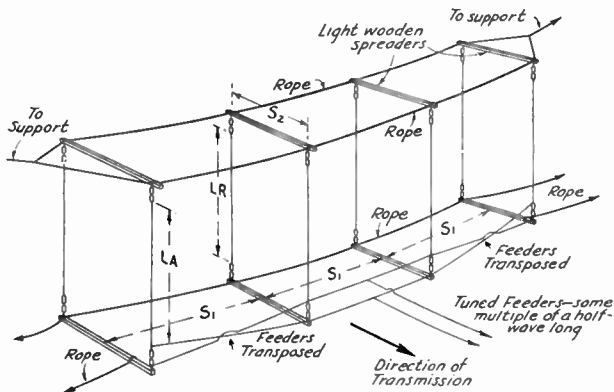


FIG. 926 — A UNI-DIRECTIONAL ARRAY FOR 56-MC.

The four front vertical wires, fed from their lower ends, are the radiators. Behind them are the four reflectors. Both antennas and reflectors are suspended from light wooden spreaders, suspended in turn by two main ropes. The assembly should be made as light as possible in order to reduce the sag to a minimum. The direction of transmission is indicated by the heavy arrow. Feeder spacing is unimportant; 2 inches is a suitable value.

The dimensions of the various elements of the array are given in the table.

along the top of the system. An alternative method of construction is illustrated in Fig. 927. This type of rigid assembly is very much to be preferred to that of Fig. 925 though it involves considerably more effort and expense in construction. The dimensions of both systems may be found by reference to the table.

Next to the accurate measurement of all wires, the most important item in these systems is the cutting and tuning of the feeders. These should always be approximately a multiple of a half-wave at the operating frequency — the exact tuning being obtained by a parallel tuning condenser across the antenna coil of the transmitter or with a series condenser in each feeder lead. The necessary feeder tuning connection may best be found after the feeder has been connected to the antenna and transmitter. The usual thermo-coupled meters may be used to indicate maximum feeder current. In low powered installations, a flashlamp bulb in each feeder is often effective. It is almost impossible to tune the feeder system without some such indicator.

Many other types of directive arrays are suited for 56-mc. work. These two are presented as representative examples which have performed well in practice. Should space be very limited, the outer antennas of Fig. 925 could be eliminated — giving an array of four antennas. Similarly, the outer antennas and reflectors of Fig. 926 could be removed.

Directive Antennas for the Higher Frequencies

▲ The two antenna systems just described should be quite effective for operation on the $2\frac{1}{2}$ -meter band providing all dimensions are divided by two. The array so obtained would be quite compact and could be built in the rigid fashion of Fig. 927 without much difficulty.

For the $1\frac{1}{4}$ -meter band, this type of antenna becomes very difficult to adjust and has not so far proved very effective in actual working. A much simpler arrangement both in construction and adjustment is that given in Fig. 928. The directivity of the system is, of course, not as high as that of the systems described but it is sufficient to facilitate experimental

work. Since the dimensions are so small, the elements of the system might well be made of $\frac{1}{8}$ -inch brass rod mounted on stand-off insulators on a "T" shaped wooden frame. The antenna rod should be about 95 per cent. of a half-wave long, the reflector rods being 97 per cent. of a half-wave. The antenna itself may be considered as being exactly similar to the half-wave antennas discussed in Chapter Twelve and may be fed in any of the conventional ways. A tuned Zepp feeder, some odd multiple of a quarter-wave long is probably the simplest arrangement.

A more advanced directive antenna for the $1\frac{1}{4}$ -meter band is that shown in Fig. 929. It is known as a "Yagi" antenna — taking its name from the scientist who developed it. The rear portion of the antenna is exactly similar to that of Fig. 928 but it will be seen that a series of director wires or rods have been added in front of the antenna. These rods are cut to about 87 per cent. of a half-wave and are mounted $\frac{3}{8}$ of a wave apart. As in the previous system, these

rods could all be mounted on stand-off insulators on a suitable wooden frame, the whole assembly being suspended as high as possible in the attic or preferably above the roof.

The Directive Antenna for Reception

▲ All the directive systems discussed are just as effective in improving reception as in aiding transmission. Since a separate receiving array would rarely be practical for 56-mc., good practice is to provide a double-pole double-throw switch in the station so that the feeder may be thrown either to the transmitter or receiver. The same length of feeder should be provided from the switch to the receiver as from the switch to the transmitter and, as we have already mentioned, the feeder should be carefully tuned. Either a parallel or series condenser may be used for the receiver input tuning, depending on the length of the feeders. Inductive coupling to the receiver is usually satisfactory but in cases where the receiver is fitted with a small antenna coupling condenser the feeders might well be clipped across portion of the coil of a tuned tank circuit, the

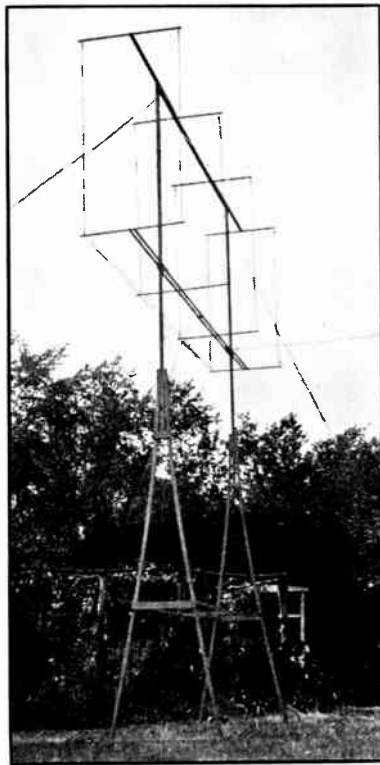


FIG. 927 — A RIGID MOUNTING FOR THE DIRECTIVE ANTENNA

Mounted on a substantial wooden framework, the antennas and reflectors of this assembly at WJHRX are held in good alignment at all times. The electrical design of this array is exactly similar to that shown in Fig. 926.

"hot" end of this tank then being connected to the antenna coupling condenser.

On the higher frequency bands the antenna is relatively small and simple and it is as well to provide a separate antenna for transmission and reception. This avoids the need for a change-over switch and allows effective duplex working.

Experiment Necessary

▲ In describing these odd pieces of representative ultra-high frequency equipment, the idea has been to sketch the requirements for effective working. None of the apparatus can be considered as the ultimate. Ultra-high frequency work is a

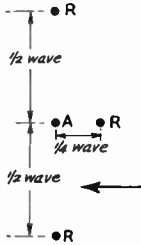


FIG. 928 — A SIMPLE DIRECTIVE ANTENNA FOR 1/4 METERS

The antenna itself is at the center of the system, the three other elements being reflectors. The gain of the system is, of course, relatively slight.

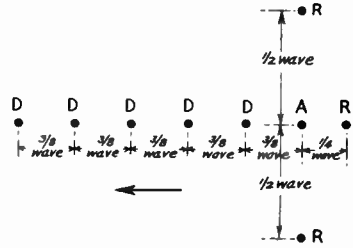


FIG. 929 — A MORE ADVANCED "YAGI" ANTENNA

In this system director wires or rods have been added to provide greater gain. Only five are shown but as many as twenty or thirty have been used effectively. The dimensions of the elements are given in the text.

relatively new field and it seems certain that many present ideas will be drastically revised in the early future. It is certain that, because the ultra-high frequencies have not been explored in the same thorough manner as the lower frequency bands have been, it is a field of particular interest to the experimentally inclined amateur. We make a special plea for careful observation of all phenomena experienced in working on these and would ask that amateurs experiencing unusual effects or obtaining unusual ranges should immediately report their results to League Headquarters.

POWER SUPPLY

FULLY as important as the transmitter itself is the apparatus which supplies the power to the tube filaments and plates. The operation of a well-designed transmitter can be spoiled by a poor power supply. Although the power supply involves only the use of simple apparatus in most cases, good design and adjustment will be well rewarded by improvement in the signal and in the over-all effectiveness of the transmitter.

In this chapter we shall consider various types of power supplies for both transmitters and receivers. It is the function of both to provide steady power for the tube filaments and direct current for the plates. Filament supply with modern transmitting and receiving tubes is relatively simple; the design of the plate supply, however, depends to a considerable extent upon the type of service to which it is to be put and is therefore worthy of careful consideration. We shall discuss first the plate supply for the transmitter.

The Plate Supply

▲ Under the regulations governing amateur stations the plate supply must deliver adequately-filtered direct current to the plates of all tubes in transmitters operating on frequencies below 14,400 kc. This requirement is designed to ensure that the emitted signal will be "pure d.c." on the four most important amateur bands, and to prevent transmitters having poor frequency stability from producing broad signals.

High-voltage direct current for the transmitting tubes can be obtained in a number of ways. These include banks of dry or storage cells connected in series to give the required voltage, dynamotors and motor-generators, and transformer-rectifier-filter systems. The latter are by far the most generally used.

The output of dry-cell or storage batteries is ideal for the transmitter because it is steady, pure direct current. Except for very low-power transmitters, however, the battery cost is a great deal more than the cost of other power supply apparatus of the same voltage output; furthermore, the current that can be taken from the

batteries is extremely limited if reasonable battery life is to be secured. Not more than 30 milliamperes should be taken continuously from standard-size "B" batteries; at this discharge rate the life of the battery should be approximately 200 hours. The heavy-duty batteries can stand higher discharge rates and will last longer. Because of their cost and relatively short life, batteries are used chiefly for portable transmitters — particularly with ultra-high frequency equipment — and in locations where no other source of power is available, such as on farms.

A direct-current motor-generator set is an excellent source of plate power. It is relatively costly, however, and its output is not as pure as that from batteries because of the ripple caused by commutation. The commutator ripple can be filtered out with little difficulty; a 1- or 2- μ fd. condenser shunting the output usually will be sufficient.

A dynamotor is a double-armature machine; one winding drives it as a motor while the other delivers a few hundred volts d.c. for the transmitting tubes. The motor winding usually operates from a six- or twelve-volt storage battery. The dynamotor also has commutator ripple, which must be filtered out just as with the motor-generator set.

The Rectifier-Filter Systems

▲ Assuming that alternating-current power is available at 110 or 220 volts, a very effective high-voltage supply system can be built up from a high-voltage transformer, a rectifier system and a filter. The details of the transformer and the filter are to be given complete treatment later in the chapter and for the moment we will limit the discussion to the rectifier.

An understanding of how a rectifier functions may be obtained by studying Fig. 1001. At (1) is a typical a.c. wave, in which the polarity of the current and voltage goes through a complete reversal once each cycle. The object of rectification is to transform this wave into one in which the polarity is always the same, although the *amplitude* of the current and voltage may vary continually. At (2) we have the secondary of a

DANGER—HIGH VOLTAGE!

It must be realized that the plate supply equipment of even a low-powered transmitter is a potential lethal machine. It is ever ready to deal out sudden death to the careless operator. A number of amateurs, indeed, have been killed by the output of their power supplies during the last few years. Many more have suffered severe injury. We cannot urge too strongly the observance of extreme care in the handling of power supplies and transmitters.

power transformer connected to a single rectifier element, represented by the arrow and dash enclosed in the circle. The rectifier is assumed to be "perfect," that is, current can only flow through it in one direction, from the arrow to the plate. Its resistance to flow of current in that direction is zero, but for current of opposite polarity its resistance is infinite. Then during the period while

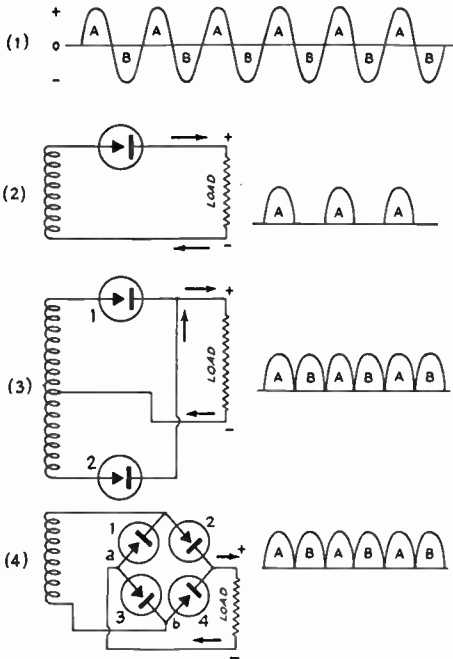


FIG. 1001 — FUNDAMENTAL RECTIFIER CIRCUITS
At (1) is the conventional representation of the a.c. wave; (2) shows a half-wave rectifier; at (3) is the full-wave center-tap system; and (4) is the "bridge" rectifier. The output wave form with each type of rectifier is shown at the right.

the upper end of the transformer winding is positive, corresponding to A in (1), current can flow to the load unimpeded. When the current reverses, however, as at (1) B, it cannot pass through the rectifier, and consequently nothing flows to the load. The drawing shows how the output from the transformer and rectifier looks. Only one-half of each cycle is useful in furnishing power to the load, so this arrangement is known as a "half-wave" rectifier system.

In order to utilize the remaining half of the wave, two schemes have been devised. At (3) is shown the "full-wave center-tap" rectifier, so called because the transformer secondary winding must consist of two equal parts with a connection brought out from the center. In (3), when the upper end of the winding is positive, current can flow through rectifier No. 1 to the load; this current cannot pass through rectifier No. 2 because

its resistance is infinite to current coming from that direction. The circuit is completed through the transformer center-tap. At the same time the lower end of the winding is negative and no current can flow through rectifier No. 2. When the current reverses, however, the upper end of the winding is negative and no current can flow through rectifier No. 1, while the lower end is positive and therefore rectifier No. 2 passes current to the load, the return connection again being the center-tap. The resulting wave shape is again shown at the right. All of the wave has been utilized, and the amount of power which can be realized at the load is doubled. In order to maintain the same output voltage (instantaneous, not average) as at (2), however, each half of the transformer secondary must be wound for the same voltage as that furnished by the whole winding in (2); or, conversely, the total transformer voltage with the connections shown in (3) must be twice the desired output voltage.

If the transformer has no center-tap, or if the total voltage it furnishes is the same as the desired output voltage, scheme (4), known as the "bridge" rectifier, may be used to obtain full-wave rectification. Its operation is as follows: When the upper end of the winding is positive, current can flow through No. 2 to the load, but not through No. 1. On the return circuit, current flows through No. 3 back to the lower end of the transformer winding. When the wave reverses and the lower end of the winding becomes positive, current flows through No. 4 to the load and returns through No. 1 to the upper side of the transformer. The output wave shape is shown at the right. Although this system does not require a center-tapped transformer, and the voltage of the winding need only be the same as that desired for the load, four rectifier elements are required, so that the center-tap may actually prove to be more economical, all things considered.

Although the rectifier output is direct current in the sense that the polarity is always the same, the amplitude is not uniform but varies continually as shown in Fig. 1001. Before the power can be supplied to the transmitting-tube plates the "humps" must be smoothed out by a filter. Filters will be considered in detail in a later section.

Types of Rectifiers

▲ Practically all rectifiers in use today by amateurs are of the vacuum-tube type; in former years when suitable tube rectifiers were not available many other types, including chemical, rotating (synchronous), and mercury-arc were in general use. These are now of relatively little importance in amateur transmitters, and since they have no particular advantages over the widely-used tube rectifiers will not be treated in this chapter.

There are two types of tube rectifiers: those

having a high vacuum, in which the conduction is purely by means of the electronic stream from the cathode to the plate; and those in which a small quantity of mercury has been introduced after the tube has been evacuated. In the latter type, part of the mercury vaporizes when the cathode reaches its operating temperature, and during the part of the cycle in which the rectifier is passing current the mercury vapor is broken down into positive and negative ions; the positive ions decrease the normal resistance of the plate-cathode circuit so that the voltage drop in the tube is less than with high-vacuum types. As a result of the lower voltage drop the power lost in the rectifier is decreased, and the efficiency of the mercury-vapor rectifier is therefore greater than that of the high-vacuum type.

Operating Limits of Rectifiers

▲ Two factors determine the safe operating limits of tube rectifiers. These are the maximum inverse peak voltage and the maximum peak current.

The inverse peak voltage is the maximum voltage which appears between the plate and cathode of the rectifier tube during the part of the cycle in which the tube is not conducting. Referring again to Fig. 1001, in (2) it is apparent that during the "B" part of the cycle when the half-wave rectifier does not conduct, the inverse potential between the plate and cathode will be equal to the full transformer voltage; the peak

value of this voltage is 1.4 times the r.m.s. or effective output voltage. In the full-wave center-tap rectifier of (3), during the part of the cycle when rectifier No. 1 is non-conducting the inverse potential across its elements is equal to the sum of the potentials of both halves of the secondary of the transformer; the peak inverse voltage is again 1.4 times the full transformer voltage. Inspection will show that this is similarly the case with the bridge rectifier, circuit (4). It is well to remember that, no matter what the type of rectifier, the inverse peak voltage is always 1.4 times the total transformer voltage. Strictly speaking, the voltage drop in one rectifier tube should be subtracted from the figure so calculated, but since the rectifier drop usually is negligible in comparison with the transformer voltage, no practical error results from neglecting it. Because it is always the total transformer voltage which must be considered, we find that for a given inverse peak voltage rating the permissible output voltage with the bridge rectifier circuit is twice that with the center-tap circuit, because in the latter circuit only half the total transformer voltage is available for the load. The bridge circuit, however, requires twice as many rectifier elements.

The peak current through the rectifier tube is chiefly a function of the load and the type of filter circuit used. We shall have more to say on this point in the section on filters.

While inverse peak voltage and peak current

RECTIFIER TUBES

Type No.	Fil. Volts	Fil. Amps.	Max. Voltage per plate (a.c. r.m.s.)	Max. Inverse Peak Voltage	Max. D.C. Output Current (ma.)	Max. Peak Current (ma.)	Type
1	6.3*	0.3	350	1000	50	400	Half-wave M.V.
1-V	6.3*	0.3	350		50		Half-wave H.V.
84	6.3*	0.5	225		50		Full-wave H.V.
12Z3	12.6*	0.3	250		60		Half-wave H.V.
25Z5	25.0*	0.3	125		100		H.V. Voltage-Doubler ¹
80	5.0	2.0	350 400 550 ²		125 110 135		Full-wave H.V.
82	2.5	3.0	500	1400	125	400	Full-wave M.V.
5Z3	5.0	3.0	500		250		Full-wave H.V.
83	5.0	3.0	500	1400	250	800	Full-wave M.V.
81	7.5	1.25	700		85		Half-wave H.V.
RK19	7.5*	2.5	1250	3500		600	Full-wave H.V.
866	2.5	5.0		7500		600	Half-wave M.V.
866-A	2.5	5.0		10,000		600	Half-wave M.V.
872	5.0	10.0		7500		2500	Half-wave M.V.

H.V. — High Vacuum, M.V. — Mercury Vapor.
* Indirectly-heated cathode.

¹ Two independent rectifiers in one bulb.
² Only with input choke of at least 20 henrys to filter.

ratings apply to both high-vacuum and mercury-vapor rectifiers, they have more significance with the mercury-vapor types than with the vacuum types. In the vacuum-type rectifiers the inverse voltage which the tube will handle safely is limited chiefly by the spacing between the plate and cathode and the insulation between the leads from these elements in the glass press and in the base. In the mercury-vapor rectifier, however, the inverse peak voltage is a function of the design of the tube and the operating temperature; for a given tube type there is a critical voltage above which an "arc-back" will occur, ruining the tube. The higher the temperature of the mercury vapor the lower the voltage at which arc-back will take place; for this reason mercury-vapor rectifier tubes should always be located so that there is free circulation of air around them for cooling. The tubes are usually rated at a peak inverse voltage which will permit safe operation at normal current in a room of average temperature.

The peak current rating is based on an electron flow from the filament which will give a filament life of 1000 hours or more. In the high-vacuum types the tube voltage drop depends upon the current; the higher the current the greater the voltage drop. High-vacuum tubes therefore tend to protect themselves under overload, because excessive current causes a larger voltage drop which in turn reduces the voltage across the load circuit, thus limiting the current flow. In mercury-vapor rectifiers, however, the voltage drop is substantially constant for all values of current, hence the rectifier cannot protect itself from overloads. A heavy overload on a mercury-vapor rectifier, even though instantaneous, is likely to destroy the filament or cathode of the tube, because under such conditions the positive ions of the mercury vapor are attracted to the cathode with such force as actually to tear off the emitting material with which the cathode is coated. A less drastic overload applied over a longer period of time will have the same effect. Mercury-vapor rectifiers should always be worked within the peak current ratings if normal tube life is to be expected.

Standard types of rectifier tubes are listed in the table, together with their ratings and a brief description of each type. In the smaller sizes, the tubes are generally manufactured as full-wave rectifiers; that is, a cathode and two plates are provided in one bulb so that full-wave rectification can be obtained with a center-tapped transformer. Tubes for high voltages are always half-wave rectifiers; two of them are needed for the center-tap system.

The principal advantages of the mercury-vapor rectifiers over the high-vacuum type are the lower voltage drop and the fact that this drop is independent of the load current. In all the mercury-vapor tubes the voltage drop can for

practical purposes be considered to be 15 volts regardless of load current. This low, constant drop results in a power supply having better voltage regulation — discussed in a later section — than one using high-vacuum rectifiers, and is responsible for the wide use of mercury-vapor rectifiers in amateur transmitting equipment. The most popular rectifier tubes are the 82, 83, and 866. Occasionally high-power transmitters will be found with 872 rectifiers.

Mercury-vapor rectifiers always should be operated with the rated voltage applied to the filament. If the filament voltage is low (filament or cathode temperature too low) the effect is exactly the same as though the tube was heavily overloaded, and the cathode will rapidly lose its emission. For this reason, in operating high-voltage mercury-vapor rectifiers the filament power always should be applied for at least 30 seconds before the plate voltage is turned on so that the filament will be certain to reach its correct operating temperature. If the rectifiers have been out of service for some time it is also advisable to heat the filaments for 10 or 15 minutes before applying plate voltage so that all the mercury that may have condensed on the filament will be vaporized.

Filament voltage should be measured right at the socket terminals, not at the transformer, when tubes such as the 866 and 872 are used because of the heavy filament currents taken by these tubes. It is also advisable to pick out a socket which will make very good contact with the tube pins and also to make sure that the socket is capable of carrying the current.

Rectifier Circuits

▲ The elementary rectifier circuits of Fig. 1001 are shown in practical form in Figs. 1002 and 1003. Fig. 1002 is the center-tap circuit for use with a full-wave rectifier tube, and is used only

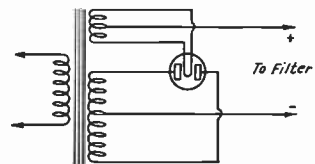


FIG. 1002 — HOW FULL-WAVE TUBE RECTIFIERS ARE CONNECTED

This diagram can be used with Type 80, 82 and 83 rectifier tubes.

for low-voltage power supplies — 500 volts or less. Both center-tap and bridge circuits are given in Fig. 1003, half-wave rectifier tubes being used in both cases. In the practical circuits, it can be seen that while a single filament transformer will suffice for both tubes in the center-tap circuit, the bridge circuit requires the use of three separate filament transformers; the filaments of one

pair of tubes can be connected together, but the filaments of the other two tubes are at different potentials and must have separate sources of filament-heating power.

Reference to the table of rectifier tubes will show that the smaller mercury-vapor tubes are rated for a given output current and a maximum r.m.s. applied transformer voltage, while the ratings on the larger tubes are exclusively in terms of inverse peak voltage and peak current. Because of the low voltage at which the small tubes are operated, the ratings for them will hold regardless of the type of filter into which the rectifier works. The 866 and 872, on the other hand, are high-voltage tubes and must be handled with more care; the peak current, which must not exceed the rated value, will depend largely on the type of filter used, while the inverse peak voltage is a function of the transformer voltage and the rectifier circuit. With rectifier tubes having an inverse peak voltage rating of 7500 volts the transformer voltage, in the center-tap circuit, should not exceed 2600 volts each side of the center tap. If the bridge circuit is to be used, the total transformer voltage should not exceed 5200 volts. The corresponding voltages with 10,000-volt tubes are 3500 and 7000 volts. Few amateurs use plate voltages exceeding 3000 volts; the average for high-power amateur transmitters is 2000 to 2500 volts. The high-voltage rectifiers in the table are therefore sufficient for practically all amateur needs.

Voltage Regulation

▲ The term "voltage regulation" is used to indicate the change in terminal voltage of a plate-supply system with different load currents. The windings of transformers and filter chokes used in plate supplies all have some resistance; as the current drawn from the power supply is increased the voltage drop in the transformer and chokes also increases with the result that the terminal voltage drops. Besides these ohmic effects, there may be other causes contributing to the decrease in terminal voltage with load, such as the behavior of the filter.

As ordinarily used in electrical engineering, the term "voltage regulation" refers to the increase in voltage resulting when the load current is decreased from the rated value to zero, expressed as a percentage of the terminal voltage at full-load current. It is often more convenient in speaking of plate-supply systems, however, to use the terminal voltage at no load as a base, in which case the percent. regulation will be the decrease in terminal voltage from the no-load value to the value of load at which the power

supply is to be worked. Amateur plate supplies are seldom used at a definitely-fixed load current, hence the greater convenience of expressing voltage regulation as a percentage of the no-load terminal voltage.

As an illustration, suppose the measured terminal voltage of a power supply is 1200 volts at no load — i.e., no current being drawn by the transmitting tubes. Then with the transmitter in operation the voltage is measured and found

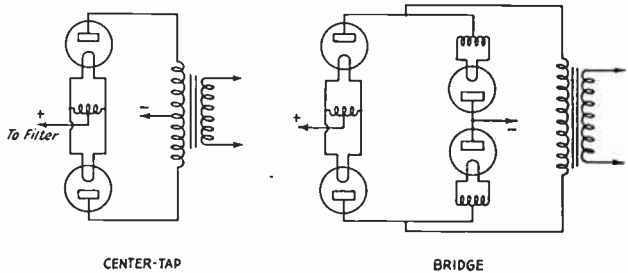


FIG. 1003 — CENTER-TAP AND BRIDGE RECTIFIER CIRCUITS

In both circuits, the peak inverse voltage is equal to the total secondary voltage of the transformer multiplied by 1.4. Therefore, twice as much voltage can be obtained from the bridge as from the center-tap rectifier without exceeding the tube ratings. The tubes will pass the same load current in both cases.

to be 900 volts. The voltage regulation will be

$$\frac{1200 - 900}{1200} = .25 \text{ or } 25\%$$

The voltage regulation will be found to vary with the load and with the type of filter used. Good plate supplies will have a regulation of the order of 10% or less; poorly-designed power supplies often have regulation as high as 50% — in other words, the voltage at full load drops to half its no-load value. Good voltage regulation is highly desirable with the self-controlled transmitter because in such a transmitter the frequency depends upon the plate voltage; if the plate voltage dives suddenly every time the key is pressed the note will have a chirpy or "yooping" character and be hard to read. While this consideration is not as important in the amplifier stages of oscillator-amplifier transmitters, good voltage regulation is still desirable because it tends to reduce key thumps.

The Filter

▲ The filter is a very important section of the power supply. Primarily its purpose is to take the electrical pulses from the rectifier (see Fig. 1001) and smooth them out so that the power delivered to the plates of the transmitting tubes is perfectly continuous and unvarying in just the same way that the current from a battery is continuous and unvarying. But in addition to this, the design of the filter will greatly affect the voltage regulation

of the power supply and the peak current through the rectifier tubes.

In analyzing the output of a rectifier-filter system, it is customary to consider the output voltage to consist of two components, one a steady "pure d.c." voltage and the other a super-

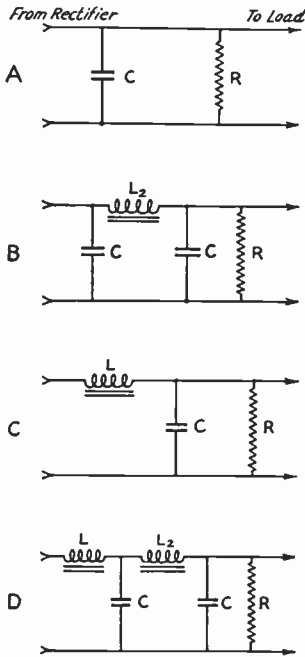


FIG. 1004 — FILTERS

At *A* is the simplest type of filter — a single condenser of high capacity connected across the rectifier output. With the addition of a filter choke and a second condenser this becomes the "brute force" circuit of *B*. *C* is a single-section choke-input filter. The two-section filter at *D* is recommended when the ripple voltage in the output must be low.

imposed a.c. voltage — the ripple voltage — which when combined with the assumed unvarying voltage gives the same effect as the actual rapid variations in the output of an incompletely-filtered power supply. When the r.m.s. or effective value of the ripple voltage is divided by the d.c. voltage the result, expressed as a percentage, gives a "figure of merit" (percent. ripple) for comparing the performance of various filter circuits; furthermore, the amount of filter needed for various transmitter applications is dependent upon the ripple percentage that can be tolerated. Experience has shown that a ripple of 5% or less will give "pure d.c." for c.w. telegraphy if the transmitter has high frequency stability; for radiotelephony the ripple should be .25% or less to reduce hum to a satisfactory level.

Filters are made up of combinations of inductance and capacity — chokes and condensers. Although there are several ways of considering

the operation of chokes and condensers in the filter, possibly the simplest is from the standpoint of energy storage. Both chokes and condensers possess the property of storing electrical energy, the former in the form of the electromagnetic field, the latter in the dielectric field. While the amplitude of the rectified a.c. wave is increasing, energy is stored in both the inductance and capacity; after the peak has been reached and the amplitude of the rectified wave begins to decrease, the stored-up energy is released and fills in the valleys between the rectified humps. A little consideration of the action will make it evident that the energy storage required will depend upon the rate of occurrence of the rectified waves; the closer they are together the less will be the energy storage required. In other words, the amount of inductance and capacity needed will be inversely proportional to the frequency of the a.c. supply. A supply frequency of 60 cycles with full-wave rectification gives 120 rectified waves per second, corresponding to a frequency of 120 cycles. Similarly, full-wave rectification with 50-cycle supply gives a frequency of 100 cycles, and with 25-cycle supply a frequency of 50 cycles. The discussion to follow is based on full-wave rectification with 60-cycle supply; to maintain a given ripple percentage at the lower frequencies both inductance and capacity must be increased over the 60-cycle values. The required increases will be directly proportional to 60 divided by the supply frequency.

Types of Filters

▲ Inductance and capacity can be combined in various ways to act as a filter. Four representative arrangements are given in Fig. 1004. The single condenser at *A* is not a complete filter, but will give considerable smoothing. This type of filter will not, generally speaking, be sufficient to meet the requirement that the plate supply for an amateur transmitter must be adequately filtered. The arrangement at *B* (the "brute force" filter) is a popular one; with suitable values of *L* and *C* the smoothing will be adequate for most amateur purposes. This is known as a condenser-input filter because a condenser is connected directly across the output of the rectifier. The condenser-input filter is characterized by high output voltage, poor voltage regulation and high rectifier peak current.

A third type of filter is shown at *C*. It consists of a single choke and condenser, and because the rectifier output goes to the choke, is known as a choke-input filter. Chief characteristics of the choke-input filter are good voltage regulation and low rectifier-tube peak current; for a given transformer voltage the output voltage will be lower than from the condenser-input filter over most of the load range, however. The choke-input filter is the only type whose performance can be cal-

culated accurately; there is no simple method of predetermining the performance of a condenser-input filter. The filter at *D* consists of two filters of the *C* type connected in series; this more elaborate arrangement is known as a two-section filter and is used to obtain greater smoothing than can be gotten economically with the single-section filter. Because of the many advantages of choke-input filters, they will be given detailed consideration in this chapter.

Designing the Plate Supply

▲ As suggested before, the ripple voltage tolerable in the output of the power supply will depend upon the type of service. We can take .25% or less as standard for radiotelephony. The percent. ripple allowable for c.w. telegraphy will, however, depend upon the design of the transmitter itself. If the dynamic stability of the transmitter is high — that is, if changes in plate voltage cause no noticeable change in the transmitter frequency — a larger ripple voltage can be tolerated without seriously affecting the tone of the transmitter than would be the case with transmitters in which a small change in plate voltage produces an audible change in frequency. As a working rule, we can say that the plate supplies for all oscillators — and especially self-controlled oscillators — should have not more than 1% ripple in the d.c. output. Since filter apparatus for low-power stages — oscillators and buffers in almost all transmitters are low-power — is inexpensive, plate supplies for all low-power stages should conform to the rule of not more than a 1% ripple. For amplifier stages in which frequency modulation is not a factor, the figure of 5% or less ripple will be satisfactory for c.w. telegraphy.

To illustrate the method of designing a plate supply, let us go through a specific problem. Suppose that two 203-A tubes are to be supplied 1000 volts at 350 milliamperes; the tubes are to be used in the final amplifier stage of a crystal-controlled transmitter and a ripple of 5% or less will be satisfactory. It can be assumed that for ripple percentages of this order a single section filter such as that in Fig. 1004-C will represent the most economical design; for 1% or less ripple two sections, Fig. 1004-D, should be used. For our particular problem, then, a single-section filter will suffice. The percent. ripple will depend upon the product of the choke inductance and condenser capacity; the following formula gives the ripple percentage directly:

$$\% \text{ ripple} = \frac{100}{LC}$$

where *L* is in henrys and *C* in microfarads. Transposing, we find that the product of *LC* must be 20 or more to result in 5% or less ripple.

The most economical filter design will be that in which choke cost is balanced against filter-

condenser cost to give the required total of inductance and capacity. There are other considerations, however, which must be taken into account before the constants of the filter can be determined upon. These have to do with the functions of the input choke in the filter system.

The Input Choke

▲ Upon the input choke falls the burden of improving voltage regulation and reducing rectifier peak current as well as contributing to the smoothing. The inductance required in the input choke to maintain a constant output voltage and a reasonably low peak current depends upon the load to be placed on the power-supply system; i.e., the amount of current to be drawn. The load on the system can be expressed in ohms, and is equal to the output voltage divided by the total load current in amperes. The optimum value of input-choke inductance is equal to

$$L_{opt.} = \frac{\text{Full-load resistance in ohms}}{500}$$

With an input choke having optimum inductance, the rectifier peak current will not exceed the d.c. output current by more than 10%; in other words, the current from the plate-supply system can approach 90% of the peak-current rating of one tube in the full-wave rectifier without danger to the tubes.

To maintain the output voltage at a constant value, it is necessary to have some load on the plate-supply system at all times. If there is no load at all on the system, the filter condensers will charge up to the peak value of the rectified a.c. wave; the peak of this wave is approximately 1.4 times the r.m.s. or rated transformer voltage. To keep some load on the system at all times a bleeder resistor, *R* in Fig. 1004, is used. Since it is desirable to keep down the amount of power dissipated in the bleeder, a fairly high resistance is ordinarily used; usual practice is to make the bleeder take 10% or less of the full load current. The bleeder resistance will therefore be much higher than the resistance of the total load, which includes the load represented by the transmitting tubes and that of the bleeder itself. The critical value of input choke inductance which will prevent the d.c. output voltage from rising to the peak of the rectified wave is equal to

$$L_{crit.} = \frac{\text{Resistance of bleeder in ohms}}{1000}$$

With this value of input choke the rectifier-tube peak current will be greater than with optimum choke inductance, but with only the bleeder as a load the current will be low and no harm will be done to the tubes.

Since the no-load current (bleeder only) will usually be only one-tenth the full-load current, it is evident that these two formulas will give widely-different values for input choke induc-

tance; in fact, the critical value of inductance will be about five times that of the optimum value. It should be pointed out that both these values represent the *minimum* input choke inductance that should be used; some improvement will result if the inductance is increased, although the improvement will be slight in comparison to the extra cost. A choke having the critical inductance value can therefore be used with entirely satisfactory results, but it is more economical to use a "swinging" choke whose inductance varies from the critical value at no load to the optimum value at full load; such chokes are available from manufacturers.

Returning now to the specific problem in hand, it will be found after consultation of manufacturers' catalogs that swinging chokes capable of carrying the desired load current can be obtained with an inductance swing of 5 to 25 henrys. Based on the critical value of 25 henrys, the bleeder resistance should be 25×1000 , or 25,000 ohms; the bleeder therefore will take 40 milliamperes. The power dissipated in the bleeder will be $1000 \times .025$, or 40 watts; a resistor having this or larger power-dissipation rating should be used. The full-load inductance value of 5 henrys should be used in the calculation for percent ripple. We have previously determined that the product of inductance and capacity must be at least 20 for 5% or less ripple, so that the required condenser capacity will be $20/5$, or 4 microfarads. A greater capacity will give a correspondingly smaller ripple voltage.

After the size of the filter condenser and choke have been determined, it is necessary to ascertain whether the particular combination chosen will be such as to resonate at or near the ripple frequency. If the combination should through accident be resonant, the operation of the plate supply system is likely to be unstable and the smoothing will be impaired. The resonance frequency will be equal to

$$f_{res.} = \frac{159}{\sqrt{LC}}$$

where L is in henrys and C in microfarads, and should be well below the supply-line frequency. In our example, the resonance frequency by the formula above is approximately 35 cycles, so the filter design is satisfactory from this standpoint.

Calculating the Required Transformer Voltage

▲ After the filter has been decided upon, the next step in the design of the power supply system is to select suitable rectifier tubes and determine the necessary ratings of the power transformer. For a plate supply of the type we have been considering, the logical rectifier tube is the 866; a pair of them can be used in the center-tap circuit, or four of them can be connected in bridge. Since the voltage is well below the inverse peak ratings

of the tubes, it is probably more economical to use the center-tap circuit. The transformer must be capable of handling the same amount of power with either type of rectifier, so that the cost of the power transformer will not be a deciding factor in the choice of the rectifier circuit. Assuming that the center-tap circuit is to be used, we are now ready to determine the secondary voltage required to ensure having 1000 volts at the power supply terminals under full-load current.

To find the secondary voltage needed, the voltage drops in the system at full-load current must be calculated. To do this it is necessary to know the resistance of the filter choke. The type of choke we have been considering probably will have a resistance of about 50 ohms; the voltage drop in it at full load will therefore be $50 \times .375$, or approximately 18 volts. There will be an additional drop in the rectifier tubes; we have only to consider one tube, however, since only one works at a time. This drop is approximately 15 volts. The total is therefore 33 volts, which added to 1000 gives 1033 volts as the average value of the a.c. voltage from one side of the transformer secondary. Transformers are rated in effective or r.m.s. voltages, however, so to find the required voltage in r.m.s. values it is necessary to divide the average value by .9. The required secondary voltage therefore will be $1033/.9$ or 1150 volts. The general formula for determining transformer voltage is

$$\text{Sec. } E_{r.m.s.} = \frac{E_o + IR_c + E_t}{.9}$$

where E_o is the d.c. output voltage of the power supply, I is the full-load current, including the bleeder current, R_c is the resistance of the choke or chokes in the filter, and E_t is the voltage drop in one rectifier tube in the center-tap circuit, or the sum of the drops of two tubes in the bridge circuit.

If the design principles given in the preceding discussion have been followed through, the required secondary volt-amperes will be

$$\text{Sec. VA} = \text{Total } E_{r.m.s.} \times I \times .75$$

where I is the d.c. output current, and $E_{r.m.s.}$ is the total secondary voltage (both sides of center-tap). In our illustration, the secondary VA capacity required therefore will be $2300 \times .375 \times .75$, or 650 VA. The actual watts drawn from the transformer will be less than this figure, but a somewhat higher VA capacity is required because the rectifier-filter system distorts the secondary-voltage wave-form, and it is necessary to take this into account in computing the heating effect of the current in the secondary winding. Because the heating effect is greater than in ordinary transformer applications, additional VA capacity must be built into the transformer.

In purchasing a transformer, it should be borne in mind that standard designs do not

always fit exactly an individual problem. It therefore becomes necessary to select a transformer with ratings which fit the desired ones as closely as possible.

Greater Smoothing

▲ In the specific design problem just used as an illustration, the permissible ripple voltage was assumed to be 5%. As we have pointed out previously, this will be satisfactory when the plate supply is to be used on the amplifier stages of an oscillator-amplifier transmitter used exclusively for c.w., but the ripple voltage must be smaller for self-controlled transmitters and radiotelephone sets. The most satisfactory way to get the additional smoothing is to use the two-section filter shown at Fig. 1004-D. The percent. ripple for a two-section filter is found by the following formula:

$$\% \text{ Ripple} = \frac{650}{L_1 L_2 (C_1 + C_2)^2}$$

For 1% ripple, satisfactory for oscillators, the numerical value of the denominator must therefore be at least 650; for .25% ripple, satisfactory for radiotelephony, the denominator must be at least 2600. The ripple in the power supply design previously discussed can be reduced considerably simply by the addition of a smoothing choke (not the swinging type) having an inductance of about 8 henrys, and a second 4- μ fd. condenser at the filter output terminals. Substituting these values in the formula above will give a ripple of approximately .25%. The two-section filter will have better voltage regulation and will require less inductance and capacity than a single-section filter having equivalent smoothing. The voltage drop in the second choke should be included in the calculation for determining the required transformer secondary voltage. If the design data given above is followed carefully, the voltage regulation of the power supply will be less than 10% — a very good figure.

Condenser-Input Filters

▲ The great advantages of the choke-input filter in reducing rectifier-tube peak current and in making possible good voltage regulation have been pointed out in the preceding discussion. These two points are of utmost importance in high-voltage plate-supply systems. The life of the rectifier tube is determined by the peak current it has to pass, while poor voltage regulation makes it necessary to buy filter condensers rated for the maximum voltage that is likely to appear across the condenser terminals. The cost of filter condensers goes up at a rapid rate as the voltage increases.

For low-voltage plate supplies — 500 volts or less — these considerations are of less economic importance. The smaller rectifier tubes, besides being inexpensive, are rated to work into either

choke- or condenser-input filters; low-voltage filter condensers also are inexpensive. Plate supplies for low-power transmitters are often built around a power transformer of fixed design (transformers giving 350 and 550 volts each side of the center-tap are legion) and in such cases the requisite smoothing is often obtained most economically by using a condenser-input filter. No simple formulas are available for computing the percent. ripple with a condenser-input filter, but experience has shown that a filter of the type shown in Fig. 1004-B will have excellent smoothing if each condenser is 2 to 8 μ fd. and if the choke has an inductance (commercial rating) of 20 to 30 henrys. With the condenser-input filter, the d.c. output voltage tends to be greater than the r.m.s. output voltage of the transformer secondary; at very light loads the output voltage will be approximately 1.4 times the secondary voltage (approaching the peak value of the rectified a.c. wave) gradually decreasing with load until at the nominal output rating of the transformer, the d.c. output voltage will be approximately equal to the secondary r.m.s. voltage. This characteristic is of value in low-power sets where the highest output voltage consistent with the power-supply apparatus used is wanted.

The large change in voltage with load represents poor voltage regulation and possibly may result in a chirpy signal from the low-power self-controlled oscillator. It has no such effect with the oscillator-amplifier transmitter, and therefore can be tolerated. The filter condensers, however, must be rated to stand continuously the *peak* value of the voltage — 1.4 times the rated secondary voltage of the transformer. This means that the filter condensers for a 350-volt transformer must be rated at at least 500 volts; those for a 550-volt transformer at at least 800 volts. With condenser-input filters the chief function of the bleeder resistor is to discharge the filter condensers when the power is turned off and thus prevent accidental shocks, because filter condensers will hold a charge for a long while. A resistor of 15,000 to 30,000 ohms is customary for low-voltage plate supplies, the higher resistances being used for the higher voltages.

25- and 50-Cycle Supply

▲ The filter design data just given is, as previously mentioned, applicable only to full-wave rectifiers working from a 60-cycle supply line. For lower frequencies, both inductance and capacity must be increased in proportion to the decrease in frequency to maintain the same reduction in ripple. After following through the design for 60 cycles, the inductance and capacity values obtained should both be multiplied by 2.4 to obtain the values necessary for 25 cycles; for 50 cycles the multiplying factor is 1.2. In practice, the 60-cycle design usually will be found to be adequate for 50 cycles as well.

Filter Chokes

▲ The inductance of a choke will vary with the current through it and with the value of the ripple voltage impressed on it in the filter; inductance decreases with increasing direct current and with decreasing ripple voltage. In purchasing a choke information should be obtained as to its actual smoothing inductance at full d.c. load current and at the ripple voltage at which it is to work. The latter requirement can be expressed more simply by determining whether the choke is to be used as an input choke or as a smoothing choke (second choke) in a two-section filter. Input chokes usually are of the swinging variety.

Most of the small chokes obtainable from radio dealers are given a commercial rating of 20 or 30 henrys. This rating is meaningless unless the conditions under which the choke's inductance was measured are stated. Fortunately the smaller chokes are inexpensive and usually have enough inductance to work quite well in condenser-input filters; it is better, however, to buy a choke of good make than to trust to luck with a cheap, but unknown, product.

Filter chokes for high voltages should in every case be purchased from a reputable manufacturer. It must be realized that the design formulas given previously are based on *actual* inductance under load conditions; an over-rated choke will nullify the calculations and probably lead to an entirely different order of performance.

Specifications for building chokes at home are given in a table at the end of this chapter. The design data apply particularly to smoothing chokes; if a choke having an inductance equal to the critical value is chosen for the input choke the results will be satisfactory, although such a choke will not be as economical of materials as a properly-designed swinging choke. The design of swinging chokes to fulfill predetermined conditions is a difficult problem and is beyond the scope of this *Handbook*.

Filter Condensers

▲ Two types of filter condensers are commonly available: electrolytic condensers, and condensers

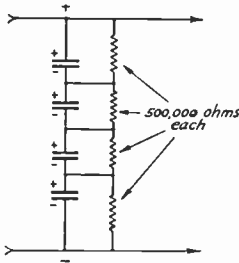


FIG. 1005 — HOW EQUALIZING RESISTORS ARE USED WITH FILTER CONDENSERS CONNECTED IN SERIES FOR HIGH VOLTAGES

using paper as the dielectric. In electrolytic condensers, the dielectric is an extremely thin film of oxide which forms on aluminum foil when the foil is immersed in a suitable electrolyte and is subjected to a d.c. voltage of the proper polarity. Electrolytic condensers are characterized by high capacity for a given size and cost, but cannot be made in single units for very high voltages, 500 volts being about the limit under present conditions. Electrolytic condensers are made in two types, "wet" and "dry." The "wet" condensers are provided with a liquid electrolyte in a sealed container; in the "dry" type the electrolyte is mixed with a filler to form a paste which is then placed between strips of aluminum foil. In neither type is the dielectric a perfect insulator; there is always an appreciable current flow between the electrodes, although it is only of the order of a few milliamperes. This leakage current is greater with the wet than with the dry types; the wet condensers, however, can stand voltage overloads better than the dry types because excessive voltage will simply increase the leakage current. Excessive voltage applied to the dry type will result in a "blown" condenser which must be replaced. Either type of electrolytic condenser will be satisfactory for condenser-input filters used with transformers delivering 350 volts each side of the center tap. Electrolytic condensers can be obtained in various capacities; 8 μ f. is a popular size.

If the maximum voltage of the power supply is greater than the rating of a single electrolytic condenser, two or more units may be placed in series to handle the higher voltage. When condensers are connected in series all the units of the string should have the same capacity so the voltage will divide equally between them. As a further assurance that each condenser in the string will take a proportionate share of the voltage, resistors may be connected across the individual units as shown in Fig. 1005. Each of the resistors should be 500,000 ohms, and should be rated to dissipate one or two watts.

Electrolytic condensers are suitable for use only in d.c. circuits, and must be connected correctly. In the types having a metal container, the container usually is the negative terminal while the stud terminal is positive. In any event the polarities are always plainly marked. Reversing the polarity will ruin the condenser.

If electrolytic condensers are allowed to stand idle for a time, the dielectric film will gradually disappear and the condenser must be "reformed." To prevent damage to the condensers and other power-supply components, the voltage always should be lowered before application to a power supply after it has been out of service for a few weeks. The film will re-form after a few minutes of low-voltage operation.

Paper condensers also are made in two types, with and without oil impregnation of the paper

dielectric. The oil-impregnated condensers generally are suitable for higher voltages than the plain types. Condensers having a working-voltage rating equal to the highest output voltage of the power-supply system (see discussion on condenser-input filters) always should be purchased. Paper condensers can be purchased with voltage ratings up to 3000 volts and more. High-voltage condensers always should be purchased from reputable manufacturers; it does not pay to "economize" by buying a cheap high-voltage condenser. Although the first cost of a good condenser may be higher, it will last indefinitely if not abused. Poor condensers may work for a time, but eventually will "blow" and have to be replaced. Failure of a high-voltage condenser may also mean the destruction of the rectifier tubes.

The Filament Supply

▲ The second division of the power supply for the transmitter is the supply to the filaments of the tubes used. Though batteries are sometimes used for this supply, alternating current obtained from the house current through a step-down transformer usually is more practical and more satisfactory. In some cases the filament-supply winding is wound over the core of the high-voltage transformer, thus eliminating the necessity for a separate filament transformer. This practice, however, is not always to be recommended. The filament supply must be constant if the transmitter is to operate effectively, and with both filament and high-voltage supplies coming from one transformer this constancy is obtained only with great difficulty, since changes in the load taken from the high-voltage winding cause serious changes in the voltage obtained from the filament winding — unless the transformer is operating well under its rating or unless special compensating apparatus is employed. Wherever possible the high-voltage and filament transformers should be separate units operating, if it can be arranged, from different power outlets, particularly with transmitters using tubes larger than the Type 10.

Examination of any of the power-supply circuits will make it obvious that the filaments of the rectifier tubes must be well insulated from the filaments of the oscillator tubes. The filaments of the rectifiers provide the positive output lead from the plate-supply system while the filaments of the transmitter tubes are connected to the negative side of the high-voltage supply. The fact that the two filament supplies must be insulated does not, however, mean that two transformers are required. The two windings can be on the same core, the necessary insulation being provided between them. Should the filament transformer be bought and should it have no windings suitable for the filaments of the rectifiers, an extra winding usually can be fitted without difficulty. For 866 rectifiers two No. 12 gauge

wires in parallel should be used for the winding, the number of turns being determined by the "cut and try" method. With most transformers only a few turns will be necessary to give the required voltage. The rectifier-filament winding can be center-tapped or a center-tapped resistor can be used across it in the manner described for the transmitter filaments. The center-tap is not an absolute necessity, however; the positive high-voltage lead can be taken from either side of the rectifier filament winding instead.

Practical Power Supplies

▲ The wide varieties of rectifying and filtering equipment available to amateurs, together with the different classes of service for which power supplies may be used, make it almost impossible for us to show complete constructional details of such equipment for any but the simplest of transmitters. The foregoing information should enable the amateur to choose the type of rectifier and filter best suited to his needs. As a guide in construction, however, Fig. 1006 shows a number of rectifier-filter combinations to give various output voltages and currents. All will give adequately-filtered direct current to the transmitting tubes, and in the cases where mercury-vapor rectifier tubes are shown the necessary protection is afforded them by the use of an input choke to the filter. In all circuits except that at *C* the voltage regulation will be good so that the voltage at no load will not be very much higher than at the load currents indicated. In these cases the filter condensers need be rated to stand only the voltage delivered by one-half of the high-voltage secondary; for example, a condenser with a working-voltage rating of 1250 volts d.c. will be ample for the 1000-volt power supply shown at *D*. This assumes, of course, that the bleeder resistance is used. Without this resistor, the condensers should be rated to stand 50% more voltage than half the secondary voltage of the transformer. In the arrangement at *C* the condensers should have the higher rating whether the bleeder is used or not.

The input choke may be omitted in diagram *A* even though the small mercury-vapor rectifiers are used because the tubes are built to stand working into a condenser-input filter. Should this be done, however, the filter condensers must be rated at 600 volts working, which means that electrolytic condensers cannot be used unless two of them are put in series to replace the single condensers shown. The condensers need not have 8 μ f. capacity each, but this is a standard size with electrolytic condensers and is recommended.

The rectifier-filter system at *A* will handle any of the small transmitters using receiving-type tubes shown in Chapter Seven. The ripple will be $\frac{1}{4}$ % or less, depending upon how well the choke inductance holds up under load. Diagram *B* will take care of a pair of Type 10 tubes with ease; the ripple should be about the same as in *A*. The

rectifier-filter at *C* does not use mercury-vapor rectifiers and hence can dispense with the input choke. Its output voltage will be variable between approximately 750 and 550 volts, however, depending upon the load current. It will be suitable for a pair of Type 10 tubes if it should be thought desirable to run them at more voltage than can be obtained with Diagram *B*. At *D* is shown a power supply for one or two tubes of the 203-A, 211 or 845 type. It is practically the same thing as the illustrative problem previously discussed. The arrangement at *E* is suitable for use

with one or two 852 or 860 tubes. With the filter values shown the ripple will be .25% or less. Other combinations can be worked out without much difficulty. It is not absolutely necessary to follow exactly the specifications in the filter section of the diagrams; for example 1- μ f. condensers or smaller chokes can be substituted in the filter of the high-power plate supply if the big tubes are amplifiers used for c.w. work in a crystal-controlled or oscillator-amplifier transmitter. For 'phone it is better to have as much filter as possible to keep the carrier free from hum.

In all these diagrams it is of course necessary to use power transformers of adequate capacity and chokes of high enough current rating to carry the load currents indicated. In *D* and *E* the plate transformers should be rated at about 650 and 850 VA, respectively, to give the necessary output.

Fig. 1007 is a photograph of a power supply suitable for use with a low-power transmitter. Its circuit diagram, Fig. 1008, will be seen to be similar to *A* in Fig. 1006 with the exception of the fact that the input choke to the filter is omitted and that no bleeder resistance is used. The filter condensers are electrolytics having a capacity of 8 μ f. each. The power transformer should deliver not more than 350 volts each side of the center tap to avoid damaging the condenser.

Electrolytic condensers have inherent leakage and the charge accumulated on them will dissipate itself in a short time, which is the reason why the bleeder can be dispensed with. If paper condensers are used a bleeder of about 20,000 to 30,000 ohms should be connected across the output of the filter. This power supply will deliver approximately 350 volts with a load of 100 milliamperes.

The location of parts in a power supply system is not of great importance. Make certain that the transformer and rectifier tubes are placed so that the heat generated by them can be radiated into the surrounding air, and have all wires, particularly those carrying high voltage, well insulated. In other respects the layout can be made anything convenient.

A Duplex Plate Supply for the Medium-Power Transmitter

▲ To illustrate one of the many modifications that can be made to straight-forward power-supply design, a diagram of a two-voltage power supply suitable for operating a complete transmitter of medium power is given in Fig. 1009. Inexpensive Type 83 tubes are used in the bridge circuit to give a high voltage of 1000 volts; simulta-

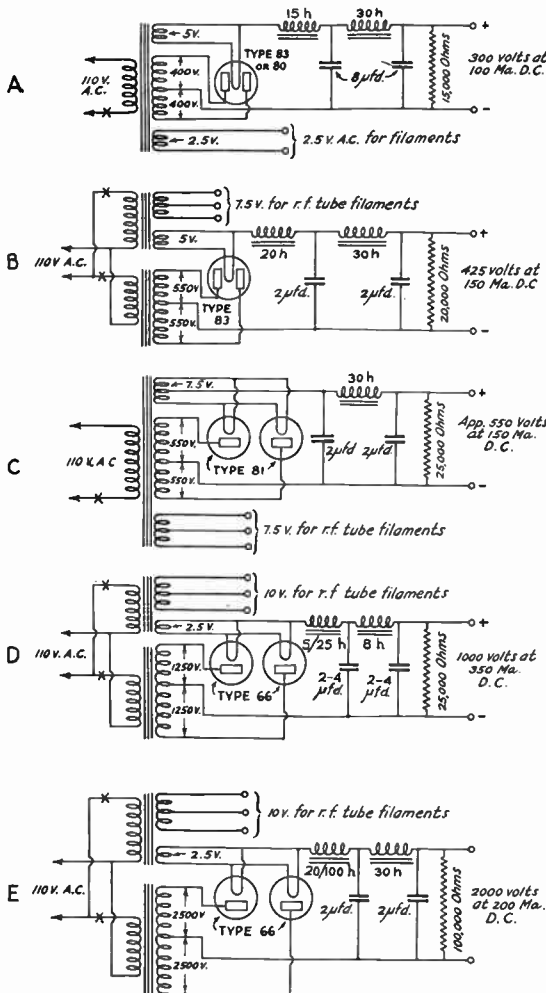


FIG. 1006 — REPRESENTATIVE POWER-SUPPLY ARRANGEMENTS FOR DIFFERENT TYPES OF TRANSMITTING TUBES

All these diagrams will give adequately-filtered d.c. output for the different classes of service. They are explained more fully in the text. Many other arrangements are possible. Control switches should be inserted in the transformer primaries at the points marked "X" to permit the filament supplies to be turned on before the plate supply.

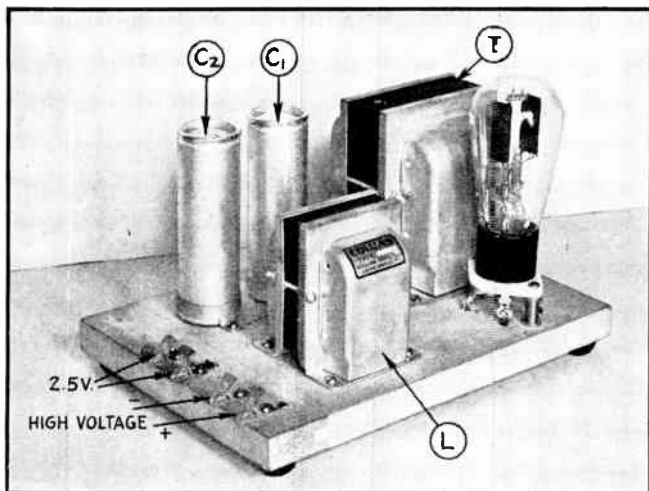


FIG. 1007 — A 350-VOLT POWER SUPPLY, OF INEXPENSIVE CONSTRUCTION, SUITABLE FOR THE LOW-POWER TRANSMITTER

neously one pair of the tubes acts as a center-tap rectifier in conjunction with the center-tap on the power transformer to furnish 500 volts for the low-power stages of the transmitter. A total of 250 milliamperes (or slightly more, since both filters have choke input) may be taken from the power supply without exceeding the rectifier-tube ratings; a representative current division would be 100 ma. for the small tubes and 150 ma. for the final amplifier stage. Such a power supply will operate either the exciter unit and RK-18 amplifier or the three-tube transmitter described in the chapter on transmitters.

With the filter values indicated in Fig. 1009, the ripple in the 500-volt output will be less than .1% and in the 1000-volt output approximately .25%, so the power-supply will be well suited to use with the r.f. end of a 'phone transmitter. For c.w., the second filter section may be omitted from the 1000-volt section, in which case the ripple will be approximately 6%; increasing the remaining condenser capacity from 2 μ fd. to 4 μ fd. will bring the ripple down to 3%. It is best to use the two-section filter on the low-voltage output; the condensers and chokes are relatively inexpensive and low ripple is desirable on low-power stages.

An input choke having fixed inductance is recommended for the 500-volt output because the load on this section usually is continuous. If the load is to be variable, a swinging choke should be used, together with a bleeder of suitable value across the output. The bleeder may be used as a voltage divider to ob-

tain still lower voltage — for instance, for a crystal oscillator.

Voltage Dividers

▲ In addition to the voltages shown in Fig. 1006, lower voltages may be taken from any of the power supplies diagrammed by substituting a voltage divider, or tapped resistor, for the plain bleeder resistor. For example, suppose the power supply of Fig. 1006-D is to be used to furnish power for all three stages of the three-tube transmitter (47, 10, 203-A) described in Chapter Seven. A voltage divider can be installed to furnish 350 volts at 30 ma. for the oscillator and 500 volts at 60 ma. for the buffer-doubler, in addition to the 1000 volts for the final amplifier.

To calculate the resistance required between taps, the voltage divider should be laid off in sections, as shown in Fig. 1010. Starting from the negative end, the voltage drop across the first section will be 350 volts, the voltage required by the oscillator. The drop across the second section will be 150 volts, bringing the total voltage between negative and the doubler tap to 500 volts. The last resistor section will have a drop of 500 volts across it. Then, knowing the current to be drawn at each tap and the idle current to be bled off through the lowest resistor section, it is an easy matter to calculate the resistances required at each section by applying Ohm's Law. The

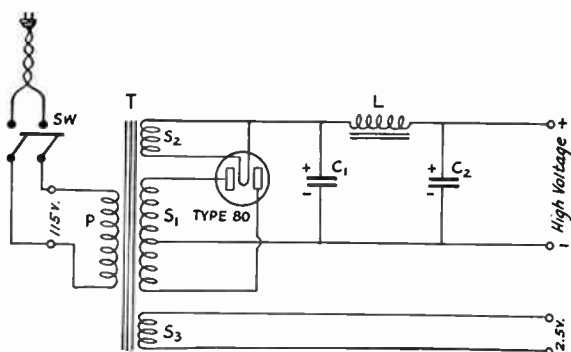


FIG. 1008 — WIRING DIAGRAM OF THE POWER SUPPLY SHOWN IN FIG. 1007

T — Power transformer; high-voltage winding, S_1 , 350 volts each side of center tap; rectifier filament winding, S_2 , 5 volts; transmitting-tube filament winding, S_3 , 2.5 volts. Transformers of this type are sold for broadcast-receiver purposes.

L — Filter choke, commercial inductance rating 20 to 30 henrys, current-carrying capacity 100 ma.

C_1 , C_2 — 8- μ fd. electrolytic filter condensers rated at 500 volts peak.

power supply Fig. 1006-D calls for a bleeder current of 40 ma. (1000 volts divided by 25,000 ohms); the lower section therefore is equal to

$$\frac{350}{.04} = 8750 \text{ ohms}$$

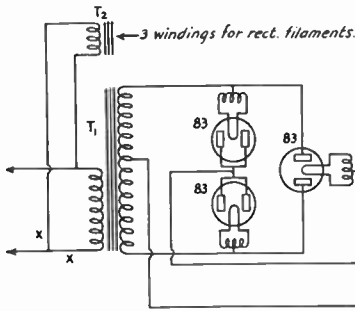


FIG. 1009 — A DUPLEX PLATE SUPPLY CIRCUIT

This plate supply will deliver 500 and 1000 volts at a total of 250 milliamperes (sum of currents from both taps).

T₁ — Power transformer, 600 volts each side center tap; 350 VA.
T₂ — Rectifier filament transformer, three 5-volt 3-amp. windings.

C₁ — 2 μfd., 1250-volt rating.

C₂ — 4 μfd., 1250-volt rating.

C₃, C₄ — 2 μfd., 800-volt rating.

L₁ — Swinging choke, 8/40 henrys, 275 ma.

L₂ — Smoothing choke, 12 henrys, 275 ma.

L₃, L₄ — 10 henrys, 200 ma.

R — 40,000 ohms, 25-watt rating.

The second section has the 30 ma. for the oscillator in addition to the 40 ma. idle current flowing through it, therefore the resistance required is

$$\frac{150}{.07} = 2150 \text{ ohms (app.)}$$

In the third (upper) section, the current becomes 60 ma. plus the 70 ma. already flowing through the section below, a total of 130 ma. The resistance value is

$$\frac{500}{.13} = 3850 \text{ ohms}$$

The total resistance of the divider is therefore 14,750 ohms, safely below the value necessary to maintain constant output voltage when the tubes are not drawing current from the power supply. This will increase the no-load bleeder current, but will not affect the operation of the power supply under full load. In the above example, the no-load resistor current will be

$$\frac{1000}{14,750} = 63.5 \text{ ma.}$$

Under no-load conditions the voltage across each resistor will be proportional to its individual resistance compared to the total resistance. The drop across the lower section would be

$$\frac{8750}{14,750} \times 1000 = 600 \text{ volts (app.)}$$

The drop across the middle section is

$$\frac{2150}{14,750} \times 1000 = 150 \text{ volts (app.)}$$

Across the upper section

$$\frac{3850}{14,750} \times 1000 = 250 \text{ volts (app.)}$$

The above calculations make it clear that the voltage regulation of the tap voltages is rather poor, since the voltage rises considerably when the load is removed. This is characteristic of voltage dividers. The output voltages will be correct only when the load currents used in the calculations are drawn.

The power dissipated by each resistor may be calculated by multiplying the voltage drop across it by the current flowing through it. This should be done for both no-load and full-load conditions, and a resistor selected having a rating well above that of the higher of the two values. It may not be possible to get stock resistors of the exact resistance calculated, in which case the nearest available size usually will be satisfactory. Semi-variable resistors, having sliding contacts so that any desired resistance value may be selected, can be used if more exact adjustment of voltage is required.

In case it is desired to have the bleeder resistance total to a predetermined value—for instance, if the bleeder in the illustration above is to total 25,000 ohms instead of the calculated value of 14,750 ohms—the same method of calculation may be followed, but different values of idle current should be tried until the correct result is found. An idle current of 20 instead of 40 ma., for instance, will work out to a total resistance of approximately 25,000 ohms in the illustration above.

The method may be extended to a greater number of taps, and is equally applicable to the calculation of voltage dividers for receivers.

Receiver Power Supplies

▲ Power supplies for a.c.-operated receivers do not differ materially from those used with trans-

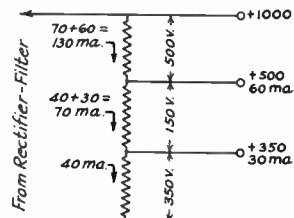


FIG. 1010 — VOLTAGE DIVIDER COMPUTATIONS CAN BE MADE BY PLOTTING THE VOLTAGE DROPS AND CURRENT DIVISION IN A DIAGRAM SIMILAR TO THIS ONE

mitters except that the voltages are lower and all ripple must be eliminated. Nothing is more annoying than a "hummy" B supply. The ripple can be reduced to satisfactory proportions by the use of three filter condensers (a three-section electrolytic condenser with capacities of 2, 4 and 8 μfd . will be satisfactory) and two receiver-type 30-henry chokes. Fig. 1010-A is the wiring diagram of a typical receiver power supply. It uses a power transformer, of the type used in broadcast receivers, delivering approximately 350 volts each side of the center-tap on the high-voltage winding. This type of power supply will take care of an ordinary amateur receiver and in addition will easily handle an audio power amplifier stage using a 47 pentode or a pair of 45's in push-pull. The output voltage will be rather higher than is required for the receiver itself, however, so the filter may be rearranged somewhat to use choke input, which will reduce the voltage and give better regulation. This is shown in Fig. 1010-B. Alternatively, a transformer giving lower output voltage might be used if the receiver has no power stages and therefore does not take much current.

Special care must be taken with power packs for autodyne receivers to make certain that the voltage output will be constant and that "tunable hums" do not appear. A varying output voltage will make the detector oscillation frequency change and hence make signals sound wavering and unsteady. The choke-input filter of Fig. 1010-B is recommended on this score; it will be especially valuable if the receiver volume control operates on the bias on the r.f. amplifiers. Tunable hums are hums which appear only at certain frequencies to which the receiver is set and only with the detector oscillating. It may be that no hum can be heard with the detector out of oscillation but a strong hum is noticed as soon as the detector is made to oscillate. This is a tunable hum and cannot be eliminated by the addition of more filter condensers or chokes since it is caused by r.f. getting into the power supply and picking up modulation. Small condensers connected across the plates and filament of the rectifier tube as shown in both diagrams usually will eliminate this type of hum. A grounded electrostatic shield between the primary and secondaries of the power transformer also will help. Not all transformers have such a shield, however. Of course the power leads coming from the receiver itself should be well by-passed to prevent r.f. from getting into the power supply.

For some applications where the current to be taken from the power supply is not more than a few milliamperes — a separate power supply for a frequency meter, for example — resistors can be substituted for the filter chokes to make a compact power supply. Resistors of 10,000 to 50,000 ohms should be satisfactory, depending upon the voltage drop that is permissible. With

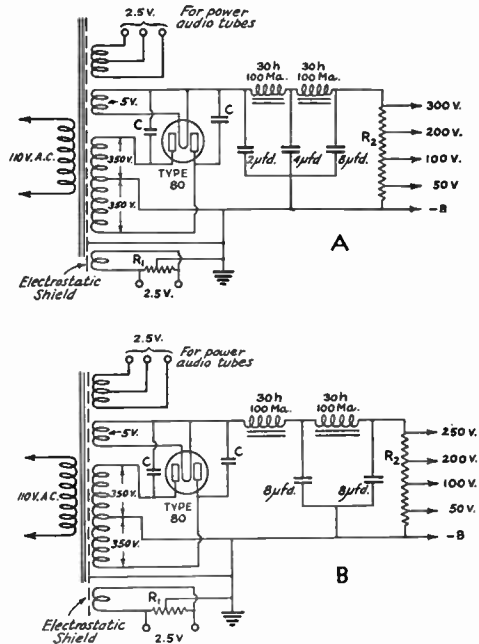


FIG. 1011 — WIRING DIAGRAMS FOR RECEIVER POWER SUPPLIES

Condenser C should be a mica condenser of about .002 μfd . capacity. Its size is not critical and it will be required only if tunable hums are present, as explained in the text. Resistor R_1 is 20 ohms total, tapped at the center. R_2 is the voltage divider for obtaining different voltages from the power supply. If the receiver itself is equipped with a divider (the preferable method) R_2 will be a simple bleeder of about 15,000 ohms. Otherwise it may be any of the regular voltage dividers sold commercially for this use, or may be a 15,000 ohm resistor tapped at every 3000 ohms. The resistance needed between taps will depend upon the currents to be drawn at each of the taps. It is not usually necessary to have the voltages nearer rated values than within 20%, with modern receiving tubes.

a midget power transformer and a low-voltage high-capacity electrolytic condenser, together with one of the smaller rectifier tubes listed in the table, a physically small but adequate power supply can be built.

Transmitter Bias Supplies

▲ Low-voltage power packs make excellent substitutes for batteries as "C" bias supplies for certain types of r.f. power amplifiers. The "C" power pack, in fact, offers the same advantages as the combination battery-and-leak bias discussed in Chapter Seven. Not all power packs are suitable as bias supplies for transmitters, however.

The power pack for "C" bias use must have a low-resistance bleeder. Since the bleeder, or at least part of it, is connected in the r.f. amplifier grid circuit, it performs in just the same fashion as a grid leak; that is, the flow of amplifier grid

current through the bleeder causes a voltage drop which may add considerably to the actual bias on the grid. For this reason, therefore, the part of the bleeder included in the biasing circuit (in case the bleeder provides taps for different voltages) should have a resistance no higher than that ordinarily required as a grid leak for the tube in use. The resistance of the bleeder then can be proportioned so that the voltage across the taps in use will be approximately equal to the cut-off bias of the tube when there is no excitation. This will give the protective feature of fixed bias and also provide the automatic biasing characteristic of grid leaks.

The transformer and rectifier for a bias supply will be identical with those used in receiver power packs. The filter may be somewhat simpler, however; it may, in fact, be found possible to get sufficient filtering with only a condenser connected across the output of the rectifier, since no current except that taken by the bleeder is drawn from the "C" supply. A choke and second condenser can be added in case actual tests show that a bias supply having only a condenser filter introduces modulation on the signal. The circuit diagram of Fig. 1012 is suggested for bias supplies; the method of calculating the bleeder resistance required also is shown.

Since the bias voltage varies with grid current, a "C" supply of this type often will be found to be somewhat unsatisfactory for biasing more than one stage, because the grid current for all stages must flow through the same resistor, thus causing all stages to be over-biased. This effect can be overcome to a considerable extent by using a low bleeder or voltage divider resistance so that voltage variations from grid-current flow are minimized. In general, the bleeder current in such

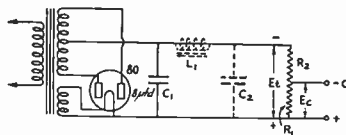


FIG. 1012 — A PRACTICAL CIRCUIT FOR THE "C" SUPPLY

A single 8- μ f. condenser often will suffice for the filter, but if trial shows that more is needed, a choke and second condenser, shown in dotted lines, may be added. The condensers should be rated at 500 volts, especially if the "C" supply is to be used on a high-power stage where the excitation is likely to be large.

The bias voltage, E_c , should be approximately that value which will cut off the plate current of the tube at the plate voltage used (roughly the plate voltage divided by the voltage amplification factor of the tube). Resistor R_1 should be equal to the grid leak value ordinarily used with the tube. The required resistance for R_2 can be found by the formula

$$R_2 = \frac{E_t - E_c}{E_c} \times R_1$$

where E_t is equal to the peak value of the transformer-rectifier output voltage (r.m.s. voltage of one side of secondary multiplied by 1.4).

a "C" supply should be just as great as the transformer and rectifier tube are capable of furnishing. The bleeder current for a 300-volt supply, for instance, would be approximately 100 milliamperes, calling for a resistor of about 3000 ohms.

For the reasons given above, "C" supplies are usually unsatisfactory in applications where the bias voltage must remain constant under operating conditions, as in Class-B audio and r.f. amplifiers. For linear output from these types of amplifiers it is essential that the bias remain constant during operation. The "C" supply will give good results with practically all other types of amplifiers, however.

Vibrator-Transformers

▲ The increasing use of automobile radio receivers has brought about a revival of the "buzzer" type of transformer to obtain power at a voltage suitable for the plates of tubes from a low-voltage d.c. source such as a storage battery. In its modern form the vibrator-transformer consists of a specially-designed transformer combined with a vibrating interrupter; when the unit is connected to a 6-volt battery the circuit is made and broken rapidly by the vibrator contacts and the pulsating d.c. which flows in the primary of the transformer causes an alternating voltage to be developed in the secondary. The transformer is usually so designed that the direct-current output of the plate supply unit, after having been rectified and filtered, is in the vicinity of 200 volts. Rectifier tube types 1, 1-V, and 84 are commonly used in this type of plate supply.

Power supplies of this type can be obtained at reasonable cost and will be suitable for transmitters of very low power. Amateurs who have no a.c. have occasionally built higher-voltage power supplies operating on the same principle. A system using 6-volt batteries and Ford spark coils was described in the June, 1932, issue of *QST*. A home-made transformer for use with 32-volt farm-lighting plants was described in the June, 1933, issue.

Building Small Transformers

▲ Power transformers for both filament heating and plate supply for all transmitting and rectifying tubes are available commercially at reasonable prices, but occasionally the amateur wishes to build a transformer for some special purpose or has a core from a burned out transformer on which he wishes to put new windings.

Most transformers that amateurs build are for use on 110-volt 60-cycle supply. The number of turns necessary on the 110-volt winding depends on the kind of iron used in the core and on the cross-sectional area of the core. Silicon steel is best, and a flux density of about 50,000 lines per square inch can be used. This is the basis of the table of cross-sections given.

The size of wire to use depends on the current

the winding will carry at full load. When a small transformer is built to handle a continuous load, the copper wire in the windings should have an area of 1500 circular mils for each ampere to be carried. (See Wire Table in Appendix.) For intermittent use, 1000 circular mils per ampere is permissible.

A table is given showing the best size wire and core cross-section to use for particular transformers. The figures in the table refer to 60-cycle transformers. The design of 25-cycle transformers is similar but a slightly higher flux density is permissible. Because the frequency is much lower the cross-sectional area of the iron must be greater or the number of turns per volt correspondingly larger, otherwise the inductance will be too low to give the required reactance at the reduced frequency. If one builds the core so that its cross-section is 2.1 to 2.2 times the value of area worked out from the table, the same number turns of wire may be used in a primary coil for

assuming that the turns are wound regularly and that no insulation is used between layers. Figures are given for three different types of insulation. The primary winding of the 200-watt transformer, which has 270 turns of No. 17 wire, would occupy 270/329 or .82 square inches if wound with double-cotton-covered wire, for example. This makes no allowance for a layer of insulation between the windings (in general, it is good practice to wind a strip of paper between each layer) so that the winding area allowance should be increased if layer insulation is to be used. The figures also are based on accurate winding such as is done by machines; with hand winding it is probable that somewhat more area would be required. An increase of 50% should take care of both hand winding and layer thickness. The area to be taken by the secondary winding should be estimated, as should also the area likely to be occupied by the insulation between the core and windings and between the primary and secondary

<i>Input (Watts)</i>	<i>Full-load Efficiency</i>	<i>Size of Primary Wire</i>	<i>No. of Primary Turns</i>	<i>Turns Per Volt</i>	<i>Cross-Section Through Core</i>
50	75%	23	528	4.80	1 1/4" x 1 1/4"
75	85%	21	437	3.95	1 3/8" x 1 3/8"
100	90%	20	367	3.33	1 1/2" x 1 1/2"
150	90%	18	313	2.84	1 5/8" x 1 5/8"
200	90%	17	270	2.45	1 3/4" x 1 3/4"
250	90%	16	248	2.25	1 7/8" x 1 7/8"
300	90%	15	248	2.25	1 7/8" x 1 7/8"
400	90%	14	206	1.87	2 " x 2 "
500	95%	13	183	1.66	2 1/8" x 2 1/8"
750	95%	11	146	1.33	2 3/8" x 2 3/8"
1000	95%	10	132	1.20	2 1/2" x 2 1/2"
1500	95%	9	109	.99	2 3/4" x 2 3/4"

25-cycle operation. If the same core and more turns of wire are used a larger "window" will be needed for the extra wire and insulation. Increasing both the number of turns per volt and the cross-section of the core gives the best-balanced design.

Most 60-cycle transformers will behave nicely on a 25-cycle supply if the applied voltage is sufficiently reduced. Up to 52 volts at 25 cycles may be applied to a 110-volt 60-cycle winding without harm. Knowing the transformer voltage ratio, the output voltage will be known. The current-carrying capacity will be the same as at 60 cycles. The KVA (kilovolt-ampere) rating will be about half the 60-cycle value.

Having decided on the core cross-section necessary to handle the power, the next step is to calculate the core window area required to accommodate the windings. The primary wire size is given in the table; the secondary wire size should be chosen according to the current to be carried, as previously described. The Wire Table in the Appendix shows how many turns of each wire size can be wound into a square inch of window area,

windings themselves. When the total window area required has been figured — allowing a little extra for contingencies — laminations having the desired leg width and window area should be purchased. It may not be possible to get laminations having exactly the dimensions wanted, in which case the nearest size should be chosen. The cross-section of the core need not be square but can be rectangular in shape so long as the core area is great enough. It is easier to wind coils for a core of square cross-section, however.

Transformer cores are of two types, "core" and "shell." In the core type, the core is simply a hollow rectangle formed from two "L"-shaped laminations, as shown in Fig. 1013. Shell-type laminations are "E" and "I" shaped, the transformer windings being placed on the center leg. Since the magnetic path divides between the outer legs of the "E," these legs are each half the width of the center leg. The cross-sectional area of a shell-type core is the cross-sectional area of the center leg. The shell-type core makes a better transformer than the core type, because it tends to prevent leakage of the magnetic flux. The

windings are calculated in exactly the same way for both types.

Fig. 1014 shows the method of putting the

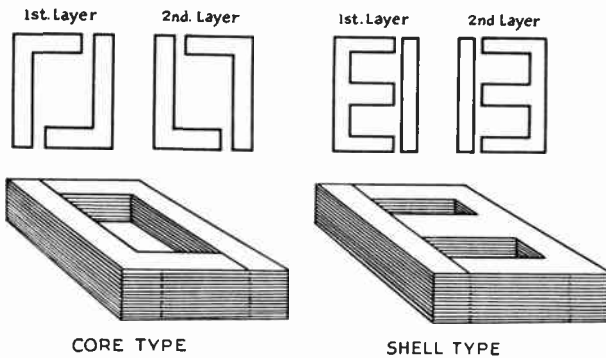


FIG. 1013 — TYPES OF TRANSFORMER CORES, SHOWING THE SHAPES OF LAMINATIONS

windings on a shell-type core. The primary is usually wound on the inside — next to the core — on a form made of fibre or several layers of cardboard. This form should be slightly larger than the core leg on which it is to fit so that it will be an easy matter to slip in the laminations after the coils are completed and ready for mounting. The terminals are brought out to the side. After the primary is finished, the secondary is wound over it, several layers of insulating material being put between. If the transformer is for high voltages, the high-voltage winding should be carefully insulated from the primary and core by a few layers of Empire cloth or tape. A protective covering of heavy cardboard or thin fibre should be put over the outside of the secondary to protect it from damage and to prevent the core from rubbing through the insulation. Square-shaped end pieces of fibre or cardboard usually are provided to protect the sides of the winding and to hold the terminal leads in place. High-voltage terminal leads should be enclosed in Empire cloth tubing or spaghetti.

After the windings are finished the core should be inserted, one lamination at a time. Fig. 1013 shows the method of building up the core. In the first layer the "E"-shaped laminations are pushed through from one side; the second "E"-shaped lamination is pushed through from the other. The "I"-shaped laminations are used to fill the end spaces. This method of building up the core ensures a good magnetic path of low reluctance. All laminations should be insulated from each other to prevent eddy currents from flowing. If there is iron rust or a scale on the core material, that will serve the purpose very well — otherwise one side of each piece can be coated with thin shellac. It is essential that the joints in the core be well made and be square and even. After the transformer is assembled, the joints can be hammered up tight using a block of wood

between the hammer and the core to prevent damaging the laminations. If the winding form does not fit tightly on the core, small wooden wedges may be driven between it and the core to prevent vibration. Transformers built by the amateur can be painted with insulating varnish or waxed to make them rigid and moisture proof. A mixture of melted beeswax and rosin makes a good impregnating mixture. Melted paraffin should not be used because it has too low a melting point. Double-cotton-covered wire can be coated with shellac as each layer is put on. However, enameled wire should never be treated with shellac as it may dissolve the enamel and hurt the insulation, and it will not dry because the moisture in the shellac will not be absorbed by the insulation. Small transformers can be

treated with battery-compound after they are wound and assembled. Strips of thin paper between layers of small enameled wire are necessary to keep each layer even and to give added insulation. Thick paper must be avoided as it keeps in the heat generated in the winding so that the temperature may become dangerously high.

Keep watch for shorted turns and layers. If just one turn should become shorted in the entire winding, the voltage set up in it would cause a heavy current to flow which would burn it up, making the whole transformer useless.

Taps can be taken off as the windings are made if it is desired to have a transformer giving several voltages. The more taps there are, the more difficult becomes the problem of avoiding weakened insulation at the points where they are made. Taps should be arranged whenever possible so that they come at the ends of the layers. If the wire of which the winding is made is very small, the ends of the winding and any taps that are made should be of heavier wire to provide stronger leads.

After leaving the primary winding connected to the line for several hours it should be only slightly warm. If it draws much current or gets hot there is something wrong. Some short-circuited turns are probably responsible and will continue to cause overheating and possibly fire-works later.

Building Filter Choke Coils

▲ Filter choke coils resemble transformers in construction, but only one winding is used. The core may be either of the core or shell type, but the corners should not be interleaved, a butt joint being used instead. This is done so that the core can be opened slightly to form an air gap in the magnetic path. An air gap actually increases the effective inductance of the choke when direct

DESIGN DATA FOR INDUCTANCE COILS WITH IRON CORES ^{Weight of Steel taken as 480 $\frac{lb}{cu. ft.}$ = 0.28 $\frac{lb}{cu. inches}$}

CORE SIZE	INDUCTANCE HENRYS	EQUIV GAP (G)	*ACTUAL GAP Decimals	NO. TURNS (N)	FLUX DENS. (B) LINE INCH	WINDING FORM		MEAN TURN INCHES	FEET OF WIRE	RESISTANCE (D.C.)	WEIGHT OF COPPER	CORE DIMENSIONS		POUNDS STEEL	
						b	c					Long Piece	Short Piece		
1/2 x 1/2	0.5	.040"	.017*	1600	6500	0.42"	0.28"	3.0	400	82.5	1.00z	1/2 x 1.6"	1/2 x .50	0.30	
	1.0	.041	.019	2300	9000	0.50	0.33	3.2	615	127.0	1.5 "	1/2 x 1.7"	1/2 x .55	0.31	
	5.0	.043	.023	5200	20000	0.75	0.50	3.8	1670	345.0	4.0 "	1/2 x 1.92"	1/2 x .75	0.37	
	10.0	.046	.030	7600	27000	0.90	0.60	4.2	2640	545.0	6.5 "	1/2 x 2.1"	1/2 x .85	0.41	
	15.0	.048	.035	9500	32000	1.00	0.68	4.5	3510	725.0	8.5 "	1/2 x 2.2"	1/2 x .85	0.43	
3/4 x 3/4	5.0	.043"	.023	3500	13000	0.62"	0.42"	4.5	1310	271	3.25oz	3/4 x 2.4"	3/4 x .75	1.0	
	10.0	.046	.030	5000	18000	0.73	0.49	4.75	2000	411	5.0 "	3/4 x 2.5"	3/4 x .75	1.0	
	15.0	.048	.035	6300	21000	0.82	0.55	5.0	2630	544	6.5 "	3/4 x 2.6"	3/4 x .75	1.05	
	20.0	.052	.044	7600	24000	0.91	0.60	5.2	3280	678	8.0 "	3/4 x 2.7"	3/4 x .85	1.1	
	50.0	.070	.100	14000	33000	1.25	0.83	6.0	7000	1445	1lb 1 "	1/2 x 3.0"	3/4 x 1.0	1.25	
1 x 1	10.0	.046"	.030	3800	14000	0.64"	0.43"	5.6	1760	364	4.25oz	1 x 3.0	1 x .75	2.1	
	15.0	.048	.035	4800	16000	0.69	0.49	5.8	2310	478	5.5 "	1 x 3.0	1 x .75	2.1	
	20.0	.052	.044	5700	18000	0.78	0.52	5.9	2800	580	6.75 "	1 x 3.1	1 x .75	2.2	
	50.0	.070	.100	11000	25000	1.10	0.75	6.7	6130	1270	15.0 "	1 x 3.5	1 x 1.0	2.5	
	100.0	.100	.250	18000	29000	1.40	0.93	7.4	11000	2280	1lb 10 "	1 x 3.8	1 x 1.1	2.75	
2 x 2	100.0	.100"	.250	1/4"	8900	14000	0.97"	0.65"	10.4	7700	1590	1lb 3oz	2 x 5.5	2 x 1.0	14.5
	1/2 x 1/2	0.5	.040"	.017	1600	13000	0.55"	0.38"	3.4	450	46	2.2oz	1/2 x 1.6"	1/2 x 0.63	0.31
		1.0	.041	.019	2300	18000	0.66	0.45	3.6	700	72	3.5 "	1/2 x 1.75"	1/2 x 0.70	0.35
		5.0	.043	.023	5200	39000	1.00	0.68	4.5	1950	200	9.5 "	1/2 x 2.10"	1/2 x 0.95	0.43
	3/4 x 3/4	1.0	.041"	.019	1500	12000	0.53"	0.37"	4.3	540	56	2.7oz	3/4 x 2.10"	3/4 x 0.63	0.87
5.0		.043	.023	3500	26000	0.83	0.56	5.0	1470	151	7.2 "	3/4 x 2.5"	3/4 x 0.80	1.05	
10.0		.046	.030	5000	35000	1.00	0.67	5.4	2250	230	11.0 "	3/4 x 2.6"	3/4 x 0.95	1.12	
1 x 1	5.0	.043"	.023	2600	20000	0.71"	0.49"	5.8	1250	130	6.1oz	1 x 2.8	1 x 0.75	2.0	
	10.0	.046	.030	3800	27000	0.86	0.58	6.1	1940	200	9.5 "	1 x 3.0	1 x 0.85	2.2	
	15.0	.048	.035	4800	32000	0.96	0.65	6.4	2550	260	12.0 "	1 x 3.1	1 x 0.90	2.25	
2 x 2	10.0	.046"	.030	1900	13000	0.60"	0.42"	9.5	1500	160	7.5oz	2 x 4.66	2 x 0.60	11.5	
	15.0	.048	.035	2400	16000	0.68	0.46	9.7	1900	200	9.5 "	2 x 4.75	2 x 0.66	12.3	
	20.0	.052	.044	2900	19000	0.75	0.51	9.8	2400	250	11.5 "	2 x 4.85	2 x 0.75	12.5	
	50.0	.070	.100	5300	24000	1.00	0.70	10.5	4600	480	11.8z	2 x 5.50	2 x 0.95	14.0	
100.0	.100	.250	8900	28000	1.33	0.90	11.2	8300	860	21.8z	2 x 5.90	2 x 1.15	16.0		
1/2 x 1/2	0.5	.040"	.017	1600	32000	0.90"	0.60"	4.2	550	22.5	7oz	1/2 x 2.2	1/2 x .85	0.40	
	1.0	.082	.120	3200	32000	1.30	0.85	5.1	1350	55	1lb 1 "	1/2 x 2.5	1/2 x 1.10	0.50	
	5.0	.043"	.023	3700	35000	1.40	0.92	7.3	2260	92	1lb 12 "	1 x 3.6	1 x 1.20	2.7	
3/4 x 3/4	0.5	.040"	.017	1000	21000	0.72"	0.46"	4.7	390	16	5oz	3/4 x 2.3	3/4 x 0.71	0.96	
	1.0	.041	.019	1500	30000	0.90	0.58	5.1	640	26	8 "	3/4 x 2.5	3/4 x 0.83	1.05	
	1.0	.041"	.019	1100	22000	0.75"	0.50"	5.8	530	22	6.5oz	1 x 2.9	1 x 0.75	2.10	
2 x 2	5.0	.086	.170	3700	35000	1.40	0.92	7.3	2260	92	1lb 12 "	1 x 3.6	1 x 1.20	2.7	
	10.0	.043"	.023	1300	23000	0.82"	0.53"	9.7	1050	43	13oz	2 x 4.9	2 x 0.80	12.7	
	15.0	.046	.030	2000	32000	1.05	0.68	10.5	1750	71	11lb 6 "	2 x 5.2	2 x 1.0	13.8	
3 x 3	15.0	.096	.200	3300	28000	1.35	0.86	11.1	3060	125	22 "	6 "	2 x 5.5	2 x 1.1	14.7
	20.0	.104	.280	4200	32000	1.43	0.95	11.5	3820	156	21lb 5 "	2 x 5.6	2 x 1.2	15.2	
	10.0	.046"	.030	1300	22000	0.81"	0.53"	14.0	1510	62	11lb 3oz	3 x 6.9	3 x 0.8	39	
	15.0	.048	.035	1600	26000	0.90	0.60	14.2	1900	77	11 "	7 "	3 x 7.0	3 x 0.85	40
3 x 3	20.0	.052	.044	1900	30000	1.00	0.65	14.4	2300	93	11 lb 12 "	3 x 7.1	3 x 0.9	41	
	50.0	.140	.330	5000	28000	1.60	1.10	15.9	6660	270	5 "	2 "	3 x 7.8	3 x 1.35	46
	100.0	.200	.600	8400	34000	2.10	1.40	17.0	12000	485	9 lb 3 "	3 x 8.3	3 x 1.65	50	
	10.0	.046"	.030	1300	22000	0.81"	0.53"	14.0	1510	62	11lb 3oz	3 x 6.9	3 x 0.8	39	
1/2 x 1/2	0.5	0.16"	.35	3200	32000	1.80"	1.20"	6.4	1700	35	2lb 10oz	1/2 x 3	1/2 x 1.45	0.62	
	3/4 x 3/4	0.5	0.08"	.170	1480	30000	1.25"	.83"	6.0	735	15	1lb 2oz	3/4 x 2.9	3/4 x 1.1	1.26
	1.0	0.16	.35	3000	30000	1.75"	1.20	7.2	1800	37	2" 13 "	3/4 x 3.5	3/4 x 1.5	1.6	
1 x 1	0.5	0.04"	.02	800	32000	0.90"	0.60"	6.2	410	8.5	0lb 10oz	1 x 3.0	1 x 0.85	2.2	
	1.0	0.082	.17	1600	31000	1.30	0.85	7.1	945	19	11 lb 8 "	1 x 3.5	1 x 1.0	2.5	
	5.0	0.387	.75	7800	32000	2.90	1.90	11.0	7000	143	10 lb 14 "	1 x 5.2	1 x 2.2	4.2	
2 x 2	1.0	0.041"	.019	560	22000	0.75"	0.50"	9.8	460	9.4	0lb 12oz	2 x 4.9	2 x 0.75	12.7	
	5.0	0.086	.17	1800	32000	1.35	0.90	11.3	1700	35	2" 10 "	2 x 5.5	2 x 1.15	15.0	
	10.0	0.184	.40	3800	33000	2.00	1.30	12.8	4100	83	6 " 6 "	2 x 6.2	2 x 1.5	17.3	
	5.0	0.043"	.023	860	30000	1.00"	0.60"	14.2	1000	21	1lb 10oz	3 x 7.1	3 x 0.85	40.0	
3 x 3	10.0	0.092	.20	1840	31500	1.40	0.92	15.3	2350	48	3" 10 "	3 x 7.5	3 x 1.15	43.5	
	15.0	0.130	.30	2620	32000	1.65	1.10	16.0	3500	71	5 " 7 "	3 x 7.8	3 x 1.4	46.0	
	20.0	0.175	.38	3500	32000	1.90	1.25	16.6	4850	99	7 " 8 "	3 x 8.1	3 x 1.5	48.0	
	50.0	0.432	.80	8700	32000	3.00	2.00	19.2	14000	282	21 " 8 "	3 x 9.3	3 x 2.3	58.0	
	100.0	0.900	1.50	16700	31500	4.10	2.80	22.0	31000	620	47 " 5 "	3 x 10.5	3 x 3.1	68.0	

* The Actual Gap can only be an approximation owing to the many factors which may affect fringing of flux, permeability of core, etc. It must be adjusted by trial until the proper value of inductance is obtained or better yet, until the set up operates at the best point.
 * The values of (B), the flux density, are those obtained with all D.C. & ac A.C., or the effective B if all A.C. The maximum value in the latter case will be $\sqrt{2}$ times as given in the case of rectified A.C. applied to coil with no previous smoothing the maximum B may be 1.57 times the values given.

current is flowing through the winding by preventing magnetic saturation of the core. Since a low-reluctance magnetic path is not necessary, the shell-type of core has no particular advantages. The full-page table of choke coil specifications is based on the core-type construction illustrated in

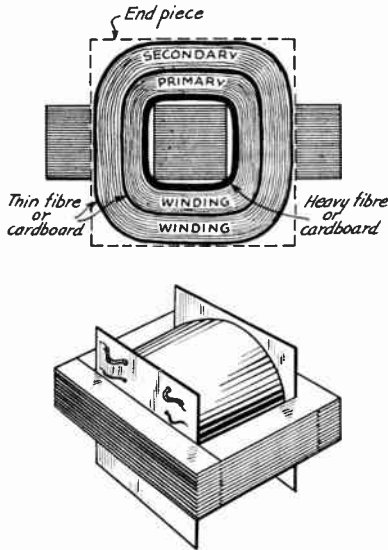


FIG. 1014 — A CONVENIENT METHOD OF ASSEMBLING THE WINDINGS ON A SHELL TYPE CORE

Windings can be similarly mounted on core-type cores, in which case the coils are placed on one of the sides. High-voltage core-type transformers sometimes are made with the primary on one core leg and the secondary on the opposite.

Fig. 1015. The core may be built of straight pieces, as shown, or from L-shaped laminations of the type shown in Fig. 1013.

The table gives specifications for chokes that will meet most needs of the amateur in filter systems. Chokes of inductances between the values given in the table can be made by using less turns of wire in the winding. Inductance varies about as the square of the number of turns so that using half the number of turns specified gives one-fourth the inductance. More turns than those specified must not be used as the core will become saturated. Dimensions b and c given in the table can be understood by reference to Fig. 1015. The arrangement of core and winding should be that of the diagram, also.

The best core material is the same as that specified for building transformers—silicon steel. The laminations should be .014" (or less) thick, covered with shellac or rust to reduce eddy-current losses. An air-gap is needed not only to prevent saturation of the core but also to offer a means for adjustment of the inductance. After the gap is adjusted the core should be clamped firmly so that the magnetic pull will not change

the adjustment and to insure quiet operation. Besides clamping the core, a substantial brass "air" gap can be used or a wooden or cloth wedge inserted in the gap to prevent vibration and make the adjustment permanent. The total air-gap, if there is more than one, will of course be the sum of the length of the separate air-gaps.

Wire with thin insulation should be used to make an economical design. Large wire uses a great deal of space without giving much inductance. It is best to wind directly on the core with just a single layer of tape between. More insulation will be required for chokes that are to be placed in high-voltage plate-supply lines but this should not be any thicker than is necessary. Before starting the winding on the core, put some cotton strips along it and fasten some heavy cardboard or thin micarta end flanges in place. After winding the coil, the tape can be tied over it to keep the wire from spreading. Too much tape should not be put on or the choke will not keep cool under load conditions. The wire sizes in the table are conservative; 10% more current can be carried continuously and even more than this intermittently.

The simplest way to adjust the air-gap is to connect the filter to the load with which it is to work, changing the gap until the best filter action is observed when listening to the output of the transmitter in the monitor. A too-large air-gap will reduce the inductance and the choke will be ineffective. A too-small gap will cause the core to become saturated, and the choke will be just as ineffective. The right value for the air-gap is one that uses up about nine-tenths of the ampere-turns of the coil to maintain flux in the gap. The rest of the magnetomotive force magnetizes the

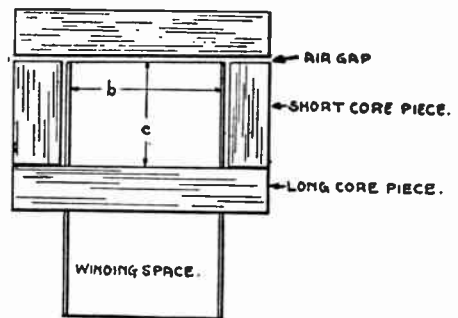


FIG. 1015 — CORE ARRANGEMENT FOR FILTER CHOKE COILS

The dimensions b and c refer to the full-page table.

core. As the permeability of air is unity and that for sheet steel is about 3,000 (average), the ratio of air to iron can be determined approximately, but the iron varies so much that the exact value must always be decided by trial. For a core of 10" total length, an air-gap of about .05" or a little less will meet average requirements.

KEYING AND INTERFERENCE ELIMINATION

TO UTILIZE the transmitter for telegraphic communication, it is necessary to break up its output into long and short pieces which, at the receiving end, will constitute the desired dots and dashes. There are many simple ways of so breaking up the output of the transmitter, but careful adjustment both of the transmitter and of the keying system usually is necessary to avoid interfering with broadcast reception.

Methods of Keying

▲ Keying can be accomplished by an arrangement which reduces the output of the transmitter to zero when the key is "open" and permits full output when the key is "closed." Perhaps the most obvious way of doing this is to put the key in series with one of the plate-supply leads to the tube, as shown in Fig. 1101-A. When the key is open the plate power is completely cut off so that there is no output. The keying method shown at (B) is known as "center-tap" keying, because the key is connected between the filament center-tap (which may be the midpoint of a resistor or a center-tap on the filament transformer) and the point where the negative side of the power supply and the grid return circuit are connected together. This system differs from (A) because in addition to breaking the plate supply from the tube, the key also breaks the d.c. return circuit from the grid and thus also prevents the flow of grid current.

In (C) the key breaks only the d.c. grid return circuit, leaving the plate supply connected to the tube at all times. It operates by virtue of the fact that in oscillators or r.f. power amplifiers a break in the d.c. path between grid and filament will cause electrons to accumulate on the grid, giving it a negative charge which prevents the flow of plate current. Since the negative voltage which the grid must assume in order to prevent plate-current flow depends upon the tube's amplification factor (μ), this method of keying is more successful with tubes having high μ 's, because a smaller "blocking" voltage is required than with low- μ tubes. Good insulation in the key is also a requisite, since poor insulation may permit some of the charge to leak off and thus reduce the negative grid voltage to a value which allows plate current to flow with the key open. This causes some energy to be radiated during spaces in the keying; such radiation is termed a "back-wave."

Other grid-blocking keying systems, in which the negative voltage applied to the grid during keying spaces comes not from natural accumula-

tion of electrons but from a bias source having a definite voltage, are shown in Figs. 1101-D and 1101-E. In the former, the grid-blocking voltage is supplied by a battery or "B" eliminator. When the key is open the full blocking voltage is applied to the grid through the resistor R ; when the key is closed the blocking voltage is short-circuited, so far as the grid of the tube is concerned. Resistor R is in the circuit simply to prevent actual short-circuiting of the blocking-voltage source. It should be of such value as to limit the current flow to a few milliamperes when the key is closed — roughly 5,000 ohms for each 50 volts of bias. The extra bias or blocking voltage required in this keying method will depend upon the type of tube, the plate voltage, and the excitation. In normal oscillator or amplifier stages a first approximation would be a blocking voltage equal to the plate voltage divided by $\frac{1}{3}$ the amplification factor, or μ , of the tube. The actual value of bias required may be somewhat greater or less, and had best be determined by experiment.

The system shown at (E) is similar to that at (D), but in this method the blocking bias is obtained from the plate supply through a voltage divider. The center-tap of the filament is connected to the junction of R_1 and R_2 , and the grid return to the negative side of the power supply, so that when the key is open the voltage drop across R_2 is applied as bias to the grid of the tube. With the key closed, R_2 is short-circuited. R_1 may be the regular power-supply bleeder. R_2 should have about half the resistance of R_1 in practically all cases.

In all of these diagrams the center-tapped resistor across the filament supply may be omitted if the filament transformer winding is center-tapped. Simply connect the center-tap of the winding to the wire which in these diagrams goes to the midpoint of the resistor. If a storage battery is used to light the transmitting-tube filament, the center-tapped resistor may be omitted and the connection which goes to its midpoint should be connected to the negative terminal of the filament. The by-pass condensers across the filament will not be necessary.

Although the foregoing keying methods or adaptations of them are almost universally used by amateurs, other arrangements occasionally are encountered. Often these operate in such a way as to detune an r.f. circuit when the key is open, thus reducing the output, or to break a radio-frequency lead. Such arrangements have not become generally popular, however.

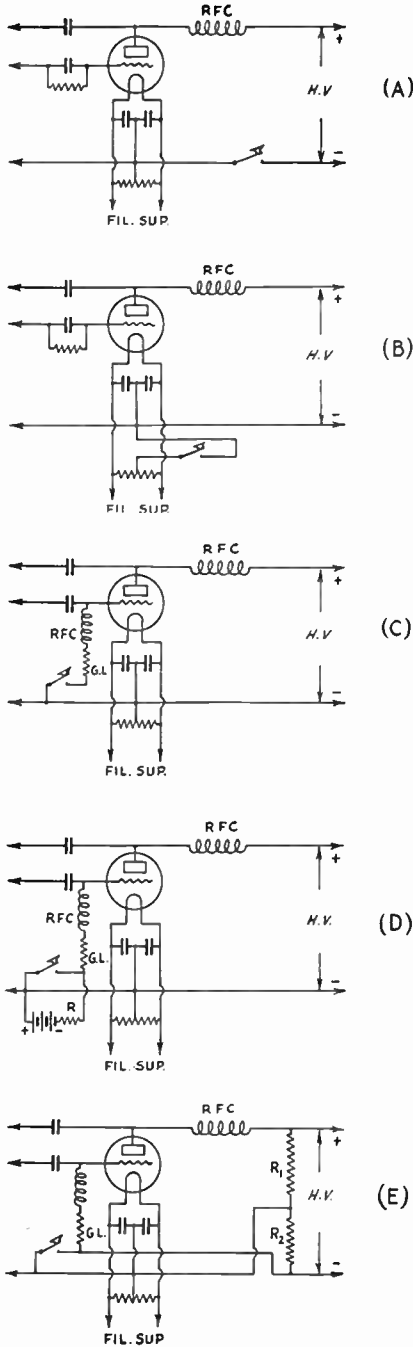


FIG. 1101 — FIVE METHODS OF KEYING AN OSCILLATOR OR AMPLIFIER

(A) Plate keying; (B) Center-tap keying; (C) Grid-leak keying; (D) Blocked-grid keying with additional bias supplied by batteries; (E) Blocked-grid keying with additional bias supplied by voltage divider in plate supply.

Choice of Keying Systems

▲ Although any of the circuits shown in Fig. 1101 may be used with any type of oscillator or amplifier, the systems shown at B, C, and E are perhaps the most used. Center-tap keying is positive — that is, completely prevents output during keying spaces — but is more likely to cause key clicks (see following section) than either of the grid-blocking systems. Keying a high voltage lead as at A is worst of all from the key-click standpoint. The method at D is good, but requires an extra source of voltage for the blocking bias.

With oscillator-type transmitters, either self- or crystal-controlled, the circuit chosen should be one which gives clean keying with least tendency toward key clicks. An actual trial of a few of the circuits will soon give the desired information. In multi-stage transmitters, the operator has the additional choice of applying the keying system to one or more stages. Many amateurs prefer to let the oscillator in an oscillator-amplifier set run continuously, keying one or more of the following amplifier stages. Or an intermediate stage may be keyed, in which case the output stages, although operative, do not receive excitation during the keying spaces and hence give no power output. Also, the oscillator itself may be keyed, an arrangement which is practically a necessity if break-in operation is to be used at the station.

In general, it is advisable to key in a low-power stage preceding the higher-power amplifiers. When this is done key clicks are less bothersome and there is less of a possibility that a back-wave will be emitted. It should be noted, however, that the amplifier tubes following the keyed stage should be provided with sufficient negative bias from a fixed voltage source to cut off plate current when there is no excitation, otherwise the amplifier tubes are likely to be damaged.

A separate filament transformer or winding for the keyed tube is necessary with center-tap keying, B, and the blocked-grid arrangement at E, when a single stage is to be keyed.

Keying Multi-Element Tubes

▲ Although Fig. 1101 shows only three-element tubes, the same keying methods may be applied to tetrodes and pentodes. It will be noticed that all of the methods work on one of three parts of the circuit: a high-voltage lead, the filament center-tap, or the d.c. grid return lead. These are common to all tubes, regardless of the number of elements. A few special features of keying tetrodes and pentodes are worth mentioning, however.

In the grid-block keying system at D in Fig. 1101, the rule for roughly calculating the blocking voltage required does not hold for tetrodes and pentodes, because the plate current is a function of the screen-grid voltage as well as the negative control-grid voltage. With these tubes the block-

ing voltage required will be almost as great as the positive voltage applied to the screen. When sufficient blocking voltage is supplied, however, the tubes will key as well as triodes. Good insulation in the key and wiring is particularly important in circuit C with tetrodes, because such tubes tend to act as low- μ triodes so far as plate-current cut-off is concerned.

Tetrodes and pentodes sometimes are keyed by breaking the positive lead to the screen grid, although this method does not always give clean keying but permits some back-wave to get through. Pentodes having separate suppressor-grid connections can be keyed by applying sufficient negative bias to the suppressor grid to cut off the plate current. The value of bias needed will depend upon the type of tube. Between 100 and 200 volts is sufficient with tubes such as the 59 and RK-20.

Tubes having indirectly-heated cathodes (many of the receiving types popular for low-power transmitters are so constructed) can be keyed by breaking the cathode lead. This corresponds to center-tap keying with filament-type tubes.

Key Clicks

▲ For intelligible code transmission a keying system which breaks the transmitter output into dots and dashes is all that is required. The rapid starting and stopping of power output, however, produces transient oscillations of very short duration which do not have a well-defined period but which spread over a good deal of the frequency spectrum and often cause interference in nearby receivers tuned to a frequency widely different from that of the transmitter. Interference of this sort manifests itself in the form of clicks or thumps in the output of the affected receiver. It is usually noticeable only in the immediate vicinity of the transmitter, seldom travelling more than a few hundred yards except on frequencies within a few kilocycles of the transmitter frequency. Such interference is particularly annoying to owners of nearby broadcast receivers.

To prevent key clicks it is necessary to prevent the radiation of transient oscillations caused by keying. The oscillations may be roughly divided into two types: those arising as the result of shock excitation of the transmitting circuits through the sudden application of power, and transients generated independently of the radio-frequency circuits, usually associated with the key wiring and power supply. The former are for the most part radiated from the antenna, the latter often from keying and power supply leads, sometimes, in fact, being carried over the ordinary electric wiring.

The first type of transient can be prevented by slowing up the rate at which power is applied to the transmitter. Provided the "slowing-up" is not too pronounced, the keying will be unaffected while the transient is eliminated. The

slowing-up may be done at an audio-frequency or low-radio-frequency rate by introducing inductance in series with the key, as shown in Fig. 1102-A. The inductance may be anything from a large r.f. choke (about 10 millihenrys) to an iron-cored choke of a few henrys inductance. Experiment usually is necessary to determine the size of inductance best fitted to eliminate clicks in a

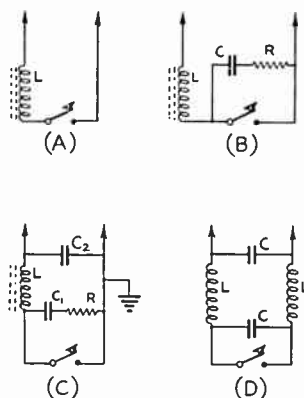


FIG. 1102 — VARIOUS TYPES OF FILTERS FOR THE PREVENTION OF KEY CLICKS

Their operation is explained in the text.

particular transmitter. It should be large enough to prevent clicks, but should not be so large that the crispness of keying is spoiled. Small transformers, such as those used for bell-ringing, often will work nicely with transmitters using power inputs of the order of 50 watts or so.

The simple circuit of Fig. 1102-A usually is not enough in itself to prevent clicks, however. Introduction of inductance in series with the key is likely to cause sparking at the key contacts, a prolific source of the second type of keying transient. It then becomes necessary to absorb the energy released by the inductance when the key is opened, the condenser C and resistor R being provided for this purpose. R usually is variable for ease in adjustment. With an inductance of a few henrys at L , C usually will be between .25 and 1 μfd , and R a variable resistor having a maximum resistance of 50 to 100 ohms.

Oscillations arising in the key circuit — the type that travels over the power wiring — may be further reduced by connecting a second condenser as shown at C_2 in Fig. 1102-C, in which L , C_1 and R have values corresponding to those in B. C_2 may be 0.1 μfd . or less. The side of the circuit which goes to a grounded or low-potential part of the transmitter (usually the negative high-voltage terminal) is indicated by the ground symbol. Another circuit which often proves effective is the balanced arrangement shown at Fig. 1102-D, in which the inductances are large r.f. chokes and the condensers about 0.1 μfd . each.

These circuits are usually most effective when

installed right at the key, with very short leads in all parts. Their purpose is to damp out the transients generated at the key contacts so that the oscillations do not get into the keying line. If long leads are used to connect the key to the click filter, the oscillations, which still exist in this part of the circuit, can be radiated from the connecting wires.

Further Click-Prevention Methods

▲ To prevent keying transients from being carried over house wiring and power lines from the transmitter to nearby receivers, a filter may be installed in the 110-volt line which feeds the power transformers. Such a filter is shown in Fig. 1103. It consists of a pair of radio-frequency choke coils, one in each leg of the line, and a pair of condensers in series across the line with their mid-connection grounded.

The wire of which the chokes are wound must be heavy enough to carry the current taken by

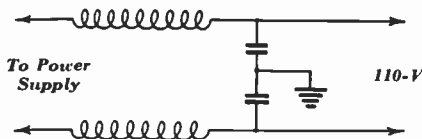


FIG. 1103 — R.F. FILTER FOR THE POWER LINE

the power-supply system. No. 14 or No. 16 will be sufficient in most cases. Mailing tubes make good winding forms for these chokes. Between 100 and 300 turns will be required. The condensers may be 0.1- μ fd. units rated at 200 volts or more.

Power transformers with electrostatic shields between the primary and secondary windings are helpful in preventing interference from being carried by the supply lines, provided the shield is connected to a good ground, and often will make extra chokes and condensers unnecessary.

It is always desirable and in some cases may be necessary to run the 110-volt leads to the transmitter in BX cable, grounding the outer shield. Shielding of the keying leads also may be helpful, especially if a long line is run between the transmitter and the key. Whenever shielded wire is used the shield should be connected to a good ground, otherwise the shielding is likely to be ineffective.

Clicks are likely to be much more serious if the plate supply has poor regulation — characteristic of all plate supplies with condenser-input filters. With no load on the plate-supply apparatus the condensers of the filter system become charged to the peak voltage of the transformer; then, when the keying circuit is closed the abnormal plate voltage causes a transient of greater magnitude than would be expected from the voltage under load conditions. A plate supply with good regulation such as a choke-input filter of the type

described in Chapter Ten will minimize this effect.

A popular keying method using vacuum tubes instead of the inductance-capacity filters of Fig. 1102 is shown in Fig. 1104. In this system a vacuum tube is placed with its plate-filament circuit in the center-tap of the tube to be keyed, while the key itself is in the grid circuit of the auxiliary or "keyer" tube. When the key is open, high negative bias is placed on the grid of the keyer tube so that the plate current is completely cut off; when the key is closed the grid of the keyer tube is connected to its filament and the tube acts like a resistance of low value, thus permitting plate current to flow to the oscillator or amplifier being keyed. The time-constant of the inductance and capacity in the grid circuit of the keyer tube provides the slow build-up of power output which prevents clicks. Since the key is in a low-voltage low-current circuit, the transients set up in the key circuit itself are of small intensity. The keyer tube has some resistance even though the grid is connected to the filament, so the plate voltage on the oscillator or amplifier will be lower than with other keying systems. To overcome this several tubes may be connected in parallel. Tubes of the 45 type are excellent for low-power transmitters because their plate resistance is low. One 45 should be used for each 50 ma. of plate current required by the tube being keyed. The filament transformer for the keyer tubes need not be center-tapped; in fact, the filaments may be connected in series if desired.

Other Types of Interference

▲ Besides key clicks, a transmitter may cause interference of a different character to nearby

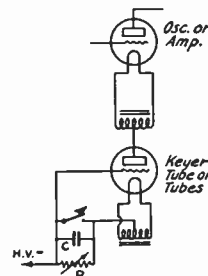


FIG. 1104 — A VACUUM-TUBE KEYING METHOD TO PREVENT CLICKS

One or more keyer tubes may be used; the larger the number the greater the plate current that can be safely passed. Condenser C may be between .25 and 1.0 μ fd. Resistor R should be adjusted to cause the plate current to drop to zero when the key is open. A variable resistor of about 50,000 ohms should give enough range.

broadcast receivers, especially those whose antennas are in the immediate vicinity of the transmitting antenna. This second type of interference is called "blanketing," because it causes the program to disappear or come in at reduced strength whenever the key is closed. It is simply a proximity effect, the affected receiver picking up enough of the radiated energy to cause overloading of one or more of the receiver tubes with a consequent reduction in amplification. This type of interference can be minimized by moving the broadcast antenna away from the transmitting antenna or by changing its direc-

tion. The pick-up will be least if the two antennas are at right angles to each other.

In severe cases it may be necessary to install a wave-trap at the receiver to prevent blanketing. A wave-trap consists simply of a coil and condenser connected as shown in Fig. 1105. The condenser may be an old one with about 250 or 350 $\mu\text{fd.}$ maximum capacity and need not be especially efficient. Most amateurs have "junk boxes" with several such condensers in them. The size of the coil will depend upon the frequency on which the transmitter is working. Representative values are given in the table.

Frequency of Interfering Signal	Coil (3" dia.)
1,715-2,000 kc.	20 turns
3,500-4,000 kc.	8-10 "
7,000-7,300 kc.	4-5 "
14,000-14,400 kc.	3 "

Bell wire (No. 18) or a size near to it may be used. When the trap is installed the transmitter should be started up and the condenser in the trap adjusted to the point where the interference is eliminated. This trap will not affect the operation of the broadcast receiver.

Blanketing may be and generally is accompanied by key clicks. The wave trap may help to eliminate the clicks but usually a key click filter will be needed as well. A key click filter alone cannot eliminate or even alleviate the blanketing effect.

The third type of interference is peculiar to superheterodyne broadcast receivers. A strong signal from the transmitter will be heard at three or four points on the dial, while over the rest of the tuning range there may be no sign of interference. The explanation lies in the fact that the transmitted signal is picked up by beating with harmonics of the superheterodyne oscillator and amplified by the i.f. stages in the receiver. If the receiver is properly shielded and the oscillator is isolated from the antenna circuit, the signal from the transmitter cannot get into the oscillator circuit to be mixed with its harmonics and this type of interference cannot occur. When it *does* occur the fault does not lie with the transmitter but with the broadcast receiver, and nothing can be done to the transmitter to prevent such interference. A wave-trap may help if the transmitter signal is brought into the receiver through the antenna, but in some cases the pick-up is direct because the receiver is inadequately shielded, and the interference is just as strong whether the antenna is connected to the receiver or not.

Rectifier Noise

▲ Mercury-vapor rectifiers often are the source of a peculiar and easily identifiable type of interference which takes the form of a raspy buzz with a characteristic 120-cycle tone (100 cycles on 50-cycle power lines and 50 cycles on 25-cycle lines)

often broadly tunable in spots on the broadcast receiver dial. At the instant the mercury vapor ignites on each half cycle of the power frequency an oscillation is set up, the frequency depending upon the characteristics of the power supply apparatus. Unless suitable precautions are taken the oscillations will be radiated or will travel back

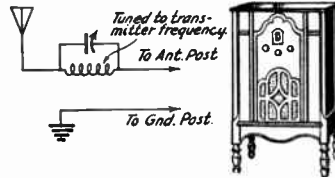


FIG. 1105 — HOW A WAVE-TRAP CAN BE INSTALLED TO PREVENT CERTAIN TYPES OF INTERFERENCE

over the power line and be detected in receivers connected to the line.

The line filter shown in Fig. 1103 usually will suppress this type of noise. Sometimes the condensers alone will do it, no chokes being necessary. Transformers with electrostatic shields between primary and secondary are not likely to transmit the oscillations to the line. Other ways of curing this type of interference are shown in Fig. 1106. They include shielding of the rectifier tubes, connecting a radio-frequency choke between each plate and the transformer winding, and shunting fixed condensers of about .002- $\mu\text{fd.}$ capacity between the outside ends of the transformer winding and the center-tap. The condensers should be rated to stand at least 50% more voltage than the r.m.s. voltage delivered by half of the secondary winding.

Checking for Interference With Broadcasting

▲ One's own broadcast receiver, if of modern design, is a good "subject" for experimenting with key click filters and other interference-prevention methods. If interference can be eliminated in a receiver in the same house, operating from the same power line and with an antenna close to the

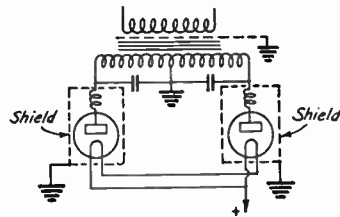


FIG. 1106 — DEVICES FOR ELIMINATING NOISE FROM MERCURY-VAPOR RECTIFIER TUBES

The r.f. chokes in series with each plate should be placed inside the shields enclosing the rectifiers. The chokes should have an inductance of about 10 millihenrys each. Small honeycomb-type windings are suitable.

transmitting antenna, the chances are good that there will be no general interference in the neighborhood. The amateur should ascertain, however, whether or not interference is caused in nearby broadcast receivers. If your neighbors appreciate that you are as much interested in preventing interference to their enjoyment of broadcast programs as they are, much more can be accomplished than by acrimonious disputes. It is better to settle the interference problem right at the beginning than to trust to luck with the possibility of an unfavorable reaction towards amateur radio in general and yourself in particular on the part of nearby broadcast listeners.

In searching for causes of interference, it is a good idea to have someone operate your transmitter while you listen on the affected receiver. Remove the antenna from the receiver, and if the interference disappears it is certain that it is coming into the set through the antenna, which simplifies the problem. The various types of interference prevention already described should work under these conditions. If the interference persists when the antenna is removed, however, it is probably getting into the receiver through the power lines. This happens occasionally with a.c. operated broadcast receivers.

House wiring may pick up r.f. either directly from the antenna or through the power-supply system of the transmitter. If the 110-volt line is found to be picking up energy directly from the antenna it is advisable to change the location of the antenna, if possible, or run it in a different direction, not only because of interference to broadcast reception but because energy so picked up is useless for radiation and decreases the effective range of the transmitter. This is particularly important when, as often happens, electric lamps in different parts of the house are found to glow when the key is pressed. The energy used in lighting the lamps is wasted.

If r.f. is found to be getting into the line through the power-supply equipment, a line filter such as is shown in Fig. 1103 should be used, together with power leads in grounded BX.

Interference usually decreases as the transmitter frequency is raised. In many cases where bad interference is caused on the 1750- and 3500-ke. bands, changing to 7000 or 14,000 ke. will cure it. If none of the usual methods is wholly effective a reduction in power often will allow the station to be worked during the evening hours without bothering the neighbors.

Radiophone Interference

▲ Key-click filters are naturally of no value on transmitters used exclusively for 'phone transmission, since clicks do not occur. A phenomenon similar to key clicks can take place if the transmitter suffers from frequency modulation or from

over-modulation because both these defects cause the radiation of side-bands often far removed from the band of frequencies normally required for the transmission of speech. These abnormal side-bands can and frequently do cause interference in the broadcast band, often just as a series of unintelligible noises when the transmitter is modulated. The obvious remedy is to use a radio frequency system in the transmitter whose frequency does not vary when modulation is taking place, and to adjust the transmitter so that over-modulation or "lop-sided" modulation does not occur. Chapter Eight covers this subject thoroughly.

Blanketing and other forms of interference caused by r.f. pickup can be treated in exactly the same way as described previously. Wave-traps in the receiving antenna lead-in and r.f. filters in the power lines will prove effective in eliminating this type of interference.

Quiet Hours

▲ In most cases interference can be prevented by the use of key-click filters or some of the other simple devices described. If the amateur is unable to solve the problem, quiet hours must be observed from 8:00 p.m. to 10:30 p.m. (local time) and on Sunday mornings between 10:30 a.m. and 1:00 p.m. upon the frequencies which cause such interference. The regulations state that the station must "cause general interference with broadcast reception on receiving apparatus of modern design" before quiet hours are obligatory. In effect, if a good many receivers are in the vicinity and only one or two of them experience interference, the inference is that the broadcast receiver is at fault, and not the transmitter. Likewise interference with a non-selective broadcast receiver is not sufficient cause for compulsory observance of quiet hours. The amateur should cooperate with such listeners to the fullest possible extent, however, and his aim should be to eliminate interference at *all* hours of the day with reasonably good broadcast receivers.

Keying Chirps

▲ Since most key thump filters in effect vary the voltage applied to the tube from zero to full voltage rather slowly, an unstable transmitter will exhibit a considerable change in frequency in the fraction of a second during which the voltage is increasing. This rapid change in frequency gives the signal of "yooping" sound or chirp which makes it annoying to listen to and difficult to copy. Self-controlled oscillators are especially subject to keying chirps unless carefully adjusted. High-C circuits such as those described in Chapter Seven are beneficial. Chirps are rarely present in well-designed oscillator-amplifier and crystal-controlled transmitters.

ANTENNA SYSTEMS

ONE can have an excellent array of apparatus and still not realize to the full its possibilities in reaching out to contact other amateurs at far corners of the earth if the final connecting link — the antenna system — is ineffective. It is the antenna, not the transmitter, which has to do the job of getting radio-frequency energy out into space with the least possible loss and in such a way that it will be most usefully employed.

Unfortunately very few amateurs have the space or facilities for the construction of an "ideal" antenna system. Nevertheless if a few general principles of antenna design are understood and applied, much more can be accomplished than by the haphazard stringing of wires here and there about the landscape. There is plenty of latitude in antenna-system design for adapting the antenna to existing local conditions; no one antenna system is "best" any more than one specific transmitter layout is better than all others. The measure of the goodness of an antenna system is its ability to radiate effectively the power supplied to it by the transmitter; if it does this well its type is unimportant.

Types of Antennas

▲ Notwithstanding the great variety of antenna systems to be seen in operation, the antennas themselves are of but two distinct types. Those in which the ground is an essential part are known as Marconi antennas. The second type is the Hertz antenna, which operates independently of the ground. In its purest form the Hertz antenna consists of a single wire suspended sufficiently high above the earth or earthed objects to have an inconsequential capacity to ground. The Hertz antenna is now used almost to the exclusion of all other types for short-wave transmission.

The fundamental principles on which antennas operate have already been discussed in Chapter Four. A complete understanding of these principles is, of course, of great value to the amateur interested in planning his own antenna system and in getting the best possible performance from it.

Contrary to usual practice throughout this *Handbook*, in this chapter we shall find it more convenient to speak in terms of wavelength than in terms of frequency. At the same time, however, the relationship between frequency and wavelength should be kept in mind continually. This becomes readily possible after a little practice.

The Grounded Antenna

▲ Fundamental forms of grounded or Marconi-type antennas are shown in Fig. 1201. They are of interest because many amateurs find it necessary to use the grounded antenna for 1715-ke. work on account of limited space. The grounded antenna can be a straight vertical wire or, as usually is the case, can be bent into the shape of an inverted L. The counterpoise in the right-

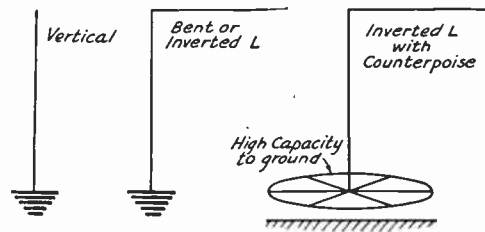


FIG. 1201 — THREE TYPES OF GROUNDED — ANTENNAS

The bent form, with or without counterpoise, is most generally used.

hand drawing of Fig. 1201 consists of several wires, all joined together and strung over a fairly large area a few feet above and parallel to the surface of the ground. This type of construction is adopted so that the counterpoise will act as one plate of a high-capacity condenser of which the ground itself is the other plate. The counterpoise is a useful substitute for a direct ground connection when such a connection cannot be made to naturally-moist soil. Dry soil usually results in a ground connection of rather high resistance, which causes a loss of power.

If a grounded antenna is to be used for transmitting, the ground should preferably be one with conductors buried deep enough to reach natural moisture. In urban locations, good grounds can be made to water mains where they enter the house; the pipe should be scraped clean and a low-resistance connection made with a tightly-fastened ground clamp. If no water-pipes are available several pipes, six to eight feet long, may be driven into the ground at intervals of six or eight feet, all being connected together. The use of a counterpoise will obviate the necessity for a buried ground and probably will give better results than the direct ground connection if made large enough. The length of the counterpoise wires bears no particular relation to the length of the antenna, except that the wires in the

counterpoise should be at least as long as the antenna itself. The shape of the counterpoise is not of great moment; it may be made in the form of a circle as in Fig. 1201 or may be square, rectangular, etc.

The natural wavelength of a bent grounded antenna is approximately 4.2 times its actual length. It is not necessary to make a highly-accurate calculation when figuring the length of a grounded antenna because the tuning apparatus inserted at the base will compensate for discrepancies between the natural wavelength and the transmitter wavelength or frequency. For example, an antenna for 1900 kc. (158 meters wavelength) should be $158/4.2$ or 37.6 meters long, corresponding to a length of 124 feet. This length, it should be noted, is the *total* length from the open end of the antenna to the ground connection or counterpoise.

Hertz Antennas

▲ The Hertz antenna in three forms is shown in Fig. 1202. It is a single-wire antenna the natural wavelength of which depends primarily upon its length and secondarily upon such factors as may operate to change the distributed constants of the wire from those it would have in free space. The natural wavelength of a free wire is twice the actual length of the wire, since the wire will be resonant when it is one-half wavelength long. Practically, the natural wavelength of the wire will be somewhat greater than its actual physical length, partly because electromagnetic waves do not travel quite as fast on wires as they do in space, and partly because the antenna is not an isolated wire but is in proximity to other objects, including the antenna poles, guy wires and insulators, all of which increase the distributed capacity and thereby increase the wavelength of the antenna. Because of the varying nature of these extraneous effects, the natural period of a given length of wire will differ with different surroundings. If the antenna is reasonably clear of other objects and is well off the ground, its natural wavelength will be between 2.07 and 2.1 times its actual length. In calculating the antenna length required for a given wavelength or frequency, the fact that local conditions will have some influence on the natural wavelength must be kept in mind.

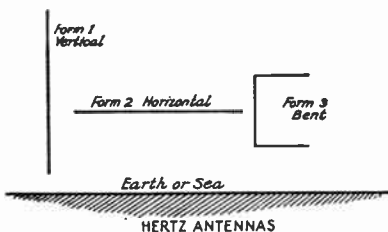


FIG. 1202 — THREE FORMS OF HERTZ ANTENNAS

In figuring antenna length it is convenient to be able to work directly from feet to wavelength in meters, or from feet to natural frequency in kilocycles. The following formulas will give direct results without the necessity for conversion from feet to meters and from meters to kilocycles:

Length in feet = $1.56 \times$ desired natural wavelength in meters; or

Length in meters = $0.475 \times$ desired natural wavelength in meters.

In terms of frequency:

Length (feet) = $\frac{468,000}{\text{Freq. (kc.)}} = \frac{468}{\text{Freq. (mc.)}}$; or

Length (meters) = $\frac{142,500}{\text{Freq. (kc.)}} = \frac{142.5}{\text{Freq. (mc.)}}$.

These formulas are based on a 2.1/1 ratio of natural wavelength to actual length. Expressed

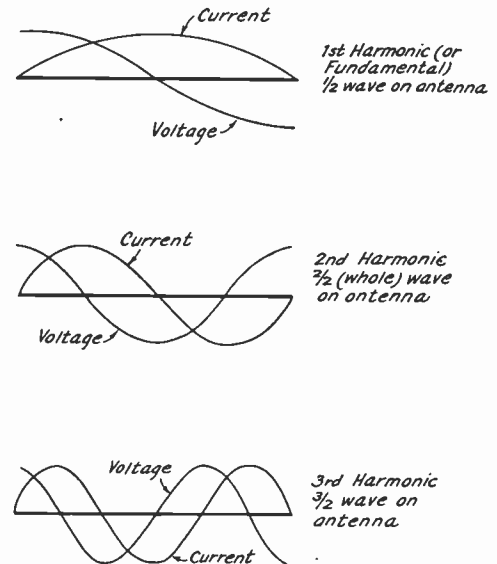


FIG. 1203 — VOLTAGE AND CURRENT DISTRIBUTION OF ANTENNAS OPERATING AT HARMONICS

another way, the actual length is approximately 95% of one-half the natural wavelength. The length should be measured off accurately, of course, preferably with a good steel tape, yard stick or meter rule. Cloth measuring tapes are unreliable.

A Hertz antenna is not necessarily cut to a length equal to half the desired operating wavelength. As already stated, the antenna length can be a half wavelength multiplied by any whole number. If more than one half wave exists on the antenna, the antenna is said to be operating on a harmonic. The number of the harmonic will be the same as the number of half waves on the antenna. The current and voltage distribution on

Hertz antennas working on the fundamental, second and third harmonics (one, two and three half waves, respectively) are shown in Fig. 1203. The antenna must *always* be cut for a definite number of half waves; there can be no odd quarter or eighth waves left over. It is often convenient and desirable to operate an antenna on harmonics; since the amateur bands are in even-harmonic relationship an antenna can be designed for a low-frequency band (where its length is greatest) and operated on the second, fourth, or even eighth and sixteenth harmonics when the transmitter is to work on a higher-frequency band.

Directional Properties of Simple Antennas

▲ The theoretical directivity of the simple antenna is of little importance because no practical amateur antenna ever works even approximately under the same conditions as the theoretical antenna far removed from the earth. The radiation characteristics of an antenna invariably are distorted by the objects surrounding it, particularly by reflection from the ground, guy wires, from nearby power or telephone lines, buildings, etc.

It is useful to know, however, the effect of the antenna in producing directivity in the vertical plane — i.e., the angle with the horizon at which the radiation is concentrated, because the angle of radiation is intimately concerned with the effectiveness of the antenna for long-distance transmission. In the discussion on the transmission of radio waves through space at the end of Chapter Four mention was made of the Heaviside layer and the effect of the angle at which radio waves strike the layer. At the very high frequencies it is necessary for the waves to strike the layer at a low angle (nearly horizontal) to be returned to earth. It is therefore desirable for the antenna to be one that will radiate most of the energy at an angle not far from the horizontal — commonly called low-angle radiation.

Vertical antennas are very effective low-angle radiators, since most of the radiation is concentrated in the plane at right-angles to the line of the antenna. Vertical antennas are rather difficult to build, however, because of the height required. The lower end of the antenna should be well removed from ground, so that few amateurs find it practical to build vertical antennas for frequencies below 14 mc.

The vertical-plane radiation characteristic of a horizontal antenna will depend upon its height above the ground. The radiation from a horizontal half-wave antenna at a height of $\frac{1}{4}$ wave above ground will in the absence of local reflections be concentrated vertically, with practically no radiation at the low angles. As the height is increased, the antenna becomes a better radiator at the lower angles. It is quite a good low-angle radiator at a height equal to one-half wavelength and there is little use in increasing the height

beyond one wavelength. It is advantageous to have the horizontal Hertz antenna at least 50 or 60 feet above the ground; most amateurs can get their antennas up to this height with relatively little expense or difficulty. The antenna can be built for the 3500-kc. band and worked on harmonics on 7000 and 14,000 kc.; the harmonic operation on the higher frequencies probably will help lower the angle of radiation and increase the effectiveness of the antenna. As a matter of fact, just this sort of antenna is used by many of the amateur stations who most consistently put signals into odd corners of the world.

If this discussion should seem discouraging to the amateur who has neither the space nor facilities for constructing such an antenna, it must be remembered that these suggestions are not to be taken as hard-and-fast rules. Because of local topography the antenna is always the unknown quantity in the amateur station; it is almost impossible to predict how it will behave when actually installed. Fortunately it nearly always performs in better fashion than purely theoretical considerations would indicate.

Feeding the Antenna

▲ Before the antenna can do any radiating it must be supplied with power from the transmitter. This process is commonly termed "feeding" or "exciting" the antenna. Antennas are ordinarily either "current" or "voltage" fed; these

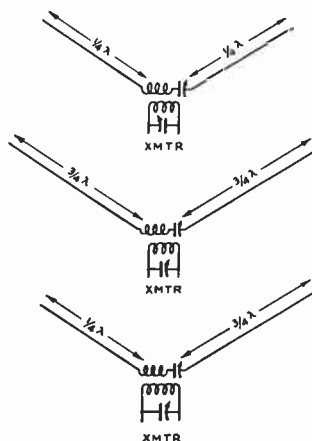


FIG. 1204 — CURRENT-FED HERTZ ANTENNAS

The coupling apparatus, which is series-tuned, should be inserted at a point an odd number of quarter waves from the open ends. There must be an even number of quarter waves on the whole system. Radio-frequency ammeters may be connected in the antenna at the coupling apparatus. With this type of feed the coupling coil usually consists of five or six turns of the same type of winding as the transmitter tank coil; the tuning condenser will have a maximum capacity of 250 to 500 μfd . Two tuning condensers may be used, one on each side of the coil, as suggested for the feeder systems described later in the chapter.

labels simply mean that the power is introduced into the antenna either at a point of maximum current — a current loop — or a point of maximum voltage — a voltage loop or current node.

Current Feed Systems

▲ A number of current-feed arrangements are shown in Fig. 1204. The antenna is split into two parts; its total length always must be a multiple of a half-wave, but the power must be introduced at a point an *odd number of quarter waves* from the open ends. Many other arrangements than those shown are possible so long as this rule is observed. Current-feed systems do not work on even harmonics because of the requirement that the coupling apparatus must be inserted at a point an odd number of quarter waves from the open ends; on the second harmonic, for instance, the antenna length which represents a quarter-wave at the fundamental frequency becomes a half wave, so the coupling coil would have to be moved to bring it back to a current loop. To work such antennas on even harmonics, it is necessary either to add more wire to the system to bring a current loop to the coupling point; to move the coupling apparatus to a current loop; or to change to voltage feed.

The practical dimensions of the systems shown in Fig. 1204 can be found by using the formulas for antenna length previously given, remembering that the length so obtained is a half wavelength and must be divided by two to give a quarter wave. For example, in the third system shown, for operation at 7000 kc. the quarter-wave section would be approximately 33 feet long, while the $\frac{3}{4}$ -wave section would be 99 feet long. The wires should preferably be run in opposite directions outside the station, and should of course be as high and clear as possible, just as with any other antenna.

Voltage Feed Systems

▲ Some of the most practical and popular amateur antenna systems are of the voltage-feed type, which differ from the current-feed types in that the energy is fed to the antenna at one of its voltage loops (current nodes) instead of at a current loop (voltage node) as in the current-feed type. Several forms of voltage feed are shown in Fig. 1205. In the two upper drawings one end of the antenna is brought into the station and attached to a tank circuit which is coupled to the output of the transmitter. The antenna length, which must be one or more half waves, is determined by the general formula previously given. The antenna can be operated at its harmonics as well as at its fundamental frequency. Moreover, this system is readily convertible to operation as a grounded antenna for operation at half the natural frequency (twice the natural wavelength) which it has as a Hertz antenna; this is accomplished by connecting the antenna to

ground through the coupling coil and antenna condenser in series. The two lower drawings in Fig. 1205 illustrate the method used for tuning the first and third systems of Fig. 1204 when they

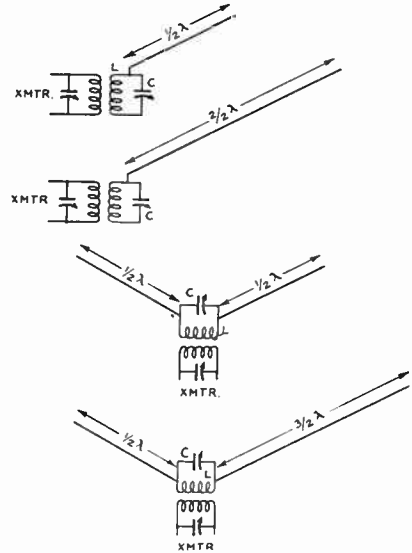


FIG. 1205 — VOLTAGE-FED HERTZ ANTENNAS

The coupling coil and condensers, which must be connected in parallel, are connected to the antenna at a voltage loop; this requires that the coupling be made at a point an even number of quarter waves (any whole number of half waves) from the open ends of the antenna. The coupling coil and condenser, LC, will be tuned to the transmitter frequency if the antenna sections are exactly half waves; if the antenna length is not an exact number of half waves the coupling circuit will be tuned to a higher or lower frequency, depending upon whether the antenna is too long or too short.

are to be operated on the second and fourth harmonics. In such a case each fundamental quarter wave becomes a half wave at the second harmonic and two half waves at the fourth harmonic, bringing voltage loops at the station ends of the wires. This calls for voltage feed, in which a coil and condenser are connected in parallel instead of in series as with the current-feed system.

Fig. 1206 shows one arrangement which a number of amateurs have found useful, since it can be used for operation in all amateur bands. The coil and condenser, LC, must be such that they will tune to the frequency of the transmitter without the antenna connected. Then if the antenna wire or wires have the correct length they may be attached to the circuit LC without affecting its tuning. Best results will be secured when L is very large and C very small for the frequency involved; that is, the antenna coupling or tank circuit should be very low-C. The coupling between the antenna tank circuit and the transmitter also should be loose.

Tuning the system is not difficult, although misleading results are likely to be secured if the right method is not followed. Since the antenna is being fed at a point of high voltage the current will be very low, hence an ammeter inserted in the antenna at the coupling coil will give no indica-

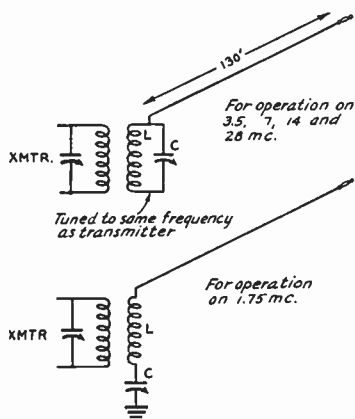


FIG. 1206 — A SIMPLE ANTENNA SYSTEM FOR FIVE AMATEUR BANDS

The antenna is voltage fed on 3.5, 7, 14 and 28 mc., working on the fundamental, second, fourth and eighth harmonics, respectively. For 1.75 mc. the system is a quarter-wave grounded antenna, in which case series tuning must be used. The antenna wire should be kept well in the clear and should be as high as possible.

If the length of the antenna is approximately 260 feet, voltage feed can be used on all five bands.

tion. The tuning procedure should be as follows: With the antenna disconnected from the circuit LC , start the transmitter and tune LC to resonance as indicated by a sharp increase in the transmitting-tube plate current. Now loosen the coupling until the plate current gives only a small kick as LC is tuned through resonance. Next, connect the antenna and retune LC for the plate-current kick; the resonance indication will be broader with the antenna connected, but should still come at the same setting of C if the antenna length is correct. Now increase the coupling in small steps, simultaneously readjusting C and the transmitter tank condenser to resonance each time the coupling is changed, until the transmitter is drawing normal plate current. Always use the loosest coupling that will give normal transmitter plate current with both the transmitter tank and coupling tank adjusted to resonance. A neon bulb touched to the end of the antenna will give, by the brightness of its glow, some indication of the r.f. voltage at the coupling point.

In using the antenna arrangement of Fig. 1206 as a grounded antenna, tuning is simply a question of adjusting the size of L and the setting of C to give resonance with the transmitter frequency. An ammeter may be inserted in the an-

tenna at the point where it is connected to the upper end of L and the tuning adjusted for maximum current, subject of course to those limitations pointed out in Chapter Seven in the discussion on antenna tuning. The ground lead with this antenna system should preferably be short, otherwise it will make the antenna length a great deal more than that of a quarter wave and necessitate a change in the tuning system.

Feeder Systems

▲ The methods of feeding the antenna just described all involve bringing part of the antenna into the station. Because this puts the radiating system in close proximity to the building and wiring, which can absorb energy, and also because it often requires that the height of at least part of the antenna be reduced, most amateurs prefer to put the whole antenna out in the clear and feed it through a radio-frequency transmission line. The transmission line does not radiate, but serves simply as a link between the transmitter and the antenna. The efficiency of lines used by amateurs is quite high when they are adjusted properly; the losses are small even though the line is carried through locations where the losses in a radiating antenna would be high.

R. F. transmission lines are of two general types: those on which standing waves similar to the standing waves on the antenna appear (tuned or resonant lines), and those having uniform current distribution along the line (untuned or aperiodic lines). Because of their greater flexibility and simpler adjusting procedure the tuned lines are in more general use in amateur stations than the untuned lines. For this reason we shall describe them first.

Tuned Transmission Lines

▲ It is not difficult to understand the operation of tuned transmission lines if the preceding discussion of current and voltage distribution on antennas has been followed closely. In fact, a resonant transmission line is simply an antenna that has been folded so that the currents flowing in the two parts are opposite in phase but of the same magnitude. Because of the folding the radiation from one wire cancels that from the other.

Two variations of the tuned transmission line are shown in Fig. 1207. At A is the simple half-wave antenna; it has been folded at the center in B so that it consists of two quarter-wave wires. Folding the wires has made the currents flowing in each oppose each other, resulting in cancellation of the fields about the wires. This is known as a quarter-wave line or feeder. The coupling coil and condenser are inserted at the junction X of the two wires; they will have no effect on the current distribution. Because the power is coupled into the line at a point of maximum current this becomes a case of current feed just

as with the antennas previously discussed, and the coil and condenser are therefore connected in series.

The antenna at C has three half waves on it; in D the two outer half waves have been folded

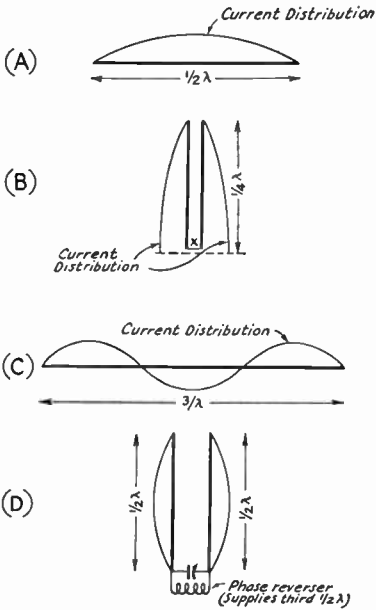


FIG. 1207 — CURRENT DISTRIBUTION ON TUNED FEEDERS

Tuned feeders can be considered simply to be an antenna folded so that the fields about the wires oppose each other, thus cancelling the radiation.

back on themselves and the middle half wave is replaced by a tuned circuit which acts as a phase reverser to bring the currents in the two wires into phase opposition. This circuit, consisting of a coil and condenser in parallel, is tuned to the fundamental wavelength represented by one of the half waves. Since the power is introduced at a point of high voltage (a current node) this is a case of voltage feed to the transmission line.

It is apparent from the figures that open-ended lines an odd number of quarter waves long (length of one wire) will require current feed, in which the coupling coil and condenser are connected in series — called series tuning; lines an even number of quarter waves long require voltage feed, with the coil and condenser connected in parallel — parallel tuning. Series tuning has no effect in the phase of the currents in the wires; parallel tuning reverses the phase in one wire.

In practice the two wires of the tuned transmission line should both have exactly the same length, and they are usually spaced from three to twelve inches apart. The spacing is not critical at most frequencies, since even a foot separation represents but a very small fraction of a wavelength and the cancellation is practically com-

plete. It is preferable to make the length of the line an exact multiple of a quarter wavelength, although this is not strictly necessary because the tuning apparatus can serve the double purpose of coupling in the power from the transmitter and of loading the feeders to compensate for differences between a quarter wavelength and the actual length of the wires.

We have discussed above the means of coupling power into the feed line. This is quite distinct from the method of coupling the line to the antenna, which we shall now take up. The antenna itself may be either current- or voltage-fed, depending upon how the transmission line is connected to it. The voltage-fed system, known as the "Zeppelin" — or simply "Zepp" — because it was first used on Zeppelin airships, is probably the most popular amateur antenna.

The Zepp

▲ In the Zepp antenna one wire of the feeder is attached to one end of a Hertz antenna. Since there is always a voltage loop at the end of the antenna, the antenna is therefore voltage-fed from the transmission line. The antenna itself may be any number of half waves long, the length

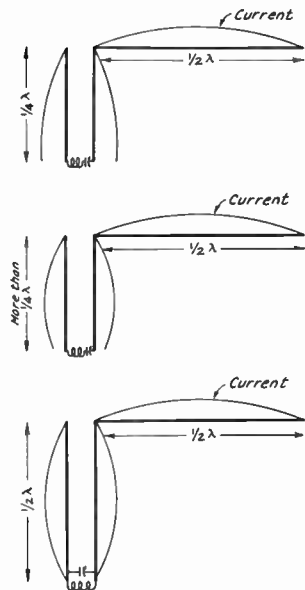


FIG. 1208 — TYPICAL ILLUSTRATIONS OF VOLTAGE FEED WITH TUNED FEEDERS (THE ZEPPEL ANTENNA)

Although usually designed to be a number of quarter waves long, the feeders can be loaded to resonance in just the same way as the simple antenna if their length is not exactly a multiple of a quarter wave. Zepp feeders are ordinarily made approximately an odd multiple of a quarter wavelength long so r.f. ammeters inserted in the feeders at the coupling apparatus will give fairly large readings and thus facilitate adjustment.

of a half wave being computed by the formula previously given. The feeder is usually an odd multiple of a quarter wavelength long, although other lengths may be used. Fig. 1208 shows a half-wave antenna fed by tuned feeders having different lengths, together with the current distribution in each case. Series tuning can be used with feeders having a length between one-quarter and three-eighths of a wavelength; for feeders much less than a quarter wave long, or for lengths from approximately three-eighths up to one-half wavelength, parallel tuning will be required. Some lengths are more easily handled than others; recommended lengths for various frequencies and the tuning method required in each case are given in Table I. Fig. 1209 shows larger-scale diagrams of series and parallel feeder tuning, and also shows how r.f. ammeters may be connected in the feeders to indicate resonance. The use of two ammeters is not actually necessary; a single ammeter may be switched from one feeder to the other during the tuning process. If the antenna length is correct and the two feeder wires have the same length, both ammeters should give the same reading. If the readings differ by more than 10% or so when the antenna system is tuned exactly to resonance with the transmitter, the system is not properly balanced. Care should be taken to see that both feeders have the same length and that the leads inside the station from the coupling apparatus to the antenna itself also must be correct if the feeder currents are to be balanced.

In the series-tuning arrangement it is not necessary to have two tuning condensers, but they are

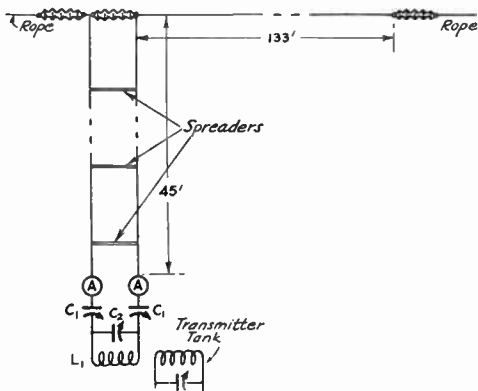


FIG. 1210 — A ZEPPELIN (VOLTAGE FEED) ANTENNA FOR SEVERAL BANDS

The antenna has a fundamental frequency of 3550 kc. but could be of any fundamental frequency between 3500 and 3600 kc. Since the feeders are less than a quarter-wave long for 3500 kc., parallel tuning should be used for this band. Series tuning will be best on the 7000- and 14,000-kc. bands and probably for the 28,000-kc. band. The condensers C_1 and C_2 may be of 250- or 350- $\mu\text{fd.}$ capacity.

often used because with two condensers it is possible to shift the voltage node to a desirable point on the coupling coil, L , and to compensate for the effect of stray capacities at the tuning apparatus. The current distribution at resonance

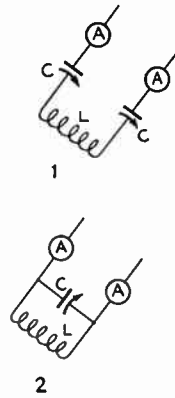


FIG. 1209 — SERIES AND PARALLEL FEEDER TUNING

Series tuning is used when there is a current loop on the feeders at the coupling point; parallel tuning when a voltage loop appears at the coupling point. The feeders are operating properly when the currents indicated by the two ammeters are identical.

will be the same with either one or two condensers provided distributed and stray capacities in the tuning apparatus are negligible. Since stray capacities cannot always be neglected, however, the use of two condensers is often preferable.

The actual value of the feeder current indicated by the antenna ammeter or ammeters is not the true indication of how well the system is operating. If the meters happen to be connected at or near current nodes (voltage loops) they

TABLE I — SOME SUGGESTED ZEPPELIN FEEDER LENGTHS AND RECOMMENDED TUNING METHODS FOR THE VARIOUS AMATEUR BANDS

This table may also be used to determine the tuning method for the center-fed antenna system of Fig. 1212. In this case it will be necessary merely to use the method opposite to that stated. Where series tuning is specified for a given feeder length for the Zepp, parallel tuning should be used with the same length of feeders in the center-feed system.

Approximate Length of Each Wire, Feet	Tuning Arrangement for Various Bands				
	1750 kc. (160 m.)	3500 kc. (80 m.)	7000 kc. (40 m.)	14000 kc. (20 m.)	28000 kc. (10 m.)
120	Ser.	Par.	Par.	Par.	Ser. or Par.
90	Par.	Ser.	Ser.	Par.	Ser. or Par.
60	Par.	Ser.	Par.	Par.	Ser. or Par.
40	(--)	Par.	Ser.	Par.	Par.
30	(--)	(--)	Ser.	Par.	Ser. or Par.
15	(--)	(--)	Par.	Ser.	Par.
8	(--)	(--)	(--)	Par.	Ser.

Ser. — Series Tuning. Par. — Parallel Tuning. (--) — Not Recommended.

will indicate very little current. This is particularly likely to happen when parallel tuning is used and the feeders are nearly multiples of $\frac{1}{2}$ -wave long for the frequency being used.

A Zepp antenna system suitable for operation in several amateur bands is shown in Fig. 1210.

Current-fed Antennas

▲ It is also possible to feed an antenna at the center through a tuned transmission line. When a half-wave antenna is fed at the center there must be a current loop at the end of the transmission line; the antenna itself is cut in the center, and each of the wires is connected to one of the feeder wires. A current-fed system, with the distribution of current shown, is given in Fig. 1211. There must be three half waves on the entire system to have the currents in the two halves of the radiating antenna in the proper phase relationship. In Fig. 1211 this is done by making each wire in the feeder one-half wavelength long. If the feeders are each one-quarter wave long it would be necessary to insert a phase-reverser at the point X; in other words, parallel tuning would be used with quarter-wave feeders in this system, just the reverse of the case of the Zepp antenna. The current-fed arrangement may be preferred when it is more convenient to feed the antenna at the center than at one end; the radiating properties of the antenna are not affected by the method of feeding it.

An antenna fed at the center by a tuned transmission line is not necessarily a current-fed antenna. For example the antenna system shown in Fig. 1212 is current-fed on 7000 kc., where the antenna is a half-wave long, but is voltage fed on 14,000 kc. and higher even harmonics; in these cases the antenna is really two Zeppelin-type antennas placed end-to-end. For 3500-kc. operation there is actually only half an antenna, because the radiating portion measures only one-quarter wave at this frequency. The other quarter-wave

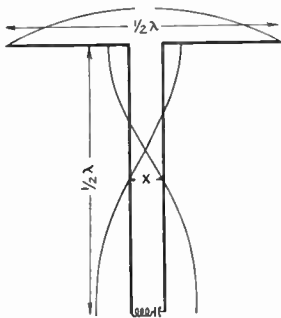


FIG. 1211 — CURRENT-FED ANTENNA WITH TUNED FEEDERS

The antenna is cut in the center and one feeder wire connected to each of the two halves. To bring a current loop at the coupling point, the feeders must be a half wavelength long.

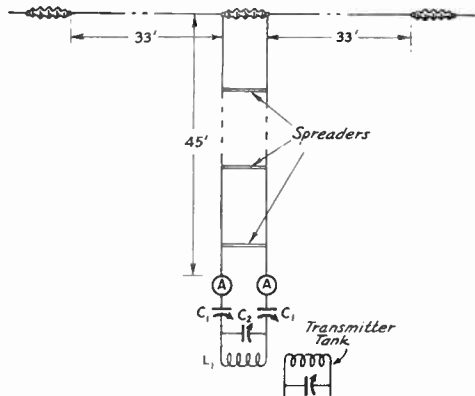


FIG. 1212 — A CENTER-FEED SYSTEM FOR SEVERAL BANDS

The antenna has a fundamental frequency of 7100 kc. and is operated on its second and fourth harmonics for 14,200 and 28,400 kc., respectively. Parallel tuning is used on 7100 kc. and series tuning for 14,200 kc., parallel tuning again being used for 28,400 kc. The system operates as two voltage-fed Hertz antennas in parallel on the two higher frequencies. The arrangement will also work quite well on the 3500-kc. band with parallel tuning of the tank circuit, the whole system being approximately a half-wave antenna with all but the two end eighth-waves "folded back on itself." With a fundamental 3500-kc. antenna (total length about 133 feet) better all-band operation could be obtained with feeders of the length given. The condensers C_1 and C_2 can be of 250- or 350- μfd . capacity. The spacing of the feeders is not critical. The optimum practical value is approximately six inches.

is made up in the feeders. Although not as effective as a full-size 3500-kc. antenna, this arrangement is useful in that it will permit operation on the low-frequency band when space for a 130-foot antenna is not available.

Tuning

▲ The tuning of voltage- and current-feed systems is quite similar and the tuning practices recommended in Chapter Seven should be observed to obtain the maximum output compatible with good frequency stability. When series tuning is used with either of the typical antenna systems shown in Figs. 1210 and 1212, the parallel tuning condenser should be set at minimum capacity and the series condensers at maximum. After the transmitter has been set on the desired frequency the antenna coupling coil should be coupled to the transmitter tank and the series condensers tuned simultaneously, from maximum capacity down, until the radio-frequency ammeter shows maximum feeder current and the plate milliammeter shows normal plate current. If the meters should show two points of maximum current, the coupling should be loosened. After tuning for maximum current the capacity of the feeder series condensers should be increased until the current drops about 15%, if the transmitter is a

self-excited rig. With an oscillator-amplifier set the best tuning adjustment is the one which gives maximum balanced feeder current. The procedure with parallel feeder tuning is similar except that the series condensers are set at maximum and the parallel condenser is tuned from maximum capacity down. If the feeder current should be very low in value with parallel tuning, the plate input as shown by the plate milliammeter will be a better indication of resonance. Plate current should be the greatest when the feeder circuit is tuned to resonance unless the feeder tuning has affected the transmitter tuning enough to necessitate readjustment of the transmitter circuits. Such readjustments should be made according to the directions given for the various transmitters in Chapter Seven.

Tuned transmission lines are particularly advantageous for amateur work because all the adjustments can be made inside the station. The dimensions of the antenna system also are less critical than when the antenna is fed by an untuned line. Inspection of the figures will show that should the length of the antenna be slightly incorrect for the operating frequency the only result will be a corresponding lack of balance in the feeder currents. While this may cause the feeders to radiate a small portion of the energy supplied to them, nevertheless the whole system can still be tuned to resonance and will operate at good efficiency.

Untuned Transmission Lines

▲ The tuned transmission lines just described operate with standing waves on them and therefore their length is an important consideration. The untuned transmission line, on the other hand, operates without standing waves and can be made any random length; that is, the line is aperiodic or non-resonant. To operate without standing waves, the line must be properly coupled to the antenna.

Any transmission line has distributed inductance and capacity, just as has the antenna. The inductance and capacity per unit length determine the characteristic or surge impedance of the line; inductance and capacity in turn depend upon the size of the wire used and the spacing between the wires, if the line consists of two parallel wires. The surge impedance will be

$$Z = 276 \log \frac{b}{a}$$

where Z is the surge impedance, b is the wire spacing, and a is the radius of the wire. Now it is a characteristic of a transmission line that if it is terminated in an impedance equal to its surge impedance, reflection cannot occur and standing waves will not be present. It is the object, therefore, in adjusting the untuned transmission line to terminate it at the antenna in an impedance equal to its surge impedance. When this is done

the line can be any convenient length, radiation will be eliminated, and practically all the power fed into the line will be delivered to the antenna.

It might be explained that the impedance of an antenna depends upon the point at which the measurement is made. It varies from an extremely high value at the open ends to a very low value at the center, assuming it is a half-wave long; if the length is a number of half waves the impedance will vary in much the same way in each half wavelength. Practically all r.f. transmission lines have fairly low impedance — 600 ohms or less — so that the line usually is terminated near the center of the antenna where the antenna impedance also is low. The termination can be made by inserting a coil at the center of the antenna (in series with a condenser so the loading effect of the coil can be cancelled) and using inductive coupling to the line, which is also provided with a coupling coil. Then by adjusting the coupling and the number of turns in each coil — while power is being supplied by the transmitter to the sending end of the line — for maximum current in the antenna and uniform current along the transmission line, the antenna impedance can be properly matched to that of the line. An untuned line is properly terminated only when the current shows no variations with distance along the line. On very long lines there may be a gradual but uniform decrease in current, but there will be no standing waves.

Terminating a line by the method just described requires that tuning apparatus be inserted in the antenna, which is inconvenient. Simpler methods make use of the fact that the impedance of an antenna varies through nearly all possible values along its length, and depend for the im-

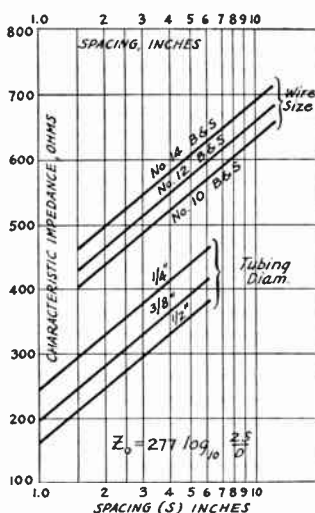


FIG. 1213 — GRAPHICAL TABLE OF CHARACTERISTIC IMPEDANCES OF TYPICAL OPEN-WIRE TRANSMISSION LINES

pedance match upon connecting the line to the proper point along the antenna. We shall now describe some of these.

The "Doublet" Antenna

▲ The construction of the doublet antenna is shown in Fig. 1214. The transmission line is usually made to have an impedance of 600 ohms. Since it is impossible to connect a 600-ohm line directly to any part of the antenna and have the proper termination, the section *E* is "fanned" to have a gradually increasing impedance so that its impedance at the antenna end will be equal to the impedance of the antenna section *C*.

▶ The antenna length *L*, the feeder clearance *E*, the spacing between centers of the feeder wires *D*, and the coupling length *C* are the important dimensions of this system. The system must be designed for exact impedance values as well as frequency values and the dimensions are therefore more critical than those of tuned feeder systems.

The length of the antenna is figured as follows:

$$L \text{ (feet)} = \frac{492,000}{F} \times K; \text{ or}$$

$$L \text{ (meters)} = \frac{150,000}{F} \times K$$

where *L* is the antenna length in feet or meters for a desired fundamental frequency *F*, and *K* is a constant depending on the frequency. For frequencies below 3000 kc. (wavelengths above 100 meters) *K* is 0.96; for frequencies between 3000 and 28,000 kc., *K* is 0.95; and for frequencies above 28,000 kc., *K* is 0.94. *F* is the frequency in kc.

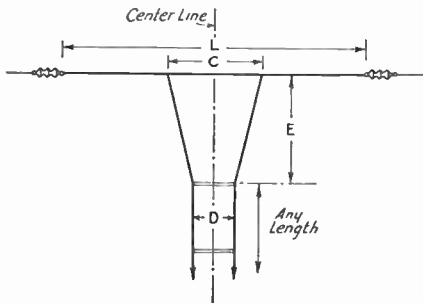


FIG. 1214 — TWO-WIRE MATCHED-IMPEDANCE ANTENNA SYSTEM

The length of the antenna section *C* is computed by the formula:

$$C \text{ (feet)} = \frac{492,000}{F} \times K_1; \text{ or}$$

$$C \text{ (meters)} = \frac{150,000}{F} \times K_1$$

*K*₁ is 0.25 for frequencies below 3000 kc., 0.24 for frequencies between 3000 and 28,000 kc., and 0.23 for frequencies above 28,000 kc.

The feeder clearance *E* is worked out from the equation:

$$E \text{ (feet)} = \frac{147,600}{F}; \text{ or}$$

$$E \text{ (meters)} = \frac{45,000}{F}$$

The above equations are for feeders having a characteristic impedance of 600 ohms and will

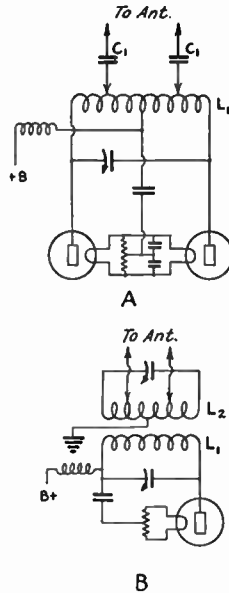


FIG. 1215 — TWO WAYS OF COUPLING THE TWO-WIRE UNTUNED TRANSMISSION LINE TO THE TRANSMITTER

A is for coupling a push-pull oscillator or amplifier. The condensers marked *C*₁ are blocking condensers of about .002 μfd. to keep the d.c. plate supply voltage from being applied to the feeders. The inductively-coupled arrangement at *B* is for use with single-ended oscillators or amplifiers. It can also be used with push-pull, thus making unnecessary the blocking condensers *C*₁.

not apply to feeders of any other impedance. The proper feeder spacing for a 600-ohm transmission line is computed to a sufficiently close approximation by the following formula:

$$D = 75 \times d$$

where *D* is the distance between the centers of the feeder wires and *d* is the diameter of the wire. If the wire diameter is in inches the spacing will be in inches and if the wire diameter is in millimeters the spacing will be in millimeters.

Fig. 1213 will be found useful in this and other problems involving untuned lines.

Since the feeder spacing is the critical dimension in determining the line impedance, the wires should be kept taut and the spacing should be kept constant. The feeders may be run around corners if suitably insulated and rigidly supported, but sharp right-angle bends in the wires must be avoided. Particular care should be taken to run the feeder clearance portion *E* straight away from the antenna. Each side of *E* should be of exactly the same length and the feeder wires should tap the antenna an equal distance on either side of its exact center.

Two methods of coupling the transmission line to the transmitter output circuit are shown

in Fig. 1215. The feeders should be clipped on the inductance an equal number of turns on either side of its center. The correct places for the taps can be found by starting at the center and moving the taps farther along the coil until the tubes are drawing their proper input power. The fixed condensers *C* in the direct-coupled circuit are used as a precaution to prevent short-circuiting

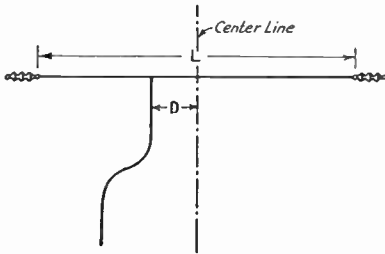


FIG. 1216 — SINGLE-WIRE FEED SYSTEM

The length *L* and coupling *D* are determined from the chart.

the plate supply in case the feeders should become grounded. Since the feeder current is very small the plate current milliammeter reading will be the most satisfactory indication of loading.

The feeder tank circuit in the inductively-coupled arrangement will be similar in construction to the usual transmitter tank circuit. This system involves an additional adjustment — that of tuning the feeder tank circuit to resonance with the transmitter and finding the optimum coupling between the two.

Single-Wire Feed

▲ The single-wire matched-impedance feed system operates on the same principle as the two-wire feed though it is usually more difficult to adjust. There will be no standing waves on the feeder and consequently no radiation from it when its characteristic impedance is matched by the impedance at its terminal. The principal dimensions are the length of the antenna *L*, Fig. 1216, and the distance *D* from the exact

center of the antenna to the point at which the feeder is attached. These dimensions can be obtained from Fig. 1217 for an antenna system having a fundamental frequency in any of the amateur bands. Although the dimensions shown in the chart are for the 3500-kc. band, the dimensions for the 7000-kc. band can be obtained by multiplying the frequency by 2 and dividing the lengths by 2; and for the 14,000-kc. band by multiplying the frequency by 4 and dividing the lengths by 4. When the antenna is to be operated on harmonic frequencies the length must be such that the harmonics of the antenna's fundamental frequency fall inside the higher frequency bands. Suppose that the antenna is to be used for the 3500-, 7000- and 14,000-kc. bands. Since the limits of the 14,000-kc. band are 14,000 and 14,400 kc., the fundamental frequency of the antenna must lie between 3500 and 3600 kc. The antenna length should be, therefore, somewhere between 132 and 135.5 feet. The feeder should be tapped on the antenna at a distance from the antenna center of 18' 11" for operation with an antenna of 135.5' length, or at 18' 5" for an antenna of 132' length.

In constructing an antenna system of this type the feeder must run straight away from the antenna (at a right angle) for a distance of at least 1/3 the length of the antenna. Otherwise the field of the antenna will affect the feeder and cause faulty operation of the system. There should be no sharp bends in the feeder wire at any point.

Twisted-Pair Feeders

▲ It is evident from the formula for characteristic impedance previously given that the closer the spacing and the larger the wires, the lower will be the impedance. It happens that the impedance of a two-wire line composed of ordinary twisted lampcord or twisted No. 14 rubber-covered wire of the type used in house wiring will be approximately that of the center of the antenna itself, thus simplifying the method of connecting the line to the antenna. Such discrepancy as may exist between line and antenna impedance can be compensated for by a slight fanning of the line where it connects to the two halves of the antenna, as shown in Fig. 1218.

The twisted line is often a convenient type to use, since it is easy to install and the r.f. voltage on it is low because of the low impedance. This makes insulation an easy matter. The losses are slightly higher than those in spaced lines, however, although in lengths up to 100 feet or so the difference is negligible.

Operating Considerations With Untuned Lines

▲ If the untuned line is to operate properly, great care must be used in making the terminating adjustment and in determining the proper antenna length. It should be realized that the fore-

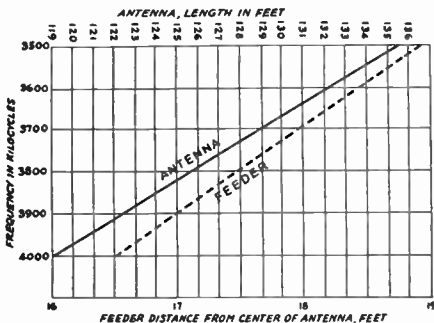


FIG. 1217 — SINGLE-WIRE FEED DATA CHART FOR NO. 14 WIRE FEEDER

going formulas are based on average conditions and that the presence of guy wires, nearby power wires, etc., can upset things to a considerable extent. The antenna length, for example, is much more critical with untuned than tuned lines, because if the antenna is not the right length it will be impossible to get an exact impedance match and standing waves will appear on the line. There

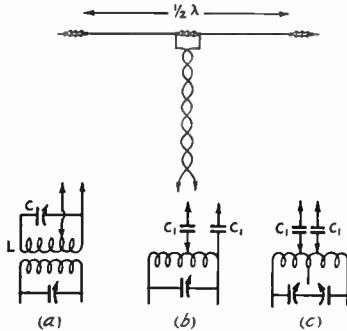


FIG. 1218 — A HALF-WAVE ANTENNA CENTER-FED BY A TWISTED PAIR LINE

An improved impedance match often will result if the antenna end of the line is fanned out in the shape of a "V" for the last 18 inches or so of its length. Two insulators also should be used at the center of the antenna so the open end of the "V" will be approximately 18 inches wide.

Three methods of coupling the line to the transmitter also are shown. The two direct-coupled methods require the use of blocking condensers, C_1 , of about .002 μfd . each, if the d.c. plate voltage appears on the transmitter tank coil. Tuning adjustments are similar to those with the two-wire untuned line or doublet.

will also be a circulating current in the line which represents a loss of power. The same thing will be true if the antenna length is correct but the terminating adjustment is incorrectly made. If possible, the operation of the line should be checked after installation by measuring the current in the line at two points a quarter wavelength apart. If the current at both points is substantially the same the line will be operating properly.

Lines depending upon correct impedance match at the antenna are not ordinarily very efficient if the antenna is to operate at a harmonic because the impedance distribution along the antenna changes with harmonic operation while the line impedance remains constant. Thus harmonic operation always results in an incorrect termination. Usually the systems matched at relatively high impedance, such as the doublet and the single-wire feeder, will operate fairly well on harmonics, however, although not as efficiently as on the fundamental. The twisted-pair line is inefficient at even harmonics, but will operate quite well on odd harmonics.

The single-wire feeder, especially, is critical in adjustment. Quite unorthodox behavior will re-

sult if the antenna length is incorrect or if the feeder is not connected at the right point along the antenna. In such cases the feeder tends to act as part of the antenna; standing waves are present and often a voltage loop appears at the transmitter. When this happens, large r.f. voltages appear in the power-supply apparatus and in other points in the transmitter which should be at zero r.f. potential, if the feeder is directly-coupled to the transmitter tank inductance. This will introduce losses and often make it impossible to adjust the transmitter for efficient operation. The antenna length and feeder position should be such that the feeder current is uniform as determined by measurements made at intervals of a quarter wavelength.

Directional Antennas

▲ By combining a number of half-wave antennas in various space relationships and exciting them in the proper phase, it is possible to concentrate the radiation in one or more desired directions. Antennas of this type require more space (on the lower frequencies) than the amateur usually has available. They are used with great benefit on the ultra-high frequencies, however, and several representative types for operation at frequencies of 56 mc. and above are described in Chapter Nine.

Where space permits, a directive array can be used with great benefit — particularly if some provision is made for rotating it. One such antenna for the 14-mc. band was detailed by John P. Shanklin in the July, 1934, *QST*.

An alternative type of fixed directive antenna is that shown in Fig. 1219. It is known as the R.C.A. Model D antenna and, in the form illustrated, transmits equally well in two directions. The system consists of two wires, one or more wavelengths long, spread out at an angle determined by the number of wavelengths on each wire. The one or two-wavelength types usually require all the space available at most amateur stations. The wires should be suspended as high as possible above ground and, if the apex of the "V" comes reasonably close to the transmitter location, may be fed with the conventional tuned feeder some multiple of a quarter-wave long. In locations where a very long line is necessary, it is advisable to provide an untuned line, matching it to the antenna with the tuned stub indicated in the lower diagram.

A complete antenna installation of this type was described by D. C. Redgrave in the November, 1934, *QST*. While a great many other types of directive antennas could be used for the medium-frequency amateur bands they are usually made impractical by restricted space. A very large and open area of ground is required if a high-frequency directive array is to produce the performance which theory would lead one to expect.

Antenna Construction

▲ For the purpose of this discussion let us divide the antenna system into two parts—the conductors and the insulators. If the system is to operate most effectively the conductors must be

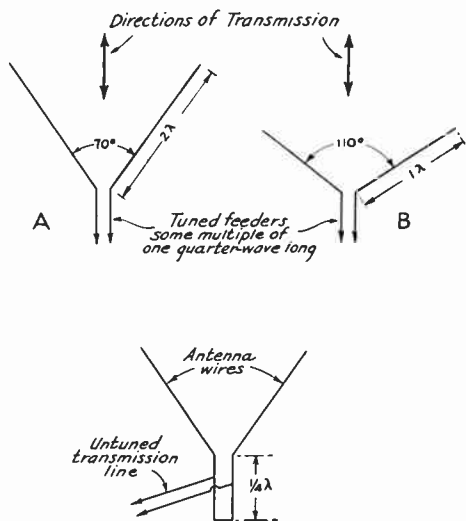


FIG. 1219 — THREE POSSIBLE VARIATIONS OF THE MODEL D DIRECTIVE ANTENNA

This system is one of the few types of directive antennas which have been found readily adaptable for amateur work on the high frequencies. Other types, suited for the ultra-high frequencies, are described in Chapter Nine.

of low resistance. On the other hand the insulators must be of the highest possible resistance. For short antennas and feeders an entirely satisfactory conductor is No. 14 gauge hard-drawn enamelled copper wire. For long antennas No. 12 gauge is preferable. Every effort should be made to make the wires in one piece so that the only joints are at the output terminals of the transmitter. Where joints cannot be avoided they should be thoroughly soldered. It should always be possible to make the Hertz antenna portion in one piece.

If the feeder system is of the tuned type the currents in it will be of the same order as those in the antenna and the same care in avoiding joints is necessary. In the untuned feeder system, however, the currents are relatively low and this consideration is therefore not as important. In these cases smaller wire can be used if necessary.

In building a two-wire feeder the wires may be separated by wooden dowels which have been boiled in paraffin. In this way the feeder is given a tendency to swing in windy weather as a unit. When heavy glass or porcelain spacers are used the tendency is for each wire to vibrate with re-

spect to the other, so causing changes in the capacity between the wires and consequent changes in the emitted frequency. The wooden dowels can be attached to the feeder wires by drilling a small hole in the dowels, then binding them to the feeders with wire.

A good insulation to use throughout the antenna system is Pyrex electrical-resistant glass. Glazed porcelain also is very good. It should be kept in mind that the ends of tuned feeders or the ends of the antenna are points of maximum voltage. It is at these points that the insulation is most important. A 12" Pyrex insulator is quite satisfactory for amateur transmitters of any power. For the low-powered transmitters one of the smaller sizes, or two in series, would be satisfactory.

It is hardly possible to give practical instructions for the suspension of the antenna since the methods used will vary so widely in individual instances. In most cases poles are desirable to lift the antenna clear of surrounding buildings but in some locations the antenna is in the clear when strung from one chimney to another or from a chimney to a tree. Small trees are not usually satisfactory as points of suspension for the antenna on account of their movements in windy weather. If the antenna is strung from a point near the center of the trunk of a large tree this difficulty is not as serious.

In most locations a variety of possible arrangements will present themselves. It will be well for the amateur to try the antenna in different positions or to try different types of antennas. Time expended in such experiment undoubtedly will be well worth while.

The Receiving Antenna

▲ Because of the high sensitivity of modern receivers a large antenna is not necessary for picking up signals at good strength. Often it will be

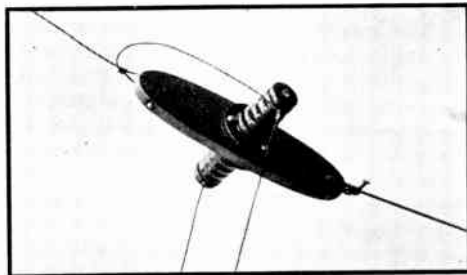


FIG. 1220 — AN IDEAL METHOD OF ATTACHING FEEDERS TO THE ZEP ANTENNA

The unit is built from a piece of half-inch maple, thoroughly boiled in paraffin, on which are mounted two stand-off insulators. Additional insulators may be inserted at the point where the tie rope is shown attached. This device has the merit of permitting the feeders to be run off at any angle to the antenna, still allowing the feeder to hang correctly. Commercially manufactured models of this unit are available.

found that the receiving antenna in the amateur station is an indoor wire only 15 or 20 feet long.

On the other hand, the use of a tuned antenna unquestionably improves the operation of the receiver because the signal strength is greater in proportion to the stray noises picked up by the antenna than is the case with the antenna of

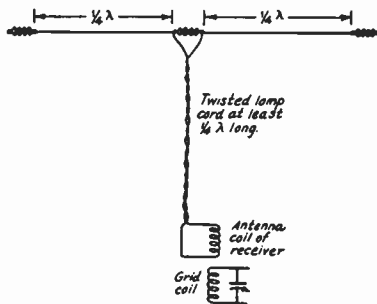


FIG. 1221 — DOUBLET RECEIVING ANTENNA

random length. Likewise, it is advantageous to have the receiving antenna well out in the clear, away from power wiring which radiates the noises resulting from the use of electrical household appliances, and to bring the signal in to the receiver over a radio-frequency transmission line. A non-radiating transmission line is inefficient at intercepting signals, hence it can pass through locations where noise is great without picking up much interference. The transmission-line fed antennas used for transmitting will make excellent receiving antennas; a switch can be fitted in the feeders inside the station so that the antenna can be connected to either the transmitter or receiver.

If a separate receiving antenna is preferred, a doublet antenna of the type shown in Fig. 1221 will give very good results. The length of the lamp cord transmission line may be anything convenient. The antenna itself should be a half wave long for the frequency band most used; despite the fact that the antenna is resonant for only one band, it will give good results on others as well. A popular length is 65 feet or so, designed to resonate in the 7000-kc. band.

Dummy Antennas

▲ The absolute value of current in an antenna or feeder system is practically meaningless so far as indicating actual power is concerned, because the resistance of the antenna or feeder at the point where the current is measured is rarely known. In tuning the antenna system to the transmitter the antenna ammeter's chief function is that of providing a means for comparing the effects of different adjustments. The actual power output must be measured by adopting a different method. The simplest of these is that involving the use of a non-radiating or "dummy" antenna.

The dummy antenna is a resistance of suitable value capable of dissipating in the form of heat all the output power of the transmitter. One of the most satisfactory types of resistors for amateur work is the ordinary incandescent electric lamp. Other non-inductive resistors of sufficient power-dissipating capacity can be used, however.

Three circuits for use with dummy antennas are given in Fig. 1222. The first of these is for use with a low-resistance dummy — say 25 ohms or less. The resistor is connected in series with a tank circuit which tunes to the same frequency as the transmitter and is coupled inductively to it. If the value of the resistance is known accurately — measurement is difficult, however, because of skin effect at high frequencies — the power may be determined by measuring the radio-frequency current in the resistor and applying Ohm's Law ($W = I^2R$). The resistor must be non-inductive.

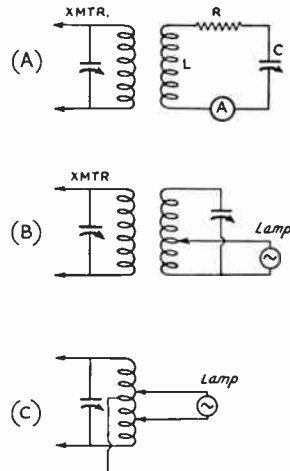


FIG. 1222 — DUMMY ANTENNA CIRCUITS

Incandescent bulbs, which in the 115-volt sizes have a resistance of 75 ohms or more at operating temperature for ratings of 150 watts or less, will work more satisfactorily in either of the other two circuits. The lamp should be equipped with a pair of leads, preferably soldered right to the terminals on the lamp base. The number of turns across which the lamp is connected should be varied, together with the tuning and the coupling between the dummy circuit and the transmitter, until the greatest output is obtained for a given plate input.

In using lamps as dummy antennas, a size corresponding to the expected power output should be selected so that the lamp will operate near its normal brilliancy. Then when the adjustments have been completed an approximation of the power output can be obtained by comparing the brightness of the lamp with the brightness of one of similar power rating in a 115-volt socket.

ASSEMBLING THE AMATEUR STATION

IN THE preceding chapters we have seen how all the component parts of an amateur station may be designed and built, and we have come to know that a complete station consists of a receiver, a transmitter with power supply, a monitor or frequency meter or both, and suitable antennas for transmission and reception. Many amateurs, on completion of the necessary units for their station, are so anxious to put the outfit into operation that they merely toss the apparatus on a table, connect it up in some haphazard fashion and begin operating. This procedure frequently results in danger to the operator and his family from exposed wiring. Also it invariably leads to unreliable and unsatisfactory operation of the equipment. The sincere amateur not only takes pride in the quality of signal his transmitter emits but also in the appearance of his station. One does not need a powerful transmitter or an elaborate receiver to have a fine amateur station.

Finding a Location

▲The first problem encountered in building a station is usually the selection of a suitable space in the house. Some fortunate amateurs are able to provide a special "shack" away from the house. Others are able to monopolize an entire room for their station. Most amateurs, however, are obliged to content themselves with a corner of the basement, their bedroom or the attic. Some fellows, living in apartments, have even been restricted to the space under the kitchen stove, or in a small closet. Still others, for the sake of convenience and comfort, have built their transmitter and receiver into a small cabinet located in the living room, the heavier power supply apparatus being arranged in the basement.

Further schemes for the amateur limited in space are made available by remote control methods—some typical examples of which are given in Chapter

Eleven. With remote control, the transmitter and its power supply may be located in the attic, in the basement or in a specially built "dog-house" in the back yard. The receiver and control switches may then be located in a small cabinet in the living room or on a small table in any other room available.

There is certainly room for an amateur station in any house or apartment.

The Operating Position

▲Convenient operation of a station calls for ample space around the receiver and key. There must be room for the log book, call book, message blanks and miscellaneous papers. For this reason, it is almost universal practice to use a table or desk as the operating position.

The items which are handled most frequently are the receiver, power switches, key, frequency meter and monitor. It is well, therefore, to group all of these on the table or desk selected. Perhaps the most popular practice is to place the receiver towards the left of the table. The monitor is then located alongside the receiver on the right (where it is near enough to give a good signal in the receiver) and the key is screwed to the table slightly to the right of this and far enough back to give a good support for the operator's arm.

Since the filaments of the transmitting tubes should be lighted before the high voltage is applied, two switches should also be fitted on the table—one for the primary of the filament transformer and one in the supply circuit to the plate supply apparatus. These switches can be mounted under the front edge of the table in a position convenient for right-hand operation. With low-power transmitters, the filament and plate power are often supplied by one transformer; in such a case only one power-line switch will be necessary.

It is usually inadvisable to mount



COMFORTABLE SURROUNDINGS INCREASE OPERATING PLEASURE

The receiving position at W2AG invites one to sit down for a "ragchew." Several unique ideas were presented with this station in July QST, 1934.

the transmitter or power supply on the operating table. In the case of the self-controlled transmitter, indeed, it is extremely bad practice. All such transmitters are susceptible to vibration and to the effects of "body capacity." Consequently, they cannot be expected to deliver an output of constant frequency when subject to the vibration of keying and the movements of the operator. It is very much better, even in the case of a crystal controlled set, to mount the transmitter itself on a shelf supported from the wall, on a separate table, or in a special frame. In any case, the transmitter should be conveniently placed with respect to the feeder or antenna leads.

The power supply equipment of even a low powered transmitter requires careful placement because of the danger involved. It should not be on the operating table nor should it be under the table in a position where the operator's feet could come in contact with it. Often it is placed on a shelf under the transmitter table or frame. Alternatively, it could be in a large and well ventilated box under the operating table and off to one side.

It is futile, of course, to attempt to outline



ONE TABLE OR SIDE OF A WALL CAN HOUSE A COMPLETE STATION

This particular station belongs to VE2HM and was described in April QST, 1934. The main interest at VE2HM is on 1.75-mc. 'phone.

every possible arrangement of the components of the station. It is better that the amateur should make a study of the stations he visits (and of those illustrated in this chapter and in *QST*) with the idea of improving on them or at least adapting them to his particular needs.

Underwriters' Rules

▲ Before actually starting on the installation and wiring of the complete station, the amateur should certainly make a study of the Underwriters' requirements.

The specific rules covering radio equipment are given in Article 37 of the National Electric Code, under the heading of "Radio Equipment." Some states have adopted this code or a more strict version of it. Certain cities have adopted it, too, and they enforce their regulations through muni-



WHEN THE OLD-TIME AMATEUR COMES BACK

After a rest of many years an amateur can get back in the game with commercial equipment available to suit the pocketbook. The station signs W2GOX and was described in August 1934 QST.

cipal inspectors. Before making an installation it is well to find out if the apparatus and wiring are subject to a state and city inspection as well as to inspection by insurance interests.

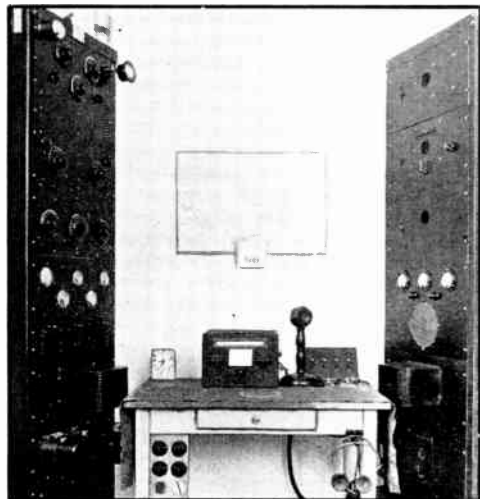
"Approved" refers to devices designed for the purpose used in accordance with recognized practice. The device must be acceptable to the inspection department having jurisdiction (there may be a city or state inspector in addition to the insurance rating or inspection bureau). When there is no inspector for the city or state, insurance interests inspect through their rating organizations, one of which covers each part of the United States. Your local insurance agent can advise you in whose territory you are located so you can get in touch with the proper authority.

A conference with the inspection department *before* making an installation or change will save inconvenience and expense later. Your own interests and those of fellow citizens will be best protected from an insurance and fire-hazard standpoint by having such a conference.

The wiring must follow the requirements observed in your particular community. In some instances a separate power line must be run directly to the watt-hour meter. A few feet of "BX" from the nearest outlet to a "Square-D" switch box, properly fused at the switch, will usually be satisfactory. The installation of high-voltage apparatus and wiring must be done in approved fashion. High-tension cable, supported on porcelain pillar insulators, keeping the high voltage away from all woodwork and neighboring conductors, is a safe type of construction.

A receiving antenna can be connected to ground before it gets to the set through either the in-door or out-door type of lightning arrester. Several approved types are sold by local dealers with complete instructions for installation. These

arresters usually are simply spark-gaps sealed in a vacuum to lower the voltage break-down. The ground can be made by scraping a water pipe or ground rod clean and bright with a file. A 10-cent ground-clamp will make a good connection to the



RELAY RACK CONSTRUCTION IS BECOMING MORE POPULAR

The commercial radio man appreciates compactness and commercial construction often creeps into the "ham" station. W2DC presents a practical station for 'phone and c.w. in September 1934 QST.

pipe. A yearly inspection will insure a good ground. An approved lightning arrester operating at a potential of 500 volts or less is required for each lead-in conductor of a receiving station. There are no requirements for indoor antennas, however.

The lead-in wires must be brought into the station through approved lead-in bushings. A good but cheap way to bring in the antenna lead is to drill a hole in the center of a large window pane. A brass machine screw with rubber gaskets will go through this and make an excellent lead-in. The lead-in insulator must have a 3-inch clearance beyond the wall of the structure. Antenna leads must never come within 5 inches of supply wires. A wooden board at the top or bottom of a window will make a good support for lead-in bushings under most circumstances.

Everyone who owns an amateur station or who plans to have one should send ten cents (not in stamps) to the Superintendent of Documents, Government Printing Office, Washington, D. C., for the booklet *Safety Rules for Radio Installations*, Handbook of the Bureau of Standards No. 9.

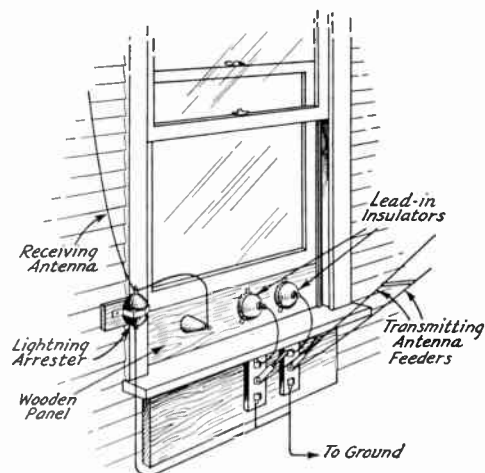
The Antenna

▲In addition to the problems of installing the apparatus inside the house, the amateur must

also concern himself with the problems of the outdoor equipment — the antenna and its support. In this connection it is very difficult to offer suggestions because of the widely different requirements in different locations. It is certain that any amateur having the patience and application necessary for the completion of the transmitter, receiver and accessories is not to be stumped by the selection and provision of suitable supports for the antenna. In some cases the lack of yard space presents a *real* problem. Usually the owner of the adjoining property will consent to the antenna being extended into his domain. Failing that, about the only alternative is to restrict one's activity to one of the higher frequency bands on which a sufficiently short antenna can be used.

Building a Mast

▲It is very rarely that an effective antenna can be erected without putting up some form of mast. And in many cases the mast must be erected and guyed in a restricted space. With the idea of providing some suggestions for the prospective mast-builder, we will present the description of a typical mast. The example selected is a 40-foot mast of simple construction and low cost. The only lumber used is 2-by-2 straight-grained pine (which many lumber yards know as hemlock) or even fir stock. The uprights can be each as long as 22 feet (for a mast slightly over 40 feet high) and the cross-pieces are cut to fit. Four pieces of 2-by-2 22 feet long will provide enough and to spare. The only other materials required are five $\frac{1}{4}$ -inch carriage bolts $5\frac{1}{2}$ inches long, a few spikes, about 300 feet of No. 12 galvanized iron wire for the guys or stays, enough No. 500 ("egg") glazed



ANTENNA AND FEEDER GROUNDING METHODS FOR LIGHTNING PROTECTION

Lightning switches are used on the transmitting antenna lead-in or feeders. A lightning arrester is satisfactory for the receiving antenna.

porcelain strain insulators to break up the guys into sections and the usual pulley and halyard rope. If the strain insulators are put in every 5 feet approximately 30 of them will be enough.

After selecting and purchasing the lumber — which should be straight-grained and knot-free — three sawhorses or boxes should be set up and the mast assembled in the manner indicated in the diagrams. At this stage it is a good plan to give the mast two coats of "outside white" house paint.

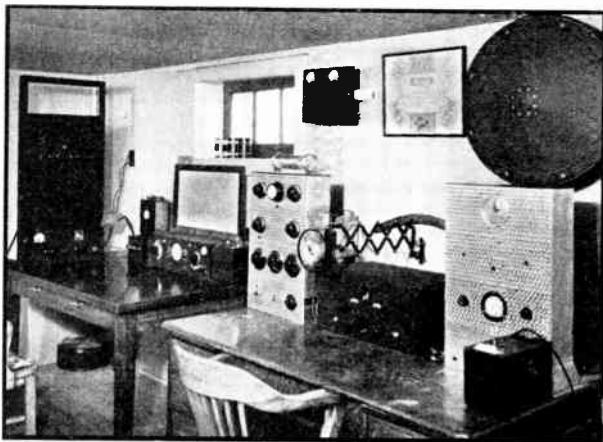
After the second coat of paint is dry, attach the guys and rig the pulley for the antenna halyard. The pulley anchorage should be at the point where the top stays are attached so that the back stay will assume the greater part of the load tension. It is better to use wire wrapping around the stick, with a small through-bolt to prevent sliding down, than to use eye bolts. The latter weaken the mast.

If the mast is to stand on the ground, a couple of stakes should be driven to keep the bottom from slipping. At this point the mast may be "walked up" by a pair of helpers. If it is to go on a roof, first stand it up against the side of the building and then hoist it, from the roof, keeping it vertical. The whole assembly is light enough for two men to perform the complete operation — lifting the mast, carrying it to its permanent berth and fastening the guys — with the mast vertical all the while. It is therefore entirely practicable to put up this kind of mast on a small flat area of roof that would prohibit the erection of one that had to be raised vertical in its final location.

Once the base has been placed on its spot and made level right-and-left, the front and back guys from the mid-section are anchored so that the mast stands vertical fore-and-aft. The last step is to anchor the top guys so that the upper section lines up vertical. This can be done quite accurately by sighting up from the bottom, while a helper tightens and loosens guys as commanded.

Transmitting antennas or feeders must be

grounded by means of lightning switches. The switch should be of the single-pole double-throw type having a minimum break distance of 4 inches and a blade of at least .0625 square inch cross-section. The switch should be in the most

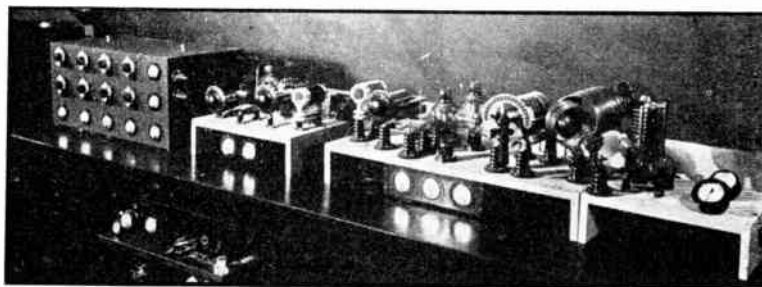


THE BASEMENT STATION CAN BE ATTRACTIVE AND HAVE ITS ADVANTAGES

Plenty of room with each piece of apparatus in its place. W9DRD was described in June 1934 QST.

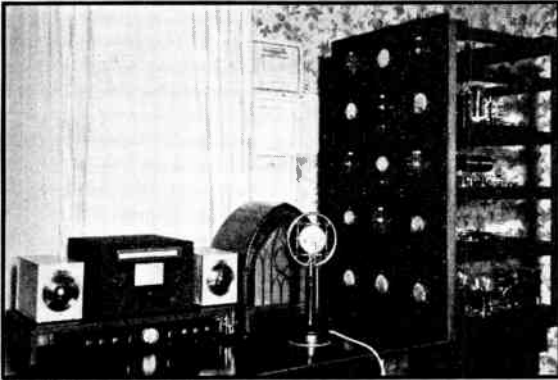
direct line between lead-in and ground but can be located either outside or inside the station. Live parts of the switch must clear the wall (or other conductors) by 3 inches. The switch must be connected to the ground wire whenever the station is not in operation.

Antennas for receiving and low-power transmitting stations should be supported and insulated similarly to public service communication lines, while for medium- and high-power stations the requirements for constructing supply lines for transmitting electrical energy in like situations must be met. Antennas should not cross over or under supply lines or telephone and telegraph wires nor should they run above and parallel to them in such a way that a falling antenna might come in contact with a live wire. Antennas should not cross railroad tracks or public thoroughfares. They should not be attached to poles owned and maintained by local public utilities for supporting



BREADBOARD CONSTRUCTION CARRIED TO THE POWER LIMIT

At W1Z1 is displayed a practical layout for the man who desires this popular form of transmitter.



THE MEDIUM-POWERED PHONE STATION

Monitor, receiver, frequency meter, transmitter and loud-speaker complete the essentials at W7VS as shown in February 1934 QST.

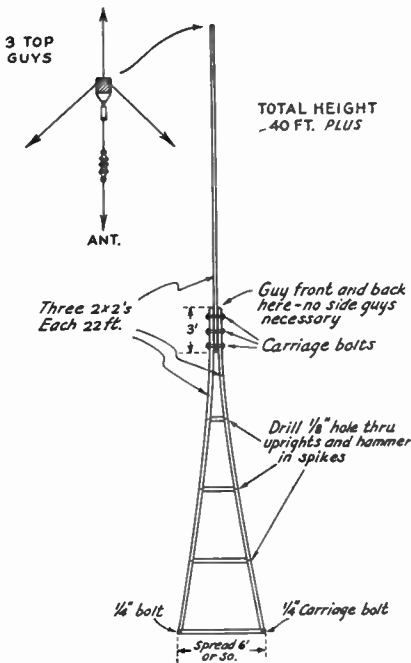
power lines or communication cables or wires. In most cases local ordinances forbid such construction as a menace to the public welfare. When antennas are put up in such hazardous locations special precautions should be taken to have ample strength in the antenna wire and its sup-

ports, as well as ample clearances. Antennas should not be supported on chimneys. When a tree is used there should be some provision for keeping the antenna from snapping when the tree sways in the wind.

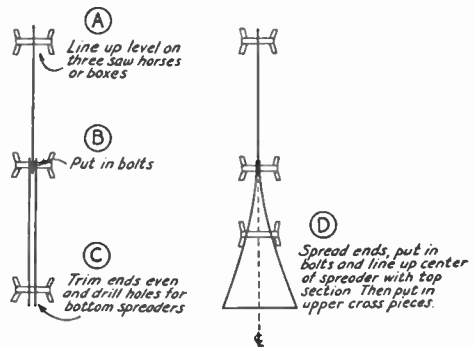
Any size of wire can be used for a receiving antenna. Probably No. 14 B. & S. (American Wire Gauge) hard-drawn copper wire, enameled to prevent corrosion, will have the best balance of electrical conductivity and mechanical strength for that purpose. Transmitting antenna wires for medium or high power amateur stations should have a strength not less than that of No. 10 hard-drawn copper wire and should be insulated with insulators having a minimum creepage distance of 10 inches.

For the amateur interested in directional antennas the mast already detailed will prove highly appropriate. A reasonable height can be obtained with a minimum of expense, space and labor.

Other types of antenna masts have been described in QST from time to time. We suggest reference to past QST indices for information on



DETAILS OF A 40-FOOT MAST SUITABLE FOR ERECTION IN LOCATIONS WHERE SPACE IS LIMITED



ILLUSTRATING THE METHOD OF ASSEMBLY

the subject. A full description of several types of mast appeared in September 1932 QST.

One cannot be too careful in the construction of the antenna system. All wires should be measured and cut carefully. All joints should be soldered and the antenna and feeder system should be rigid. If there is any sway in the feeder system it should move as a unit. To accomplish this result it will be necessary to use light spreaders and plenty of them. Spreader every four feet in the feeder system will be adequate.

Any time spent on antennas and masts will be well repaid after gales and storms have been weathered and the system stands still intact.

CHAPTER FOURTEEN

A.R.R.L. COMMUNICATIONS DEPARTMENT

BBETTER communication results in all aspects of our hobby, amateur radio, can be achieved through better operating. The Communications Department is concerned with the practical operation of the stations of League members. Its work includes arranging amateur operating activities, establishing standard operating procedure, encouraging good operation, improving message relaying, and concluding tests to these ends.

The aim of the Communications Department is to keep in existence an active organization of League stations made entirely of privately-owned radio stations covering the entire continent of North America. One of its objectives is to create a body of skilled operators whose services and abilities will further the general knowledge of the art of radio communication. The relaying of friendly messages between different parts of the country without charge is one of the important phases of the work coming under the supervision of the Communications Department. Amateur operators have also always been of great assistance to our country in times of emergency in which quick communication has been a factor, especially when other methods of communication have failed.

These objects of our organization must be kept in mind at the same time we, as individuals, are getting enjoyment from our chosen hobby. By operating our stations with some useful end in view we can improve the service which we give others and increase the pleasure we get, at the same time justifying our existence.

Your A.R.R.L. does not aim to reform or change the hobby of the 'phone man, the DX man, the traffic enthusiast, rag chewer, or the experimenter. All hams should know all aspects of our hobby and be tolerant of the other fellow's viewpoint. Most hams do and are. Sooner or later, an amateur who starts in one branch of the game aspires to DX, 'phone, traffic, or the novelty of ultra-high frequencies, abandoning, at least for the time, his first interest in amateur radio. When a DX test is on many hams go after the DX fun thus made available by A.R.R.L., soon returning to their regular bent. It is our aim to benefit all concerned along the lines of natural interest.

The activities of the Communications Department are arranged and recorded through *QST* and by special correspondence. Tests and relays are arranged from time to time to develop new routes for traffic handling, to prepare ourselves to render emergency service in time of need, and

to bring to light additional general radio information. In this way all members of the League benefit from the experience of certain individuals who excel along specified lines of work.

The policies of the Communications Department are those urging members to adopt uniform operating procedure and to use system in their station operating. The Communications Department constantly works to make our communication system as efficient as a non-commercial message-handling organization can be. Compliance with government regulations, orderly operating, and cooperation with each other and with outside interests for the advancement of the art are a part of its policies. The first duty of the department to member-stations is to supervise operating work so well that the amateur will continue to justify his existence in the eyes of his Government. Then he will be allowed a continuance of the privileges which he has received as his due in the past.

Records of tests are included in *QST*. Active stations in the A.R.R.L. organization receive special mimeographed bulletins on all new developments. Through such bulletins and a large volume of routine correspondence with individual members, the contact is kept good and the activities we have outlined are effectively carried out by the interested member-stations.

Official Broadcasting Stations have been appointed and regularly transmit addressed information to all amateurs by voice and in telegraphic code. This service of sending addressed messages to A.R.R.L. members on current matters of general interest is supplemented by official and special transmissions on timely subjects from Headquarters Station W1MK (schedule given on page 12).

In these pages we are going to explain the organization of the Communications Department, the proper message forms to use, and some special practices which experience has proved best. We urge that you help strengthen amateur radio by studying the operating practice suggested and by adopting uniform operating procedure.

Everyone at League Headquarters welcomes criticism that is accompanied by constructive suggestions. The fullest benefits of organization are realized only when every member participates freely in his organization and gives brother amateurs and his organization the benefit of his advice, suggestions, criticism, participation and cooperation in the common cause, amateur radio. In individual operating work as well, advancement comes as we learn to exchange con-

structive suggestions in the true amateur spirit.

In some department of the A.R.R.L.'s field organization there is a place for every active amateur who has a station. It makes no particular difference whether your interest lies in getting started and learning the code, traffic handling, DX, friendly contacts by 'phone, or other aspects of amateur radio. Whatever your qualifications, we suggest that you get into the game and cooperate with your Section Manager by sending him a monthly report of the particular work you are doing. As you become experienced in amateur work of different kinds it is likely that you will qualify for appointment as O.R.S. or O.P.S. or that you can accept other important responsibilities in connection with the conduct of A.R.R.L. work in the different sections. Operating work and the different official appointments will be explained in detail in this and the following chapter. We want to make it clear right at the start that the Communications Department organization exists to increase individual enjoyment in amateur radio work, and we extend a cordial invitation to every amateur and reader of this book to participate fully in the different enterprises undertaken by and for amateur operators.

Organization

▲ The affairs of the Communications Department in each Division are supervised by one or more Section Communications Managers, each of whom, elected by the A.R.R.L. members of his territory, has jurisdiction over his section of Division.

For the purpose of organization the A.R.R.L. divides the United States and Possessions (plus Cuba and the Isle of Pines) and Canada (plus Newfoundland and Labrador) into divisions as follows:

ATLANTIC DIVISION: Delaware, District of Columbia, Maryland, Pennsylvania, that section of New Jersey within the Third Federal Inspection District, and that section of New York within the Eighth Federal Inspection District.

CENTRAL DIVISION: Illinois, Indiana, Kentucky, Michigan, Ohio and Wisconsin.

DAKOTA DIVISION: Minnesota, North Dakota and South Dakota.

DELTA DIVISION: Arkansas, Louisiana, Mississippi and Tennessee.

HUDSON DIVISION: The entire Second Federal Inspection District, consisting of certain counties of New Jersey and New York States.

MIDWEST DIVISION: Iowa, Kansas, Missouri and Nebraska.

NEW ENGLAND DIVISION: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

NORTHWESTERN DIVISION: Idaho, Montana, Oregon, Washington and the Territory of Alaska.

PACIFIC DIVISION: Arizona, California, Ne-

vada, the Territory of Hawaii and the Philippine Islands.

ROANOKE DIVISION: North Carolina, Virginia and West Virginia.

ROCKY MOUNTAIN DIVISION: Colorado, Utah and Wyoming.

SOUTHEASTERN DIVISION: Alabama, Florida, Georgia, South Carolina and the Island of Porto Rico. (*The Republic of Cuba and the Isle of Pines are attached to this Division for Communications Department activities.*)

WEST GULF DIVISION: New Mexico, Oklahoma and Texas.

MARITIME DIVISION: The provinces of New Brunswick, Nova Scotia and Prince Edward Island. (*Newfoundland and Labrador are attached to this Division for Communications Department activities.*)

ONTARIO DIVISION: Province of Ontario.

QUEBEC DIVISION: Province of Quebec.

VANALTA DIVISION: Provinces of Alberta and British Columbia and Yukon Territory.

PRAIRIE DIVISION: Provinces of Manitoba and Saskatchewan and the Northwest Territories.

Each United States Division elects a Director to represent it on the A.R.R.L. Board of Directors and the Canadian Divisions elect a Canadian General Manager who is also a Director. The Board determines the policies of the League.

A.R.R.L. operating territory is subdivided into Sections to facilitate the collection of reports, and more important, the efficient supervision of activities and appointments in the field organization.

The field officials (S.C.M.s) are listed on page 5, while the names and addresses of the Directors are printed on page 6, of each *QST*.

Whenever a vacancy occurs in the position of Section Communications Manager in any section of the United States, its island possessions or territories, or the Republic of Cuba, the Communications Manager announces such vacancy through *QST* or by mail notice to all members of the Section, and calls for nominating petitions signed by five or more members of the Section in which the vacancy exists, naming a member of the Section as candidate for Section Communications Manager. The closing date for receipt of such petitions is announced.

After the closing date, the Communications Manager arranges for an election by mail or declares any eligible candidate elected if but one candidate has been nominated. Ballots are sent to every member of the League residing in the Section concerned, listing candidates in the order of the number of nominations received. Section Communications Managers are elected for a two-year term of office.

The office of any Section Communications Manager may be declared vacant by the Executive Committee upon recommendation of the Communications Manager, with the advice and

consent of the Director, whenever it appears to them to be in the best interests of the membership, and they may thereupon cause the election of a new Section Communications Manager.

Communications Department Officials and Appointments

▲ These S.C.M.s elected in each Section by the A.R.R.L. members in that Section, appoint active qualified amateur stations for special types of radio work in the A.R.R.L. field organization. Whether your activity is directed toward DX, experimenting, 'phone or traffic, there is a place

quarters for maintenance of records of all his appointments, and cancellations of such appointments either for violations of the regulations under which these are issued, or for violations of the F.R.C.'s amateur regulations. The Form 4 (appointment) and Form 4C (cancellation) cards provided, must be sent to Headquarters that A.R.R.L. mailing lists and records may be kept exactly in accordance with those of the S.C.M. office. Annual endorsement of O.R.S. and O.P.S. certificates (and S.C.M. notification-to Headquarters by Form 4) is required to keep these appointments in effect.

4. The Section Manager is responsible for the cooperation of active station-owners in A.R.R.L. activities, contests, traffic work, etc. and is authorized to devise and develop special plans in the furtherance of Section interest and esprit de corps.

5. The Section Manager is the Section executive. His leadership must take into consideration the proper distribution of basic and key appointments to those best qualified in the different cities and in each radio club in the Section. Such problems as the geographical distribution and coverage of stations (OBS) sending addressed information to members, the distribution of appointments in the different frequency bands for effective Section activities require careful study. The S.C.M. must in his decisions try to grant recognition to the best qualified operators and stations, and endeavor to insure A.R.R.L. representation and activity in each amateur group.

6. The S.C.M. may appoint *only League members* to any A.R.R.L. office. He must see that each O.R.S. and O.P.S. appointed has the proper qualifications, as indicated by actual operating radio tests and/or station inspection made by him or under his direction. The S.C.M. shall also conduct investigations of radio organizations and interference cases whenever such cases are referred to him by Headquarters or the Division Director. It is his duty to demonstrate Section leadership and coordinate all types of amateur operating work to make his Section as effective and active as possible.



for you in League work. Your S.C.M. welcomes a monthly report from every active ham. The following regulations will explain the duties of the S.C.M. and the specialized radio work of all stations honored by holding A.R.R.L. appointments.

Section Communications Manager

▲ 1. The Section Manager shall appoint Route Managers, Official Observers, Official Broadcasting Stations, Official Relay Stations, Official 'Phone Stations, and individuals and/or stations for specific work in accordance with the qualifications and rules for such appointments. He shall likewise make cancellations of appointments whenever necessary.

Appointees shall have full authority within the section over the activities indicated by their titles. They will report and be responsible to the Section Communications Manager for their work. With the consent of the Communications Manager the Section Manager may, if necessary, designate a competent League member to act for him in a particular matter in any part of his territory. He shall be careful to instruct such an appointee properly in the duties he is to execute while acting for the S.C.M.

2. His territorial limitations are determined by the Division Director (or C.G.M.) and the Communications Manager.

3. The Section Manager is responsible to the Communications Manager at League Head-



7. The S.C.M. may requisition necessary Communications Department supplies provided for making appointments and supervising the work in his section. He may render an itemized postage expense account at intervals, for reimbursement. Section Managers are entitled to wear the distinctive A.R.R.L. pin with red background, similar in other respects to the regular black-and-gold A.R.R.L. membership pin.

8. The S.C.M. shall render a monthly report or activity summary to Headquarters. It shall be made up from all reports from all active stations, whether members or not, and include comprehensive information on each appointee. Reports shall be mailed to Headquarters by S.C.M.s on or before the 20th for the reporting month (16th to the 15th inclusive) in the mainland U. S. A. and Canada.

Official Observers

▲ Each S.C.M. recommends for appointment one or more Observers who report regularly to the S.C.M. on off-frequency operation noticed, sending out notification forms (provided from Headquarters) to help amateurs in keeping within the assigned bands.

Each Official Observer shall have an accurately calibrated monitor or frequency meter, checked regularly against A.R.R.L. Standard Frequency Station transmissions and by government or commercial "marker" stations of known frequency operating adjacent to our own amateur channels. Observers are provided with notification postal card forms and report blanks. The stations notified are reported to A.R.R.L. (through the office of the S.C.M.) as rapidly as the blanks are filled out. Radio contacts with off-band stations shall be made by O.O.s wherever possible. Operators in different bands are needed to specialize on conditions in those bands, 'phone observers to help improve 'phone operating conditions, etc.

Observers also shall report harmonic or parasitic radiations and other operation of commercial or government telegraph services or broadcasting stations causing interference in the amateur bands, these being reported direct to Headquarters as promptly as possible so that remedial action may be taken.

The notification service to amateurs is designed as a friendly move to protect amateur privileges from official government restrictions. These are invited by careless or intentional disregard of regulations by individuals who may thus jeopardize the enjoyment of all amateurs. Observers also report all flagrant violations of good amateur practice, including improper procedure, poor spacing, "a.c." notes, unstable signals, overmodulation, unethical "music" broadcasting, or other abuses; all to the end that these things may be brought before the operators concerned, the effectiveness of stations improved,

and high standards of amateur operating maintained. Observers also make station-distribution surveys showing actual density of stations and operating conditions in our different amateur bands.

Route Managers

▲ The Route Manager is the authority on schedules and routes and his station must be active in traffic and organization work. Section Managers



generally appoint one Route Manager to every twenty or twenty-five Official Relay Stations. The Route Manager's duties include cooperation with all radio amateurs in his territory in organizing and maintaining traffic routes, nets, and schedules. His authority extends to station inspection and/or radio operating tests of candidates for O.R.S. appointment as directed by the S.C.M. Each R.M.'s territory and jurisdiction over special projects is determined by the S.C.M. who expects monthly progress reports. R.M.s may wear the League emblem with the distinctive deep-green background.

'Phone Activities Manager

▲ The 'Phone Activities Manager has authority to sponsor 'phone operating activities in his territory, in the name of the League. The P.A.M. appointment, while paralleling that of R.M. in



some respects, has nothing to do with "traffic" organizing whatsoever, but with the upbuilding of A.R.R.L. Section and National 'phone organization. The 'Phone Activities Manager conducts station inspections and/or radio operating tests of candidates for O.P.S. appointment as directed. P.A.M.s wear the League emblem with the distinctive deep-green background in recognition of their official status.

Official Broadcasting Station

▲ The Official Broadcasting Station transmits information on timely subjects addressed to radio amateurs and A.R.R.L. members. This must be sent at scheduled times during the week following receipt of the information from A.R.R.L. Headquarters.

Applicants for this appointment must submit their qualifications to the Section Manager with the proposed dates, times and frequencies for transmission of the broadcasts. In deciding on the times of transmission schedules, preference should be given to those times when the largest number of amateurs are listening, that is, the hours between 6:00 p.m. and midnight. Station power, geographical location, frequent transmissions, ability to copy messages direct from W1MK in advance of mail, should all receive consideration by S.C.M.s in making appointments. Section Managers are instructed to cancel the appointments of stations not adhering to the schedules agreed upon, and the appointments of stations not returning information on current or revised schedules when periodic surveys of the broadcasting system are made.

Basic A.R.R.L. Appointments

▲ Both Official Relay Station and Official 'Phone Station appointees receive an appointment certificate to be displayed in the station, a quarterly bulletin from Headquarters, and Form 1 reporting cards on which to turn in the monthly reports to the Section Communications Manager.

Appointment certificates (O.R.S. and/or O.P.S.) must be returned to Section Managers annually for proper endorsement to keep these in effect more than one year. Any applicant who fails to qualify may again apply for appointment after three months have elapsed. In making application, forms indicating knowledge of recommended procedure must be filed with the S.C.M. on blanks available from each S.C.M. office. New applicants must communicate *by radio* with a Section official and receive approval of this official or his representative. Operators with personal responsibility and high standards of operating are recognized as O.R.S. and O.P.S., and appointed to these important basic posts in A.R.R.L. organization because they have the qualifications. As a result of operating appointments carefully supervised and given only to active men with demonstrated ability in technical

and operating matters, the present effective field organization, in successful operation for many years, is maintained.

It is the duty of Official Relay Station and Official 'Phone Station appointees (a) to report activities monthly to the S.C.M., whether or not a special reporting form is available; (b) to keep stations always on the air, i.e., in readiness for operation and in actual service; (c) to follow A.R.R.L. operating practices; (d) to take part in the activities of the League whenever possible; (e) to hold message files three months ready for any call by the S.C.M. or licensing authority. *Reports are due on the 16th of each month for mainland United States stations.*

O.R.S. and O.P.S. appointments are not transferable from one station-owner to another. When an appointee moves they may be transferred from one Section to another by arrangement with the S.C.M.s concerned who notify Hq. of cancellation and re-appointment. Appointments may be cancelled by S.C.M.s whenever three consecutive reports are missed, and evidence of regular work and reports for three months must be submitted before such a station may be reinstated. "Earned reinstatements" may be made within one year without filing new application papers. After this the filing of new application papers is desirable, and discretionary with the Section Manager.

The Official 'Phone Station Appointment

▲ This appointment is for every qualified ham who normally uses his "mike" more than his key in his amateur station, and who takes a pride in the manner of signal he puts on the air, and aims to have his station really accomplish worthwhile communication work. Official 'Phone Station appointees must endeavor to live up to the Amateur's Code of good fraternalism and operating equality. The appointment gives 'phone operators the advantages of organization for systematic coöperation in emergencies, quarterly bulletin news, and operating tests. *O.P.S. appointment does not stress traffic handling by voice, but aids 'phone operating enjoyment by helping to formulate good voice operating practices, not overlooking the emergency organization aspect.* The operating standards established make voice work more enjoyable and systematic.

1. O.P.S. use circuit precautions that avoid frequency modulation and overmodulation, and employ indicators in their transmitters to detect maladjustments.

2. O.P.S. coöperate with each other, and with all amateurs, regardless of power, or frequency. No "monopolization" of a frequency channel by an individual operator is permissible, excepting such a situation is demanded by emergency conditions at a station in an isolated area.

3. Major adjustment of transmitters is completed outside of heavy operating hours.

(No needless music playing under the guise of legitimate testing to increase QRM and constitute an exhibition of selfishness. Such tests should be performed using dummy antennas, and radiating antennas connected only for bona fide voice communication.)

4. O.P.S. endeavor at all times to make the



operation of their stations an example to be looked up to by other amateurs; they will stand ready to assist other amateurs in observing frequency bands, in complying with F.R.C. regulations, in adopting and furthering common sense, effective, voice operating procedure as formulated and codified by the group of O.P.S. for the benefit of all, and the furtherance of radiotelephone work.

All operators who use voice should use the suggestions codified to improve operating conditions in the 'phone bands. Official 'Phone Station appointment differs from O.R.S. appointment in that the operators are *not appointed specifically to handle traffic*. Of course when traffic is handled these stations observe the same high standards of responsible operating work; they will therefore at all times cooperate with S.C.M.s and R.M.s by prompt dispatch or delivery of any traffic that may be sent via the 'phone bands. Stations holding O.P.S. appointment will, of course, insist on complete addresses, and give city of origin and number each message carefully in accordance with A.R.R.L. procedure.

The application for O.P.S. appointment does not require a 15-w.p.m. code speed such as prescribed in the test for O.R.S. applicants. Applicants must have had at least one year of amateur operating experience. A description of the station for which appointment is sought must be given the S.C.M. If the arrangement meets modern technique, if the operating experience is adequate, and if the adjustment of the station checked by inspection, or test over the air, is also approved, the A.R.R.L.-O.P.S. appointment may be granted by the S.C.M. and Headquarters so notified at the same time the appointee receives his certificate. The station signal, and its operation too, must meet satisfactory standards.

Appointments may be cancelled for inactivity, or failure to meet prescribed qualifications (like all other A.R.R.L. appointments) to make the O.P.S. appointment really stand for something worth while to all voice-operated amateur stations.

A 'Phone Route Manager or Activities Manager may assist the S.C.M. in necessary station inspection or test-over-the-air for O.P.S. applicants.

This appointment is for every live-wire operator of a first class 'phone, working any 'phone band. Like all other C.D. appointments, one makes application to the Section Communications Manager for O.P.S. appointment, and receives the necessary application forms. A certificate of appointment is issued by the S.C.M. if and when an appointment is granted. Appointments are issued good for one year, but must be kept in effect by activity and annual endorsement by the S.C.M.

If you have a year or more of radiotelephone operating experience behind you, and a well adjusted voice station of modern technique on the air, this is a cordial invitation to you to get in touch with your Section Manager. Tell him you are interested in the Official 'Phone Station appointment; ask him for application forms.

The Official Relay Station Appointment

▲ Every radio telegraphing amateur interested in traffic work and worthwhile operating organization activities who can meet the qualifications is eligible for appointment of his station as A.R.R.L. Official Relay Station. Brasspounders handle traffic because they enjoy such work. There is fun in efficient operation; pride in accomplishing something; opportunity to demonstrate operating proficiency at the same time this is maintained and increased. The potential value of the operator who handles traffic to his community and country is enhanced by his ability, and the readiness of his station and schedules to function in the community interest in case of emergency. Operators with good signals and personal responsibility toward the communications they handle seek and hold Official Relay Station appointment. Traffic-awareness is often the sign by which mature and experienced amateurs may be distinguished from newcomers to the ranks of hamdom.

1. O.R.S. must be able to transmit and receive at least 15 words per minute.

2. O.R.S. cooperate with each other, and with all amateurs. They must make their stations and operating an example to other amateurs. They must follow standard A.R.R.L. operating practices (use proper message form, finish signals, misc. abbreviations, etc., as set forth in the next Chapter).

3. Appointees must keep a transmitter and receiver in operative condition at all times. Consistent activity is required to keep appointments

in effect and must be demonstrated by regular reports to the S.C.M.

4. O.R.S. must display a high degree of interest in relay traffic activities, nets, schedules, trunk lines, and such.

O.R.S. are the "minute men" of amateur radio



— always organized, reporting, active, and holding their equipment in tip-top condition ready for instant service on any communicating problem, large or small. Official Relay Stations are, as the name implies, stations that can be depended on absolutely to see a hard job through. They are ready for every opportunity of service to the public or amateur radio that may come their way, whether a special emergency, test, experiment, or just in the line of ordinary operation. They deliver and relay promptly all traffic that comes their way. O.R.S. appointment is highly significant since it puts the station owner in a special position as respects the opportunities of service. The appointment certificate also has come to be known as the badge that shows an amateur station has "arrived" in the dependable class.

O.R.S. appointees are entitled to wear the distinctive blue A.R.R.L. pin which is similar to the regular membership pin except that it has a blue instead of a black background.

To secure an appointment as Official Relay Station is quite a simple matter if you have the qualifications and a little experience. After building the station, gaining some code speed, and reporting your activities to the S.C.M. as suggested, ask the S.C.M. to furnish you with an application for appointment as Official Relay Station (or use the one printed for your convenience in the rear of this book). The S.C.M. will be glad to send you the necessary forms to be filled out and returned to him, and to give you advice on the application as may be necessary. But you must be willing to accept a certain amount of "personal responsibility" in regard to regular reporting each month, and absolute reliability in forwarding and delivering a number of messages

regularly through your station. The appointment is one made with advantage to yourself. Fill out the application form as soon as you can qualify!

An Invitation

▲ Any A.R.R.L. member who has a station and operator's license and wants to "do things" with his equipment will find it easy and very much worth while to earn an appointment in the Communications Department organization. As has been explained, knowledge and use of certain fundamentals of operating procedure are prerequisite to appointment to the important basic posts in our field organization. Study procedure. Put into practice the things that you read. Originate and relay some traffic regularly. Keep a few schedules with other amateurs. Report all your activities on time (the 16th) each month to your S.C.M. whose address is given on page 5, any *QST*, to prove your qualifications and interest. Regardless of whether you have yet applied for appointment, a postal to the S.C.M. will give him information to use in his report for *QST* and boost the standing of your station and Section.

"Being active" in amateur work should not mean sacrificing all the varied interests we have as individuals. A few hours daily spent in *planned* radio work, a postal to our S.C.M. once each month about our activities, and including traffic handled, gives us credit for all we attempt, contact with and news from fellow hams through *QST*, and adds the touch that makes the difference between organized ham radio and merely haphazard unchronicled work. All reports summed up, make the record for Section and Division. There are many kinds of amateur work; each has its benefits and its leaders. Friendships, DX, technical knowledge, proficiency in construction, ability to operate or communicate, all are important. Interest in a special phase of amateur work is all right if moderation is observed.

The well-balanced amateur will not only know how to handle a message, but will have extended the principles of neatness and efficiency to his other station activities. The complete amateur station includes attention to traffic matters as part of its regular routine; it is one essential in building a reputation for "reliability" in amateur work. Communication (general) involves an exchange of thoughts. "Traffic" is merely the exchange of thoughts for ourselves or others using messages as a simple medium to get the thought "exact and concise." The development of systematic habits of work is beneficial and may extend to fields other than amateur radio with profit also. To get full value from amateur organization work you must take part in such work. The different appointments have been explained. If your station is active you are invited to qualify and take part fully in A.R.R.L. work.

OPERATING A STATION

THE enjoyment of our hobby comes from the operation of our station once we have finished its construction. Upon the *station* and its *operation* depend the traffic reports, DX, and communication records that are made. We have taken every bit of care that was possible in constructing our transmitter, our receiver, frequency measuring and monitoring equipment and in erecting a suitable antenna system. Unless we make ourselves familiar with uniform standard operating procedure, unless we use good judgment and care in operating our stations, we shall fall far short of realizing the utmost in results achieved. More than this, we may make ourselves notorious unless we do the right thing, because we may interfere with other stations or delay their work.

After some listening-in experience you will hear both kinds of operators and realize the contrast that exists between the operation of the good men and that of "lids" and "punks" who have never taken the trouble to familiarize themselves with good practice. Occasionally you will pick up an amateur whose operating is so clean-cut, so devoid of useless efforts, so snappy and systematic, that your respect is gained. It is a pleasure to listen and work with him. On the other hand the operator who sends forty or more CQ's and signs two or three times in a slipshod manner gains the respect of no one. His call may be impossible to identify. His lack of operating judgment seriously impairs and handicaps *his own success and enjoyment* in addition to causing other amateurs to form an unfavorable opinion of his work and the uncalled-for interference he creates. By *proper* procedure the number of two-way contacts (QSO's) and the enjoyment and profit in each will be a maximum.

For most efficient operation, the transmitter should be adjusted for satisfactory, stable, operation on *one frequency* in the amateur band. Use of quartz crystal control helps to insure close adherence to one frequency and gets results when once a dependable arrangement has been installed. With self-controlled sets known condenser settings to approximate certain frequencies will make it possible to change location in the band slightly to get around interference if necessary. But when such a change is made take no chances; always check frequency with care for there is *no* good excuse for off-band operation. Calibrations of the station frequency standard should be checked at least once a month by A.R.R.L. standard frequency transmissions to guard against variations, and daily comparison

with dependable stations assigned channels adjacent to our bands is desirable. Do not try to work too near the edge of an amateur band. Keep well *within* the estimated accuracy of your frequency measuring equipment and means of measurement. Check frequency often.

The operator and his methods have much to do with limiting the range of the station. The operator must have a good "fist." He must have patience and judgment. Some of these qualities in operating will make more station records than many kilowatts of power. Engineering or applied common sense are as essential to the radio operator as to the experimenter. Do not make several changes in the set hoping for better results. Make one change at a time until the basic trouble or the best adjustment is found.

An operator with a clean-cut, slow, steady method of sending has a big advantage over the poor operator. Good sending is partly a matter of practice but patience and judgment are just as important qualities of an operator as a good "fist."

The good operator sends signals which are not of the "ten words per minute" variety, but they are slow enough so that there is no mistaking what he says. The *good* operator does not sit down and send a long call when he wants to work someone. He puts on the 'phones and *listens in*. He goes over the dial thoroughly for some time. The fellow that is admired for his good operating is the one who is always calling some particular station instead of using the "inquiry signal." Because he *listens* until he hears someone to work and *then* goes after him, our good operator gets his man nearly every time. A good operator chooses the proper time to call, he makes plain signals, and he does not call too long. A short call is sufficient because if a station does not get the call it is likely that he is listening to another station. A long call makes the receiving operator lose patience and look for someone else.

The adjustment of the receiver has much to do with successful operation, too. The good receiving operator notes the dial setting and when he has completed calling in proper fashion, he waits a moment and then tunes above or below the logged dial setting just in case something has shifted slightly in the receiver or transmitter. The best operator has patience and waits a few minutes in case of delay at the transmitter or in case fading signals make a second answer necessary.

Communication

▲ After all, communication has as its object the exchange of thought between two minds.

Sometimes those minds are near each other and it is possible for the individuals concerned to converse at length and exchange their thoughts freely. At other times, and this when radio communication is involved, the individuals are miles apart and the thoughts to be transmitted must be condensed to just a few words. Then these words must be relayed or passed on from operator to operator. When they reach their ultimate destination someone can interpret them fully if they have been properly and carefully handled by the intermediate operators.

Time is involved in making any exchange of thought. Because every man's life and experience is measured by time, this factor becomes important in everything we do or say. The number of messages handled, the number of distant stations worked, the number of records made at our station, all depend in some degree on the time available for our hobby. The more time we spend at the set, the more well known our station becomes and the more extensive will be the sum total of our results in amateur radio.

As time is a factor, uniform practices in operating have become necessary to insure a ready understanding of what is going on in the minds of each operator. "Q" signals and abbreviations of various sorts have been devised and are in general use to-day just because of the time element involved, to enable every operator to exchange intelligible thoughts with as little waste effort as possible. So proficiency in the commonly-used abbreviations and in knowledge of uniform operating practices is to be desired. Proficiency comes with practice. In the Appendix are the "Q signals" and some abbreviations used by amateur operators.

Accuracy is of first importance. Then *speed* in transmission and handling of radiograms must be considered. Very often, transmission at moderate speeds moves traffic more quickly than fast sending. A great deal depends on the proficiency and good judgment of the two operators concerned. Fast sending is helpful only when two fast operators work together.

Procedure

▲ Official Relay Stations and Official Phone Stations conform in their operating procedure to definite high standards which are mentioned on the appointment certificate. Some specific rules and regulations have been made to raise the standard of amateur operating. Official A.R.R.L. Stations observe the rules regarded as "standard practice" carefully.

Any actively-operating stations will do well to copy these rules, to post them conspicuously in the station, and to follow them when operating.

1. The calling station shall make the call by transmitting not more than three times the call signal of the station called and the word DE, followed by its own call signal sent not more than

three times, thus: VE9AL VE9AL VE9AL DE W1MK W1MK W1MK. In amateur practice this procedure may be expanded somewhat as may be necessary to establish communication. The call signal of the calling station *must* be inserted at frequent intervals for identification purposes. Repeating the call signal of the called station five times and signing not more than twice (this repeated not more than five times) has proved excellent practice in connection with break-in operation (the receiver being kept tuned to the frequency of the called station). The use of a break-in system is highly recommended to save time and reduce unnecessary interference.

Stations desiring communication, without, however, knowing the calls of the operating stations within range, may use the signal of inquiry CQ, in place of the call signal of the station called in the calling formula. The A.R.R.L. method of using the general inquiry call (CQ) is that of calling three times, signing three times, and repeating three times. CQ is not to be used when testing or when the sender is not expected or looking for an answer. After a CQ, the dial should be covered thoroughly for two or three minutes looking for replies.

The directional CQ: To reduce the number of useless answers and lessen QRM, every CQ call shall be made informative when possible. Stations desiring communication shall follow each CQ by an indication of direction, district, state, continent, country or the like. Stations desiring communication with amateur stations in a particular country shall include the official prefix letters designating that country after each CQ. The city, state, point of the compass, etc., is mentioned and the thrice-repeated station call. International prefixes (page . . .) may be used to identify a particular country. Examples follow. A United States station looking for any Canadian amateur calls: CQ VE CQ VE CQ VE DE W1MK W1MK W1MK K. A western station with traffic for the east coast when looking for an intermediate relay station calls: CQ EAST CQ EAST CQ EAST DE W6CIS W6CIS W6CIS K. A station with messages for points in Massachusetts calls: CQ MASS CQ MASS CQ MASS DE W3QP W3QP W3QP K. In each example indicated it is understood that the combination used is repeated three times.

2. Answering a call: Call three times (or less); send DE; sign three times (or less); and after contact is established decrease the use of the call signals of both stations to once or twice. Example. W1BIG DE W1MK GE OM GA K (meaning, "Good evening, old man, I am ready to take your message, go ahead").

3. Ending signals and sign off: The proper use of AR, K and SK ending signals is as follows: AR (end of transmission) shall be used at the end of messages during communication and also at the end of a call, *indicating when so used that com-*

munication is not yet established. In the case of CQ calls, the international regulations recommend that K shall follow. K (invitation to transmit) shall also be used at the end of each transmission when answering or working another station, carrying the significance of "go ahead." SK (or VA) shall be used by each station only when signing off, this followed by your own call sent once for identification purposes. SK (end of work) sent alone, or for clarification followed by a single (never more) "CQ DE - - - -," indicates to others that you are through with the station which you have been working and will listen for whomever wishes to call. Examples:

(AR) G2OD DE W1AQD AR (showing that W1AQD has not yet gotten in touch with G2OD but has called and is now listening for his reply). Used after the signature between messages, it indicates the end of one message. There may be a slight pause before starting the second of the series of messages. The courteous and thoughtful operator allows time for the receiving operator to enter the time on the message and put another blank in readiness for the traffic to come. If K is added it means that the operator wishes his first message acknowledged before going on with the second message. If no K is heard, preparations should be made to continue copying.

(K) ZL2AC DE W6AJM R K. (This arrangement is very often used for the acknowledgment of a transmission. When anyone overhears this he at once knows that the two stations are in touch, communicating with each other, that ZL2AC's transmission was all understood by W6AJM, and that W6AJM is telling ZL2AC to go ahead with more of what he has to say.) W9APY DE W3ZF NR 23 R K. (Evidently W9APY is sending messages to W3ZF. The contact is good. The message was all received correctly. W3ZF tells W9APY to "go ahead" with more.)

(SK) R NM NW CUL VY 73 AR SK W7NT. W7NT says "I understand OK, no more now, see you later, very best regards. I am through with you for now and will listen for whomever wishes to call W7NT signing off.")

4. If a station sends test signals to adjust the transmitter or at the request of another station to permit the latter to adjust its receiving apparatus, the signals must be composed of a series of V's in which the call signal of the transmitting station shall appear at frequent intervals.

5. When a station receives a call without being certain that the call is intended for it, it shall not reply until the call has been repeated and is understood. If it receives the call but is uncertain of the call signal of the ending station, it shall answer using the signal - - - - (?) instead of the call signal of this latter station. QRZ? (see Appendix) is the appropriate signal to use, followed by your call to ask who is calling and get this station to call again.

6. Several radiograms may be transmitted in series (QSG) with the consent of the station which is to receive them. As a general rule, long radiograms shall be transmitted in sections of approximately fifty words, each ending with - - - - - (?) meaning, "Have you received the message correctly thus far?"

7. A file of messages handled shall be kept, this file subject to call by the Section Manager at any time at his discretion. Only messages which can be produced shall be counted in the monthly reports, and these under the A.R.R.L. provisions for message-counting.

Above all, the operator will *never make changes or alterations in the texts or other portions of messages passing through his hands*. However slight or however desirable such changes may seem, the changing of a message without proper authority or without the knowledge of the originator of the message may be considered the "unpardonable sin." The proper thing to do of course is to notify the party filing the message or the originating station of your observations, secure permission from the proper source for making the change by sending a "service message" or other means. If the case seems urgent, the traffic should not be delayed but should be delivered or forwarded with appropriate notation or service accompanying it.

In acknowledging messages or conversation: Never send a single acknowledgment until the transmission has been successfully received. "R" means "All right, OK, I understand *completely*." When a poor operator, commonly called a "lid," has only received part of a message, he answers, "R R R R R R R R R R R R, sorry, missed address and text, pse repeat" and every good operator who hears, raves inwardly. The string of acknowledgments leads one to believe that the message has been correctly received and that it can be duly filed away. By the time this much is clear it is discovered that most of the message did not get through at all, but must be repeated. The part after the string of R's may be lost due to fading or interference. It may be assumed the message was correctly received. (The message then filed never arrives at its destination.) Be clear and understandable. Use R *only* when *all* is received correctly.

Here is the proper procedure to follow when a message has been sent and an acknowledgment is requested. When all the message has been received correctly a short call followed by "NR 155 R K" or simply "155 K" is sufficient. When most of the message was lost the call should be followed by the correct abbreviations (see Appendix) from the international list, asking for a repetition of the address, text, etc. (RPT ADR AND TXT K). When but a few words were lost the last word received correctly is given after ?AA, meaning that "all after" this should be repeated. ?AB for "all before" a stated word

should be used if most of the first part of the copy is missing. ?BM AND (two stated words) asks for a fill "between" certain sections. If only a word or two is lost this is the quickest method to get it repeated.

Do not send words twice (QSZ) unless it is requested. Send single unless otherwise instructed by the receiving operator. When reception is very poor, a QSZ can be requested to help make better copy. When conditions are even moderately fair, a QSZ is unnecessary. Few things are as aggravating as perfect transmission with every word coming twice. Develop self-confidence by not asking others to "QSZ" unless conditions are rather impossible. Do not fall into the bad habit of sending double without a request from fellows you work.

Do not accept or start incomplete messages. Omission of the fundamental parts of a message may keep a message from getting through to its destination. Official Relay Station appointments are subject to cancellation for failure to make messages complete enough.

Operating Notes

▲ A sensitive receiver is often more important than the power input in working foreigners. There is not much difference in results with the different powers used, though a 250-wattter will probably give 10% better signal strength at the distant point than a Type '52, 800 or 10's, other factors being the same. It will not do much better than this because the field strength drops so rapidly as we get away from the antenna. In working foreign countries and DX stations you should be able to hear ten or a dozen stations before expecting that one of them will hear your call.

Hams who do not raise DX stations readily may find that (a) their sending is poor, (b) their calls ill-timed or judgment in error. It is usually wasted effort for W/VE stations to send CQ DX. When conditions are right to bring in the DX, and the receiver sensitive enough to bring in several stations from the desired locality, the way to raise DX is to use the appropriate frequency and to call these stations. Reasonably short calls, with appropriate and brief breaks to listen will raise stations with minimum time and trouble. The reason W/VE CQs do not raise DX is that the number of U. S. A. and Canadian hams is so great that it is always possible for a foreign station to find a large number of W/VE's calling, without wasting time on stations not definitely looking for this station.

The signal "V" is sometimes sent for two to five minutes for the purpose of testing. When one station has trouble in receiving, the operator asks the transmitting station to "QSV" while he tries to adjust his receiving set for better reception. A decimal point is often sent by the letter "R." Example: 2.30 PM is sent "2R30 PM." A long dash for "zero" and the Morse C (. . .) for

"clear" are in common use. An operator who misses directions for a repeat will send "4," meaning, "Please start me, where?" These latter abbreviations, like others in our present-day practice, are hybrids, originating in wire practices and Morse usages.

Improper calling is a hindrance to the rapid dispatch of traffic. Long calls after communication has been established are unnecessary and inexcusable. Some stations are slow to reply to a call. However, the day of the station with dozens of switches to throw is past. Controls for both receivers and transmitters are simpler, fewer in number, and more effective. The up-to-date amateur station uses a "break-in" system of operation and just one switch controlling the power supply to the transmitter.

Poor sending takes the joy out of operating. There are stations whose operators are not able to send better and those who can send better but do not. The latter class believe that their "swing" is pretty. Some use a key with which they are not familiar.

Beginners deserve help and sympathetic understanding. Practice will develop them into good operators. The best sending speed is a medium speed with the letters quickly formed and sent evenly with proper spacing. The standard type telegraph key is best for all-round use. Before any freak keys are used a few months should be spent listening-in and practicing with a buzzer. Regular daily practice periods, two or three half hour periods a day, are best to acquire real familiarity and proficiency with code.

No excuse can be made for a "garbled" text. Operators should copy what is sent and refuse to acknowledge messages until every word has been received correctly. *Good operators never guess at anything.* When not sure of part of a message they ask for a repeat. The "lid" operator can be told very quickly when he makes a mistake. He does not use a definite "error" signal and go on with his message but he usually betrays himself by sending a long string of dots and nervously increasing his rate of sending. The good operator sends "???" after his mistakes and starts sending again with the last word sent correctly. Unusual words are sent twice; "???" is sent and then the word repeated for verification.

The law concerning superfluous signals should be noted carefully by every amateur. Some operators hold the key down for long periods of time when testing or thinking of something to send. Whenever this is done during operating hours, someone is bothered. Unnecessary interference prevents someone from getting in contact with (QSO) someone else, and if messages are being handled the copy is ruined. If you must test, disconnect the antenna system and use an equivalent "dummy" antenna (made of lumped resistance, capacity and inductance). Always send your call frequently when operating with the

antenna. Pick a time for adjusting the station apparatus when few stations will be bothered.

Using a Break-in System

▲ A break-in system of operation makes it possible for us to interrupt the other fellow if we miss a word or do not understand him. With a telephone we stop talking as soon as the distant party speaks and interrupts us. In a telegraph office the operator who misses a word opens his key so that the sending is interrupted and cannot go on until the receiving operator has had his say and again closed the circuit. In a radio system using break-in the receiving operator presses the key and makes some long dashes for the transmitting operator to hear. As soon as he gets the signal he stops transmitting and listens to what the receiving operator says, before resuming sending.

A separate receiving antenna makes it possible to listen to most stations while the transmitting tubes are lighted. It is only necessary with break-in to pause just a moment occasionally when the key is up (or to cut the carrier momentarily and pause in a 'phone conversation) to listen for the other station. Appreciation of the many advantages should make the use of break-in wide-spread for both voice and code work.

Useless calling and unnecessary transmission during periods of heavy QRM can be prevented through intelligent use of break-in. Long calls, for example, are inexcusable, inconsiderate and unnecessary. Every transmitter can be so arranged that by lifting the key (and connecting 'phones to the receiver if these are cut off during transmission) the operator can ascertain if the station called is replying. Brief calls with frequent short pauses to listen for replies constitute intelligent operating, devoid of useless effort. During c.w. transmissions insert a "BK" and pause briefly at intervals. This makes it possible for the other operator to stop you, or get fills, if necessary. If not, transmission may be resumed. If you find that the station you are calling has, in the meantime, connected with another amateur instead of answering your call you will have at least saved yourself some wasted effort. QRM will also be lessened thereby. If the operators understand that break-in is being used, a "bk" and "g.a." will be of greatest value to interrupt transmission and direct when it shall be resumed. Where voice is being used similarly, conversations resemble wire telephone communication, and flow smoothly from subject to subject, and the "click" noted when the carrier is cut off momentarily can be as effective as the word "break" (so this can be eliminated) when two operators experienced in this mode of operating use this improved system of operation.

The faster the change from transmitting to receiving can be engineered the better. A Morsewire type key with a switch on the side, in series

with either the filament center-tap (cathode) of the oscillator stage, or in the negative high voltage supply can be used for *voice* break-in. (There must be enough fixed bias on amplifier stages to keep the plate current low when r.f. excitation is nil, and h.v. on, of course.) If there is audio feedback from speaker to microphone, head-phones should solve the problem, or if desired a relay can be used to short the microphone transformer. A push button to put the carrier on the air only while talking is a completely practical device, and amateur 'phone operators would do well to emulate the push-to-talk efficiency of the Airways operators to improve conditions in the 'phone bands.

C.w. telegraph break-in is usually simple to arrange. With break-in, ideas and messages to be transmitted can be pulled right through the holes in the QRM. Snappy, effective, efficient, enjoyable amateur work really requires but a simple switching arrangement in your station to cut off the power and switch 'phones from monitor to receiver. If trouble occurs the sending station can "stand by," (QRX) or it can take traffic until the reception conditions at the distant point are again good.

In calling, the transmitting operator sends the letters "BK," "BK 1N," or "BK ME" at frequent intervals during his call so that stations hearing the call may know that a break-in is in use and take advantage of the fact. He pauses at intervals during his call, to listen for a moment for a reply from the station being called. If the station being called does not answer, the call can be continued. If the station called answers someone else, he will be heard and the calling can be broken off. When two stations are using break-in, they can interrupt each other at any time when something goes wrong or a letter is dropped, and traffic can be handled in half the usual time. There is a real "kick" from working a break-in arrangement.

Keeping a Log

▲ Every operator of an amateur station must keep a log of the operating work that is done; it should cover, as well, the tests of an experimental nature that are carried out with the transmitter or receiver.

The well-kept log is invaluable in checking up reports of any nature concerning amateur station operation. It contains positive evidence of every transmission. It is a permanent record of the achievements of the station. The Federal Communications Commission obliges every amateur station to maintain an accurate log of the time of *each* transmission, the station called, the input power to the last stage of the transmitter, the frequency band used, the time of *ending* each QSO and the operator's personal "sine" for each session of operating. So, in addition to other excellent reasons for log-keeping, the regulations

make a complete record of transmitting activity compulsory.

Amateurs always have kept logs because of the ready-reference value in proving records and because of the pleasant recollections and associations that come from reviewing the history of friendly radio contacts and from displaying the record of the accomplishments of the station to interested visitors and friends.

A loose-leaf notebook can be used. The sheets can be renewed each month and those used can be taken out and filed away with the cards and station records. A stenographer's ordinary notebook costing from ten to thirty cents and about 4½" by 8½", takes little space on the operating table and also makes a good log book. If simplicity and low cost are the only considerations, such a modified notebook-log is recommended.

A dozen pages may be ruled in advance with vertical lines. In the first column the date and time are noted. In the second column the calls of stations worked, heard, and called are put down. A circle, parentheses, or a line drawn under the call can indicate whether a station was worked, heard and called, or simply heard. A special designating sign or abbreviations before or after the call letters can show this information. Provision must be made for entering the power, the time of ending QSOs, and the frequency band used. W, H, and C can be used for "worked," "heard" and "called."

Most amateurs find it more convenient to get an inexpensive ready-made log, instead of going to the trouble to rule the home brewed variety. In keeping a log, power and frequency can be written across the page, or in the page heading, new entries being made only when these are changed. The dial settings of receiver or frequency meter may be entered in logging stations so that we can come back to these same stations without difficulty when desired.

Figure 1 shows the official A.R.R.L. log. The first entry for each watch is that for the date and time. Greenwich Civil Time is the logical reference standard but local standard time is easiest to use to avoid confusion and so this is used by most amateurs, PST, MST, CST, EST, GCT, etc., is entered in the heading of the first column in the A.R.R.L. log and then the date which corresponds to that kind of time is put in the first space below the heading, and time entries on the first vacant line below that, those to be entered progressively until a change in date.

CW and F (or P) can be used in the heading to distinguish between your use of c.w. telegraphy and radiophone operation; or A1, A2, or A3 standing for c.w. telegraphy, c.w. telegraphy modulated at audible frequencies, and radiotelephony (speech), respectively.

Log users will quickly adopt certain convenient practises which simplify the keeping of a log such

as use of an X for one's own call signal, to save time in making the entries. When several stations answer a CQ, each should be listed in the third column following your own call signal in the second column. Any unusual data requiring explanation, such as an interrupted or incomplete contact due to power line failure, local interference, etc., should go in the "remarks" column. Also a detailed record of messages exchanged should be entered. This last column

AMATEUR RADIO STATION LOG											
Input power in last space		275		watts		If operating as portable or portable mobile.		Appropriate location.			
Frequency		3600 KC		Type of antenna		C.W.		Type of vehicle or vehicle used in which installed.			
DATE (M/D/Y)	STATION CALL LETTERS	CALL BY	STATION WORKED OR HEARD			IF QSO RESULTED			CHANGES FROM PREVIOUSLY RECORDED AND DATA RECORDED PREVIOUS ETC.		
			CLASS	TIME	POWER	TYPE OF	TIME OF	POWER	REMARKS	REMARKS	REMARKS
10/15/39											
6:30 PM	W7WY	X	32	5	4	4	4	4	4	4	4
6:35	WE8H	VE5AC	22	5	5						EP sig. clear! Next time "Q"
7:01	CG	X									Change initial traffic.
7:04	X	W7XY	1035	4	5	8	1	5	4	7:22 PM	Work! What QRM!! Made
											What for? Too many QRM!!
7:37	W7LIE	X	49	3	3	7					QRM! same line
7:40	W7EY	X	67	4	4	9	7	5	7	8:11 PM	Washington, D.C. Amateur!!
8:15	W7FLN	X	30.00	5	5	7				8:30 PM	Altd. Ave S. Riv. 3
8:30	ORZ	X									
8:31	X	W5CEZ								8:40 PM	Home 850 with W7ELN. And 1
8:36	CA	X									No work.
8:36	W7TY	W7BVC	89								Conversations on 'com.
9:02	NA	off									

FIG. 1

KEEP AN ACCURATE AND COMPLETE STATION LOG AT ALL TIMES! THE F.C.C. REQUIRES IT

The official A.R.R.L. log is shown above, answering every government requirement in respect to station records. Bound logs made up in accord with the above form can be obtained from Headquarters for a nominal sum or you can prepare your own, in which case we offer this form as a suggestion, hoping that you find it worthy of adoption. Every station must keep some sort of a log.

should show the "sine" of a new operator taking the key, remarks, message notations, changes from previously recorded (heading) information, etc. Special provision is made in the A.R.R.L. log, for recording signal reports, and the time of ending each QSO as required by the F.C.C. Entries in this column at once show which stations were "worked" without special indications of C, W, or H being necessary.

Left-hand pages in the log may be left blank to use for extensive remarks on emergencies or expeditions, for diagrams, records of tuning adjustments and ranges, or changes in equipment.

A log is of great value in a number of additional ways through use of these left-hand pages. A comparison of the operating results obtained with different apparatus in use at different times is valuable. The "DX" or traffic-handling value of the various frequencies over varying distances may be readily found from the log. The effect of weather or time of day may be also quickly found. Every change made in either the transmitter or antenna system should be noted down in the log so that results may be compared for dates before and after the date when a change was made. No matter how trivial the change,

put it down in the log. Remember that only one change at a time should be made if the changed results are to be attributed to one definite cause.

Word List for Accurate Transmission

▲ When sending messages containing radio calls or initials likely to be confused and where errors must be avoided, the calls or initials should be thrown into short code words:

- | | | |
|------------|-----------|-----------|
| A — ABLE | J — JIG | S — SAIL |
| B — BOY | K — KING | T — TARE |
| C — CAST | L — LOVE | U — UNIT |
| D — DOG | M — MIKE | V — VICE |
| E — EASY | N — NAN | W — WATCH |
| F — FOX | O — OROE | X — X-RAY |
| G — GEORGE | P — PUP | Y — YOKE |
| H — HAVE | Q — QUACK | Z — ZED |
| I — ITEM | R — ROT | |

Example: *WIBCG* is sent as *WATCH ONE BOY CAST GEORGE*.

A somewhat different list can be obtained from the local Western Union telegraph office and posted beside the telephone to use when telephoning messages containing initials and difficult words. Such code words prevent errors due to phonetic similarity. Here is the Western Union word-list:

- | | | |
|-------------|--------------|-------------|
| A — ADAMS | J — JOHN | S — SUGAR |
| B — BOSTON | K — KING | T — THOMAS |
| C — CHICAGO | L — LINCOLN | U — UNION |
| D — DENVER | M — MARY | V — VICTOR |
| E — EDWARD | N — NEW YORK | W — WILLIAM |
| F — FRANK | O — OCEAN | X — X-RAY |
| G — GEORGE | P — PETER | Y — YOUNG |
| H — HENRY | Q — QUEEN | Z — ZERO |
| I — IDA | R — ROBERT | |

'Phone Procedure

▲ Amateur radiophone stations should use the international radiotelephone procedure which is part of the supplementary regulations to the International Radiotelegraph Convention.

For spelling call signals, service abbreviations and words, such lists as just given should be used.

At the start of communication the calling formula is spoken twice by both the station called and the calling station. After contact is established it is spoken once only. Examples of 'phone procedure in accordance with the International Radiotelegraph Convention:

W5QL calls: "Hello W3JZ Philadelphia, hello W3JZ Philadelphia, W5QL Oklahoma City calling, W5QL Oklahoma City calling, message for you, message for you, come in please."

W3JZ replies: "Hello W5QL Oklahoma City, hello W5QL Oklahoma City, W3JZ Philadelphia answering, W3JZ Philadelphia answering, send your message, send your message, come in please."

W5QL replies, "Hello W3JZ Philadelphia, W5QL Oklahoma City answering, the message begins, from Oklahoma City Oklahoma W5QL number [usual preamble, address, test,

signature, etc.], message ends; I repeat, the message begins, from Oklahoma City Oklahoma W5QL number [repetition of preamble, address, text, signature, etc.], message ends, come in please."

W3JZ replies: "Hello W5QL Oklahoma City, W3JZ Philadelphia answering, your message begins, from Oklahoma City Oklahoma W5QL number [repetition of complete message], end of your message, come in please."

W5QL replies: "Hello W3JZ Philadelphia, W5QL Oklahoma City answering, you have the message correctly, you have the message correctly, W5QL Oklahoma City signing off."

Note that in handling traffic by voice, messages are repeated *twice* for accuracy, using the word list to spell names and prevent misunderstandings. The receiving station must repeat the message back *in addition*. Only when the sender *confirms* the repetition as correct can the message be regarded as handled.

Amateur Status

▲ It is most important that individually and as an organization we be most careful to preserve our standing as amateurs by doing nothing to harm that most precious possession, our amateur status.

No brief can be held for the amateur who accepts direct or indirect compensation for handling specific messages. This is in direct violation of the terms of the amateur station license and the regulations of the Federal Radio Commission.

It is the purpose of these paragraphs to warn amateurs to avoid being "used" by commercial interests in unethical ways. An amateur asked our advice recently on accepting a whole set of fine station equipment from a business house — the only string being that he should consistently try to handle some traffic with a certain foreign point. A hotel on the Pacific Coast offered an amateur radio club a fine meeting place with free light, power and heat — provided the amateurs would establish an amateur station and relay messages for guests of the hotel. A certain newspaper planned to "organize an amateur radio club" and establish a "net" for the collecting of amateur news for the paper. It offered the amateurs a club room and the facilities of a powerful station that it would install as "net control station" in return for the things it could gain by making amateurs violate their amateur status!

There are plenty of legitimate activities in which amateurs may participate. The League approves amateur cooperation with worthy enterprises, sponsors tests to show the utility of short-wave communication, encourages worth-while service to expeditions in getting their messages from the far parts of the earth. Be assured that there is nothing wrong in accepting trophies and prizes of any sort for legitimate amateur competition in communication contests. Watch carefully

BEFORE EMERGENCIES

Be ready, with really portable sets, and emergency power supply.

Overhaul and test periodically.

Give local officials and agencies your address; explain the availability of amateur radio facilities through your station in emergencies.

IN EMERGENCY

CHECK station operating facilities; offer your services to all who may be able to use them; inform A.R.R.L. an emergency exists, if possible.

QRR is the official A.R.R.L. "land SOS," a distress call for emergency use *only* . . . for use *only* by station asking assistance.

THE KEY STATION in emergency zone is the first and the supreme authority for priority and traffic routing in the early stages of emergency relief communications.

PRIORITY must be given messages in the general public interest (relief plans, re food, medicine, necessities). Press reports and personal assurance messages can then be handled if practicable.

COÖPERATION is required of all amateurs. Don't clutter the air with useless CQs. The majority of amateurs must *listen in*; QRX; avoid QRMing. Be ready to help; operate as intelligently as possible; coöperate by staying off the air while vital first information and relief measures are handled, if stations able to help as well as yours are on the job. (CQ STORM AREA is nothing but "more QRM.")

AFTER EMERGENCIES

REPORT to A.R.R.L. as soon as possible and as fully as possible so amateur radio can receive full credit. Amateur radio communication in 33 major disasters since 1919 has won glowing public tribute. Maintain this record.

and refuse to enter into any agreement or alliances through which you accept anything in the nature of a consideration for services rendered in connection with your amateur radio station. There is no question of the good intentions of the amateurs involved in the several cases cited. Very great damage can be done unless there is strict observance of both the spirit and letter of the regulations involving amateur status. Avoid sugar-coated promises and opportunities which might be construed as direct or indirect compensation and a violation of amateur status. Seek competent advice before you jump at chances to get something for nothing. Preserve your most valued possession, your status as an amateur.

Our right to handle friendly communications of worth-while character and to engage in valuable work of all kinds in emergencies and with expeditions remains unquestioned. A "consideration" of any nature whatsoever absolutely establishes the "commercial" nature of any traffic.

Emergency Work — QRR

▲ Amateurs have always given an excellent account of themselves in many emergencies of local and national character. In every instance, the amateurs who have considered the possibilities of an emergency arising *before* the trouble actually came to pass were the ones who must be credited with doing the most important work. They were ready, prepared for the crisis when it came.

Considerations of an emergency power supply are of first importance in many cases where radio is destined to play a part. If local electric service mains are crippled one may have recourse to B batteries, dynamotors driven from storage batteries, and the like. By consulting with other amateurs and putting all the available facilities together in the most favorable location a station can be made operative in short order. An order from some competent authority will make supplies of batteries or temporary service from a public utilities company available for emergency stations. It is sometimes as easy to move the amateur station to a power supply as to collect a power supply together and bring it to the amateur station. This is especially true if the transmitter and receiver are built as independent units. In some emergencies B batteries have been provided from local electrical supply stores.

During emergencies it is often possible to send press addressed to U.P., A.P., N.A., A.N., etc. between the transmissions of relief priority traffic. Invariably such messages are correctly delivered to local member-newspapers in such associations, the public kept informed, and amateur radio credited. Such broadcasts should be sent at regular intervals if possible. They have sometimes been overlooked in the rush.

Be ready for the emergency call, QRR, when it comes. Jump into the breach with your station if feasible or stand by and avoid interference to those handling emergency traffic if this seems to be the right thing to do. "Standing by" is sometimes the harder but wise course if the important communications are being handled satisfactorily by others and your traffic is "public correspondence" for individuals.

Make note of the address of railroads, of Red Cross headquarters, of local military units, police departments, representatives of press associations and the like, if possible putting your station on record with such organizations and other competent authorities so that you will be called upon to assist when emergency communication is necessary. When storms approach or disaster threatens it is best to keep in touch with the situation by radio and again to offer service to these agencies well in advance of the actual emergency. Emergency work reaps big returns in public esteem and personal satisfaction.

After emergency communications are completed, report in detail direct to A.R.R.L. just

what part you and fellow amateurs played in the situation. On such reports *QST* articles are written. From analysis of all reports an Award Committee of A.R.R.L. Headquarters officials, base their recommendations for awards granted for notable "public service" work. Certificates are given individual amateur operators from time to time in recognition of meritorious work contributing substantially to the service record of the amateur through noteworthy achievement in emergencies, and regular work with expeditions. Report your work!

Stations outside an "emergency zone" in communication with relief stations in that zone are requested to inform A.R.R.L. Headquarters of this situation by telegram to facilitate traffic movement and for the information of the press.

The R-S-T System of Signal Reports

▲ A standard system of reporting signals is recommended by the A.R.R.L. The R-S-T system is, in short, an abbreviated method of indicating the main characteristics of a received signal, the Readability, Signal Strength, and Tone. The method of using the R-S-T system is extremely simple. The letters R-S-T determine the order of sending the report. In asking for this form of report, one transmits RST? or simply QRK?

Such a signal report as "RST 347X" (which may be further abbreviated to 347X whenever it is clearly understood that reports follow the R-S-T system) will be interpreted as, "Your signals are readable with considerable difficulty; good signals (strength); near d.c. note, smooth ripple; crystal characteristic noticed." Unless it is desired to comment in regard to a crystal characteristic of the signal, a single three-numeral group will constitute a complete report on an amateur signal. Various report combinations are based on the following tables:

READABILITY

- 1 — Unreadable
- 2 — Barely readable, occasional words distinguishable
- 3 — Readable with considerable difficulty
- 4 — Readable with practically no difficulty
- 5 — Perfectly readable

SIGNAL STRENGTH

- 1 — Faint, signals barely perceptible
- 2 — Weak signals
- 3 — Fairly good signals
- 4 — Good signals
- 5 — Very strong signals

TONE

- 1 — Extremely rough hissing note
- 2 — Very rough a.c. note, no trace of musicality
- 3 — Rough, low-pitched a.c. note, slightly musical
- 4 — Rather rough a.c. note, moderately musical
- 5 — Musically modulated note
- 6 — Modulated note, slight trace of whistle
- 7 — Near d.c. note, smooth ripple
- 8 — Good d.c. note, just a trace of ripple
- 9 — Purest d.c. note

(If the note appears to be crystal controlled simply add an X after the appropriate number.)

The QSA- and R-Systems

▲ The Madrid Convention (Appendix 10, General Regulations) gives a scale of definitions which indication, given after the appropriate Q signal, is specified to show progressive signal strength. QSA means, "The strength of your signals is . . ." Some of the definitions, however, appear to confuse audibility or signal strength with readability, which may be impaired even when signals are strong, by atmospherics, interference, a noisy receiver, etc.

- QSA1 — Hardly perceptible, unreadable
- QSA2 — Weak, readable now and then
- QSA3 — Fairly good, readable but with difficulty
- QSA4 — Good, readable
- QSA5 — Very good, perfectly readable

Since, due to the wording, the internationally-formulated definitions of signal strength by the QSA system have been used by amateurs as a "readability" scale, amateurs have supplemented this by use of the following table of definitions, constituting the R system of indicating audibility, or signal strength without regard to other sounds in the 'phones or room. The QSA and R systems are usually used together, when used. The R-S-T reports are given as a three-numeral block, so the definitions will not be confused with QSA-R designations.

- R1 — Faint signals, just audible
- R2 — Weak signals, barely audible
- R3 — Weak signals, copiable (in absence of any difficulty)
- R4 — Fair signals, readable
- R5 — Moderately strong signals
- R6 — Strong signals
- R7 — Good strong signals (such as copiable through interference)
- R8 — Very strong signals; can be heard several feet from phones
- R9 — Extremely strong signals

Interference Problems

▲ The subject of public relations is important to us amateurs both individually and as an organization. No amateur can long afford to operate when he knowingly interferes widely with broadcast reception in his neighborhood and when there are simple remedies to be applied. Even the observance of prescribed quiet hours, while covering the situation legally, does not entirely suffice. Patience in explaining, frankness, tolerance in listening to other viewpoints and other qualities of diplomacy are needed to give the full technical explanations required. Evidence of fair dealing, and cooperation with listeners is always given weight when F.R.C. representatives find it necessary to investigate facts in an interference case.

Actually most interference is traceable to faulty electrical equipment, inadequate shielding or poor design of receivers, and less than one per cent. of the interference reported is traceable to amateur sources.

It is necessary for both parties to an interference problem to understand that *both the*

transmitter and the receiver are part of the problem — improved adjustment of the former — improved design of the latter to increase its selectivity, may be necessary. Where "proximity" is part of the problem special measures should be considered to isolate circuits and equipment by installation of suitable "traps," to aid selectivity, or by chokes and condensers to prevent "coupling" through common supply line wires. Each individual must accept responsibility for his equipment. Coöperation is the only policy that will help either party — a full measure of coöperation and understanding must be brought about in every interference case.

Club Interference Work

▲ We recommend and request that each A.R.R.L. affiliated club organization maintain an interference committee, to keep order, make investigations and recommendations locally, coöperate with the press, the public, and listeners who wish to file complaints of amateur interference. These committees can be composed of representative broadcast listeners, amateurs and with one member from a local newspaper to assist in collecting and referring complaints. A few leading questions will disclose the amateur cases and other difficulties can be referred to local power and communications companies.

The club interference committees investigate reports of *amateur* interference, put the interested parties in touch with each other and suggest ways of reducing or getting rid of the interference. When quiet hours are necessary, they are recommended.

Call Books

▲ The "Radio Amateur Call Book Magazine," listing amateur and many high-frequency commercial stations of the entire world, may be obtained from A.R.R.L. Headquarters, 38 La Salle Road, West Hartford, Conn., single copies, \$1.25 (foreign \$1.35). This call book now appears in March, June, September and December, with new calls added up to the date of issue. Yearly subscription, \$4.00 (foreign \$4.35). This publication is the most up to date of all such books, since it is issued and revised quarterly. An up-to-date call book is a practical necessity and convenience in just about every ham station.

A complete list of Canadian amateur station calls can be obtained for 25 cents from the Department of Marine and Fisheries, Ottawa, Canada.

Operating Hints

▲ Listen carefully for several minutes before you use the transmitter to get an idea of what stations are working. This will help in placing messages where they belong.

Use abbreviations in operating conversations. This saves time and cuts down unnecessary interference.

Stand by (QRX) when asked to by another station who is having difficulty working through your interference. It is equally courteous to shift frequency to a point where no interference will be caused. Sometimes a change in frequency will help the station you are working to get your message through interference. Accurate frequency meters at both stations will make this change speedy and the contact sure.

Report your messages to the local traffic official every month on time, otherwise you cannot expect your report to reach *QST*. Reports sent to Headquarters are routed back to the local officials who make up the monthly report.

Don't say, "QRM" or "QRN" when you mean "QRS."

Don't acknowledge any message until you have received it completely.

Don't CQ unless there is definite reason for so doing. When sending CQ, use judgment. Sign your call frequently, interspersed with calls, and at the end of all transmissions.

Abbreviated standard procedure deserves a word in the interest of brevity on the air. Abbreviated practices help to cut down unnecessary transmission. However, make it a rule not to abbreviate unnecessarily when working an operator of unknown experience.

W1AUF DE W1BMS P, meaning paid, personal, or private message (adopted from commercial procedure) is much quicker than *IIR MSG* added to a call. *NIL* is shorter than *QRU CU NEXT SKED*. Instead of using the completely spelled out preamble *IIR MSG FM AUGUSTA MAINE W1BIG NR 156 OCTOBER 13 CK 14 TO*, etc., transmission can be saved by using *AUGUSTA ME W1BIG 156 OCT 13 14 TO*, etc. One more thing that conserves operating time is the cultivation of the operating practice of writing down "156 W1UE 615P 11/13/33" with the free hand during the sending of the next message.

"Handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and entry of date, time and station call *on the traffic*, as handled, for purposes of record.

All messages should be handled in standard A.R.R.L. form.

Be courteous over the air. Offer suggestions for improving the other fellow's note or operating methods. Expect and ask for similar suggestions without expecting any praise. Constructive things can be said without being disagreeable or setting one's self up as a paragon. *Be truthful but tactful.*

CHAPTER SIXTEEN

MESSAGE HANDLING

ONE activity of the League that is quite important is the accepting and relaying of messages. Station owners may originate traffic of *any kind* going to any part of the United States, Hawaii, Porto Rico, Alaska, or the Philippines. Messages with amateurs in Canada, Chile, and Peru may be handled under certain restrictions. Important traffic in emergencies or messages from expeditions for delivery in Canada must be put on a land wire by the U. S. amateur station handling. International regulations prohibit the handling of third party messages to the majority of foreign countries. Messages relating to experiments and personal remarks of such unimportance that recourse to the public telegraph service would be out of the question may be handled freely with the amateurs of any country, but third party messages only under special arrangements between U. S. A. and other governments, and only to the extent agreed upon by the contracting governments.

Messages may be accepted from friends or acquaintances for sending by amateur radio. Such messages should be put in as complete form as possible before transmitting them. *Incomplete messages should not be accepted.* As messages are often relayed through several stations before arriving at their destination, *no abbreviations should be used in the text* as mistakes are bound to happen when the text is shortened in this manner. To people not acquainted with radio abbreviations, messages written in shortened form are meaningless. Delivering stations must be careful to see that messages are written out fully.

In handling messages we are doing something really worth-while. We want to start only good worth-while messages from our stations. Our efforts should be directed to making the quality of our message service high. The number of messages we handle is of secondary importance. The *kind of messages* we originate or start from our stations and the *speed* with which the messages pass through our station and the *reliability or accuracy* with which the messages are handled are the things of paramount importance.

Message Form

▲ Each message originated and handled should contain the following component parts in the order given:

- (a) City of origin
- (b) Station of origin
- (c) Number
- (d) Date

- (e) Check (optional)
- (f) Address
- (g) Text
- (h) Signature

(a) The "city of origin" refers to the name of the city from which the message was started. If a message is filed at League Headquarters by someone in Hartford, Conn., the preamble reads *Hr msg fm Hartford Conn W1MK Nr 457 April 9, etc.*

If a message is sent to your radio station by mail the preamble reads a little differently to show where the message came from and from what city and station it originated as well. If a message was filed at A. R. R. L. Headquarters and if it came by mail from Wiscasset, Maine, the preamble would run like this to avoid confusion: *Hr msg fm Wiscasset Maine via Hartford Conn W1MK Nr 457 April 9, etc.*

(b) The "station of origin" refers to the call of the station at which the message was filed and this should always be included so that a "service" message may be sent back to the originating station if something interferes with the prompt handling or delivery of a message. In the example of preambles just given W1MK is the station of origin, that call being the one assigned the League Headquarters Station.

(c) Every message transmitted should bear a "number." Beginning on the first day of each calendar year, each transmitting station establishes a new series of numbers, beginning at Nr. 1. Keep a sheet with a consecutive list of numbers handy; file all messages without numbers; and when you send the messages, assign numbers to them from the "number sheet," scratching off the numbers on that list as you do so, making a notation on the number sheet of the station to which the message was sent and the date. Such a system is convenient for reference to the number of messages originated each month.

(d) Every message shall bear a "date" and this date is transmitted by each station handling the message. The date is the "day filed" at the originating station unless otherwise specified by the sender.

(e) Every word in the address text and signature of a message counts in the check using radio cable-count. Words and abbreviations in the preamble are not counted.

(f) The "address" refers to the name, street and number, city, state, and telephone number of the party to whom the message is being sent. A *very complete address* should always be given to insure delivery. When accepting messages this

point should be stressed. In transmitting the message the address is followed by a double dash or break sign (—...—) and it always precedes the text.

(g) The "text" consists of the words in the body of the message. No abbreviations should ever be substituted for the words in the text of the message. The text follows the address and is set off from the signature by another break (—...—).

(h) The "signature" is usually the name of the person sending the message. When no signature is given it is customary to include the words "no sig" at the end of the message to avoid confusion and misunderstanding. When there is a signature, it follows the break; the abbreviation "sig" is not transmitted.

The presence of unnecessary capital letters, periods, commas or other marks of punctuation may alter the meaning of a text. For this reason commercial communication companies use a shiftless typewriter (capitals only). The texts of messages are typed in block letters (all capitals) devoid of punctuation, underlining and paragraphing except where expressed in words. In all communication work, accuracy is of first importance.

Numbering Messages

▲ Use of a "number sheet" or consecutive list of numbers enables any operator to tell quickly just what number is "next." Such a record may be kept in the log, or with the message file, or posted on the wall of the station. Numbers may be crossed off as the messages are filed for origination. Another method of use consists of filing messages in complete form except for the number. Then the list of numbers is consulted and numbers assigned as each message is sent. As the operator you work acknowledges (QSLs) each message cross off the number used and note the call of the station and the date opposite this number.

A "number sheet" is quite essential to help in keeping records straight, and to avoid possible duplication of numbers on messages. It is of assistance in checking the count of originated messages in a given month. With each amateur station log book A.R.R.L. provides C.D. Form 3, a number sheet of originated messages — or you can start a consecutive list of numbers in January of each year on a blank sheet, adding numbers as needed.

The original number supplied each message by the operator at the originating station is transmitted by each station handling the message. No new numbers are given the message by intermediate stations. If a message is filed at W1MK on April 9 and when sent is given the number "nr 458," this same call, date and number are used by all stations handling this message. The number and date become a part of the city-and-station-of-origin identification used for the pur-

pose of tracing. Only at stations where a message originates or is filed can a number be assigned to a message. Intermediate relaying stations neither change numbers nor supply new ones to messages.

Checking Messages — Cable Count

▲ All radiograms are counted by the "cable" system, that is, all words in the address, text, and signature are counted and added together in determining the "check" of the message. Checking messages is very easy. The following paragraphs classify the types of messages to be counted, and go beyond this fundamental statement to help solve special problems of word counting.

Messages may be worded in clear language or in secret language. Secret language may be either code or cipher language. A clear language message gives an intelligible meaning in one of the languages authorized for international telegraph work. Each word in a plain-language message has its regular dictionary meaning.

All ordinary messages are plain-language messages. Every 15 characters or fraction thereof counts as one word. 5 figures or groups of five (or less) numerals also count as one word in an ordinary plain-language message. (A fraction bar or decimal point counts as one character or figure.)

Examples (plain language):

USS.....	1 word	91¾.....	1 word
ARRANGEMENT.....	1 word	396¾.....	2 words
UNCONSTITUTIONAL	2 words	2961.....	1 word
X-RAY.....	2 words	85772.....	1 word
(the hyphen is not transmitted)		171186.....	2 words

Counting Special Words

Any character, letter, isolated figure, any punctuation marks, apostrophe (JN), hyphen (BA), fraction bar (DN), colon (OS), quotes (AF), underline (UK) (regardless of its length), or parenthesis (KK) (both signs used to form it), counts as one word in checking messages. In the text or signature, periods, commas, colons, dashes and fraction bars shall be counted as one character in the group in which they appear.

Mixed letters and figure combinations count a word to each character. *R4TG* counts as four words unless it is an established trade mark or trade name. Radio calls are always counted as cipher. *W1MK* counts as four words in the text or signature of a message (though but one word if sent "en groupe" in the address). For accuracy it should be written in texts as *watch one mike king*. A misspelled word with missing letters takes the same count as though it were correctly spelled.

In the address the names of cities, states, countries or other divisions of territory each count as one word regardless of the number of letters they contain. Proper names in the address and signature are counted at the rate of one word for each 15 letters or fraction thereof. The words "street," "avenue," "square" or "road" are always to be

THE AMERICAN RADIO RELAY LEAGUE, INC.
WEST HARTFORD, CONN., U. S. A.

Fellow Amateur:

This acknowledges with sincere thanks your remittance of \$2.50 for which you have been entered as a member of the A. R. R. L. for one year. Your membership certificate is attached.

Membership includes a subscription to our official magazine, *QST*, and your subscription has been entered accordingly to commence with the **MARCH 1935**.....issue.

If, when forwarding your membership entry, you ordered League material (emblem, Handbook, printed forms, etc.) this material was promptly forwarded to you. Also, if special information was requested, your communication has been routed to the proper department for handling.

K. B. WARNER, Secretary.

counted each as one word separately from the name of the street, etc., whether written with it or separately. The fraction bar is not counted as a character in the group of figures (or figures and letters) indicating a house number. Names of ships, telegraph offices, or land stations are counted as one word *in the address* irrespective of the number of letters they contain. When there are two ships of the same name, the name and the call letters of the ship are together counted as one word. The name of the state is always counted as one word in addition to the name of the city. Initials in the address are counted each as one word. Each group of house or street numbers is allowed to pass as one word, however.

It is customary to omit the count of the name of a state in the check when it is written and sent in parentheses in the address.

If a telephone number is included in the address, the word "telephone" or "phone" counts as one word. The name of the exchange is an additional word in the check. Each group of five figures or fraction thereof counts as one word. Mixed letter and figure combinations are counted as a word to each character. A house number followed by a letter counts as but one word, however. *Fifth Avenue* counts as two words. *Hydepark* counts two words, *Hydepark* as one word.

Radio calls are often included in the address to make proper routing easy. *W5XAY* counts as one word in the address but as five words in the body or signature of the message.

In the text, words are counted for every fifteen characters or fraction thereof if the message is a plain language message. A word containing from 16 to 30 letters counts 2 in the check.

Names of cities in the address count always as one word, while in the text they may count as more than one word depending on how written in official telegraph nomenclature. *New York City* counts as one word in the address but three words wherever it appears in the body (or signature) of the message. *New York City* is counted as one word when written and sent *without spacing between the parts*.

Isolated characters each count as one word. Five figures or less in a group count as one word. Words joined by a hyphen or apostrophe count as separate words. Such words are sent as two words, without the hyphen. A hyphen or apostrophe each counts as one word. However, they are seldom transmitted. Two quotation marks or parenthesis signs count as one word. Punctuation is never sent in radio messages except at the express command of the sender. *Even then it is spelled out*. In the text of messages, the names of ships are counted at the rate of 15 letters to a word if the names are written out separately. *Two hundred and forty* counts as four words. Written *twohundredandforty* (18 characters) it counts as only two words.

When the letters "ch" come together in a

dictionary word, they are counted as one letter.

Either whole or fractional numbers spelled out so each group forms a continuous word may be checked at the 15-letter rate. *FOB, W3ATJ, SS, ARRL, QST*, standard terminology of commerce, trademarks, and such expressions in current use, are counted five letters to a word wherever they appear. Each group must of course be sent and counted separately to indicate separate words. Groups of letters are not acceptable in the address but must be separated and checked as one word each. Roman figures shall be sent as arabic figures. The word "roman" may be added after such a numeral if necessary to so identify it. The multiplication sign (X) can be transmitted X. When so sent it counts as one word. *W3ATJ* sent as one word counts "one" in the text. Sent as five separated characters, it counts "five."

Here is an example of a plain-language message in correct A.R.R.L. form and carrying the "cable-count" check:

(HR MSG FM HARTFORD CONN W1MK NR 83 —
217P MAY 3 CK 50)
I B ALLEN
416 MOUNTAINVIEW AVE
MOUNT HOLLY NEW JERSEY —
PLEASE COMMENT ON PROPOSED OLD TIMERS
WEEK USING 3500 KILOCYCLES STOP BACK
NUMBER OF QST WAS FORWARDED MONDAY
STOP WHAT FREQUENCY IS MOST IN USE AT
W3ATJ QUESTION 73 TO YOU AND NEW JERSEY
GANG-

ARRL COMMUNICATIONS MANAGER

The count on each part of the message is added to give the "check" shown. Address, 8; text, 39; signature 3. The check is the sum of these three or 50 words. The first parts of the message in parentheses are always transmitted but do not count in the check. "Sig" is not transmitted.

The words that give most trouble in counting this message add into the "check" as follows:

H.	1	QST.	1
R.	1	W3ATJ.	5
416.	1	73.	1
AVE.	1	NEW JERSEY.	2
NEW JERSEY.	1	ARRL.	1
3.500.	1		

The use of a check on amateur messages is optional. Where employed, however, it is a matter of courtesy to see that the check is correct and is handed on along with the rest of the message. Very important messages should be checked carefully to insure accuracy, and if an important message is received with no check, a check should be added.

Request originators of messages to *spell all punctuation marks out that must appear in delivered copies. Likewise, never abbreviate in texts, or use ham abbreviations except in conversations.*

CHECKING CODE AND CYPHER

In coded secret messages the words do not have the normal dictionary meanings, but are

given artificial or special meanings. Real words with artificial meanings, and also artificial or synthetic words are used. These words do not normally form intelligible sentences. The preamble of coded messages starts with CDE (just as SVC is used to indicate a service message). Several selected words or word groups express more extensive thoughts. Every *five* characters or less count as one word. Words containing 6 to 10 letters count "2" in the check. When one has a copy of the simple and commonly used codes the business of coding and decoding is easy.

In cipher messages, groups or series of arabic figures (or words, names, expressions, or letter combinations, *not* conforming to clear language) having a secret meaning, are used. Cipher also is counted at the rate of 5 (or fraction thereof) characters per word. Groups of letters are checked at the same rate as groups of figures.

Examples (cipher count):

XYPFQ	1 word
d6w	3 words
CXQFVL	2 words

If a message is written partly in plain language, partly in cipher, and partly coded, the words are all checked at the 5-letter rate. When messages are written in plain language and part in cipher, the whole dispatch takes the 5-letter count. Likewise messages part in plain language and part in code take the 5-letter count throughout.

Foreign Traffic Restrictions

▲ Any and all kinds of traffic may be handled between amateur stations in different parts of the United States, Hawaii, Alaska, and Porto Rico. There is no qualification or restriction except that amateur status must be observed and no material considerations become involved in the communications. Radio amateurs in all U. S. possessions except the Philippines (which has its own radio administration) are licensed by the U. S. Federal Communications Commission. The F. C. C. permits U. S. amateurs to handle with P. I. all types of communication permitted internally in the U. S. as with the other possessions. But the Philippine Island administration, since part of the inter-island communications system is government owned, leans toward the incorporation of certain additional restrictions on its amateurs relating to the handling of messages of "business importance."

Internationally the general regulations attached to the international communications treaty state the limitations to which work between amateur stations in different foreign countries is subject. In practically every country outside our own country and its possessions, the government owns or controls the public communications systems. Since these systems are maintained as a state monopoly, foreign amateurs have been prohibited by their governments from exchanging traffic which might be regarded as "competition"

with state owned telegraphs. The international treaty regulations reflect this condition and the domestic traffic restrictions (internal policy) of the majority of foreign countries. August 1934 *QST* (pages 52-53) gives an interesting résumé of the amateur regulations of many foreign countries. Any country ratifying the Madrid (1932) Convention can make its domestic arrangement as liberal as it likes; in addition it may conclude special agreements with other governments for amateur communication that are *more liberal* than the quoted terms of the treaty itself. If no specific formal negotiations have been concluded, however, amateurs must observe the following (treaty) regulation in conducting international amateur work. Article 8:

The exchange of communications between amateur stations and between private experimental stations of different countries shall be forbidden if the Administration of one of the interested countries has given notice of its opposition to this exchange.

When this exchange is permitted the communications must be conducted in plain language and be limited to remarks of a personal nature, for which, by reason of their lack of importance, recourse to the public telegraph service would not be warranted. It shall be absolutely forbidden to licensees of amateur stations to transmit international communications emanating from third parties. The above provisions may be modified by special arrangements between the interested countries.

Referring to the first paragraph above, in the years since the Washington Convention (1927) *no* prohibition on amateur communication (international QSOs) has been filed by *any* country with the Berne Bureau. In some countries, principally European, amateurs are restricted by regulation to privileges much *less* than made available by international agreement. The use of some amateur bands is withheld, or the width of certain bands severely restricted by proclamation of "buffer bands," power is restricted, absurd time regulations restricting operation to two hours per day, fifteen minutes per hour, etc., enacted, and "third party" messages absolutely forbidden *domestically* as well as internationally. In the U. S. A. it is the policy, and of course necessary to take care of our greater numbers of amateurs, to give amateurs the fullest frequency allocations and rights possible under international treaty provisions, and to permit free exchange of domestic non-commercial traffic addition. This policy has justified itself, giving the public amateur radio traffic service, and developing highly skilled operators and technicians who have the ability to keep the U. S. A. in the lead in radio communications facilities. Many countries have the false notion that their security or revenue might be endangered by giving citizens any such freedom of action.

The second paragraph of Article 8 prohibits *international* handling of third party traffic, except where two governments have a special arrangement for such exchange (we have such agreement with Canada and are negotiating

similar agreements with other countries). In any event, traffic relating to experimental work, and personal remarks which would not be sent by commercial communications channels may be sent, when in communication with foreign amateurs.

As always, the major opportunity for outstanding message-handling work exists right at home. There are chances to render a real service to local communities everywhere that an amateur puts up a station and gets on the air, and especially in time of emergencies. Excellent work in traffic handling is so very common that it takes almost exceptional emergency and expedition work, or work with unusual characteristics, to "rate" special mention. Many expeditions and exploring parties go to the far parts of the earth—and now they always take high-frequency equipment along for contact work.

The Canadian Agreement

▲ The special reciprocal agreement concluded between our country and the Dominion of Canada at the behest of the A.R.R.L. permits Canadian and U. S. amateurs to exchange messages of importance under certain restrictions. This agreement is an expansion of the international regulations to permit the handling of important traffic.

The authorized traffic is described as follows:

"1. Messages that would not normally be sent by any existing means of electrical communication and on which no tolls must be charged.

"2. Messages from other radio stations in isolated points not connected by any regular means of electrical communications; such messages to be handed to the local office of the telegraph company by the amateur receiving station for transmission to final destination, e.g., messages from expeditions in remote points such as the Arctic, etc.

"3. Messages handled by amateur stations in cases of emergency, e.g., floods, etc., where the regular electrical communication systems become interrupted; such messages to be handed to the nearest point on the established commercial telegraph system remaining in operation."

The arrangement applies to the United States and its territories and possessions including Alaska, the Hawaiian Islands, Porto Rico, the Virgin Islands, the Panama Canal Zone and the Philippine Islands. Similar special agreements have been concluded by the U. S. A. with Chile and Peru, and are under consideration by other countries.

Originating Traffic

▲ Every message has to start from some place and unless some of us solicit some good traffic from friends and acquaintances there will be no messages to relay. Of course the simplest way to get messages is to offer to send a few for friends, reminding them that the message service is free and no one can be held responsible for delay or

non-delivery. A number of the amateur fraternity have distributed pads of message blanks to local stores and business houses to assist in getting good traffic to originate regularly. A neatly typed card is displayed near-by explaining the workings of our A.R.R.L. traffic organization, and *listing the points to which the best possible service can be given.*

The time of collecting messages and the list of schedules kept may also be posted for the benefit of those interested. Wide-awake amateurs have distributed message blanks to the nearest tourist camps during the summer seasons of recent years and lots of good traffic has been collected through a system of message-collection boxes placed in public buildings and hospitals. A sign prominently displayed outside the radio station has in some instances proved a good source of obtaining worth-while messages. Messages from broadcast listeners to the stations where programs originate have helped in the search of the traffic-minded amateur to be of service to the public at the same time he enjoys his hobby.

Messages that are not complete in every respect *should not be accepted* for relaying. The city of origin, station of origin, number, date, address, text, and signature constitute a complete message. All these parts are necessary to make a message of value to the recipient, to make it possible to deliver the message and to route an answer back to the sender. A very *complete* address on every message is important.

To properly represent amateur radio, placards when used should avoid any possible confusion with telegraph and cable services. Any posters should refer to AMATEUR RADIOGRAMS, and explain that messages are sent through AMATEUR RADIO STATIONS, as a HOBBY, FREE, without cost (since amateurs can't and will not accept compensation). The exact conditions of the service should be stated or explained as completely as possible, including the fact that there is NO GUARANTEE OF DELIVERY. The individual in charge of the station has full powers to refuse any traffic unsuitable for radio transmission, or addressed to points where deliveries cannot be made. Relaying is subject to radio conditions and favorable opportunity for contacting. Also, it is desirable to word messages as telegrams would be worded instead of writing letters. Better service can be expected on 15-word texts of apparent importance than on extremely long messages. Traffic should *not* be accepted for "all over the world" since there are not active amateurs in all countries, and more important, since the majority of countries outside the U. S. A. and Canada prohibit the handling of third party traffic altogether, by a restriction written into the station licenses of foreign amateur stations.

Careful planning and organized schedules are necessary if a *real* job of handling traffic is to be

done. Advance schedules are essential to assist in the distribution of messages. It may be possible to schedule stations in cities to which you know quantities of messages will be filed. Distribute messages, in the proper directions, widely enough so that a few outside stations do not become seriously overburdened. Have the latest copies of *QST* at hand and study the traffic summaries at the end of sectional activity reports. Nearly all these stations are reliable Official Relay Stations interested in traffic handling. The list of calls will help you to identify or distinguish reliable consistent operators to whom to entrust valuable messages.

Operators must route traffic properly — not merely aim to “clear the hook.” New stations worked should be informed of the amount of traffic you wish to clear and agree to handle the messages, *before* they are sent. Delays and non-deliveries result from giving an operator more than he can handle efficiently. Operators should *not* accept traffic when not in a position to continue operating their stations to give it proper handling.

It is better to handle a small or moderate volume of traffic *well*, than to attempt to break records in a manner that results in delayed messages, non-deliveries, and the like which certainly cannot help in creating any public good-will for amateur radio.

Tracing Messages

▲ *Tracing messages* is sometimes necessary to find where traffic was held or delayed. Tracing is usually accomplished by sending a copy of the message and a letter requesting that the time, date, and station calls of the stations from whom the message was received and to whom the message was given, be noted. Tracers are forwarded in rotation to all stations handling a message.

Amateur Stations at Exhibits and Fairs

▲ Where installation of an amateur radio station in a booth is planned, a *portable* amateur station can be installed. The station must operate under F. R. C. license of course. Since every amateur station owner can use his regular authorization for portable work under certain regulations, a local amateur already licensed, can accept responsibility for the station. Of course the proper F. R. C. office must be notified of the location from which the equipment will be operated, and the dates of such operation, in advance, as provided in the regulations. No license for station equipment is required if the exhibit will not include a transmitter in actual operation. Whatever type of exhibit is planned, write A.R.R.I. in advance, in order to receive sample material to make your amateur-booth more complete.

If the time is short and there is no opportunity for special organization of schedules to insure reliable routing and delivery, quite likely exhibit

work, to be most productive of good-will results, had best *not* include message handling plans — at least not from the booth-station itself where subject to noise, electrical interference, and other handicaps. To handle such traffic as offered with *real efficiency*, it should be distributed for origination via existing schedules of the *several most reliable local amateur stations*. By *dividing the traffic filed with other stations it may be sent more speedily on its way*. The full coöperation of all local stations should be requested. However, be sure that the operators undertaking to help are qualified and have good schedules for distributing messages.

“Show stations” must avoid origination of “poor traffic” by rigid supervision and elimination of meaningless messages with guessed-at inaccurate and incomplete addresses right at the source. Misaddressed and rubber-stamp-type traffic will always be subject to serious delays and non-delivery, and especially so when the traffic load is so great that handling such messages becomes irksome and work instead of fun. What good is any message if it cannot be delivered?

The “Apparent Importance”

▲ The “apparent importance” of a dispatch has been proved to have a very direct bearing on the speed of relaying a message and the likelihood of its delivery, especially if the relaying is to be attempted through several unknown stations instead of between one or two known reliable stations keeping regular schedules. It may seem a strange commentary on amateur relaying that such is the case, but examination of delivery results proves the statement; and the very fact that amateur radio is a hobby, and that it is “human nature” to devote most time and effort to doing what seems most worthwhile, will afford sufficient explanation. In successful relaying work *all* factors must be taken into account.

Troubles to Avoid in Originating Traffic

▲ Incomplete preambles seem to be the most common fault in message handling. The city of origin, the station of origin, the number, the date, and the check are all a part of the preamble which goes at the beginning of every message. The *city* and *station of origin* are most essential. Without them it is impossible to notify the sender that his message could not be delivered and without this information it is not possible to route the reply speedily. The number and date are essential in servicing and tracing radiograms. All Official Relay Stations are instructed to refuse to accept messages without this necessary information. Every station should demand an “office of origin” from stations who have messages, and traffic may be rightly cancelled (QTA) on failure to include it. Thus messages will never get on the air without a starting place.

Many messages carry an insufficient address and cannot be delivered. Originating stations should refuse to accept messages to transmit when it is apparent that the address is too meagre.

Some stations lose track of the messages which they accept for delivery or transmission. They use scratch pads to copy signals on and they never clean up the operating table or have a place for things. The remedy is to adopt a few of the principles of neatness and to spend about two minutes each time you are through operating to put things in order. Write messages on message blanks of a uniform size when they arrive at the station. Keep together the messages to be sent. A good system to use is to mark the state of destination in the upper right hand corner of each message, arranging the messages in a heavy clip so that the names of the states are in easy view. A file box may be similarly arranged. A simple log book, a good filing system, an accurate frequency meter and an equally accurate clock, are sure signs of a well-operated station. The apparatus on the operating table will tell a story without words.

Volumes vs. Deliveries

▲ In passing we should add that starting traffic in volume always results in lowering percentage deliveries simply because "operating enjoyment" becomes "work" and amateur operators with limited time are able to cope with only definite quantities of messages. While in emergencies traffic could and would be willingly moved at any sacrifice of time, thus giving great credit to the amateur, the transmission of less important material, especially in volume, meets resistance, due to the characteristics of human nature and the fundamental aspects of amateur radio as a hobby (not a job). This of course does not excuse any amateur from accepting messages he knows he cannot handle. *It is best to refuse traffic when not in a position to handle it, and especially if unwilling to accept proper responsibility for doing your best to see it on its way — or delivered — speedily.*

Relay Procedure

▲ Messages shall be relayed to the station nearest the location of the addressee and over the greatest distance permitting reliable communication.

No abbreviations shall be substituted for the words in the text of a message with the exception of "service messages," to be explained. Delivering stations must be careful that no confusing abbreviations are written into delivered messages.

Sending "words twice" is a practice to avoid. Use it only when expressly called for by the receiving operator when receiving conditions are poor.

Messages shall be transmitted as many as three times at the request of the receiving operator. Failing to make a complete copy after three

attempts, the receiving operator shall cancel the message (QTA).

Agreement to handle (relay or deliver) a message properly and promptly is always tacitly implied in accepting traffic. When temporarily *not* in a position to so handle, it is a service to amateur radio and your fellow ham to courteously *refuse* a message.

Let us assume that a station in Hartford, Conn., receives a message whose destination is Dallas, Texas. The message is at once written out on a message blank, filling in the city and station of origin, leaving only the "number," "rec'd," and "sent" spaces vacant.

The operator does not hear any western stations so he decides to give a directional "CQ" as per A.R.R.L. practice. He calls, CQ CQ CQ TEXAS DE W1MK W1MK W1MK, repeating the combination three times.

He listens and hears W9CXX in Cedar Rapids calling him, W1MK W1MK W1MK DE W9CXX W9CXX W9CXX AR.

Then he answers W9CXX indicating that he wishes him to take the message for Dallas. W1MK says W9CXX W9CXX DE W1MK R QSP DALLAS? K.

After W9CXX has given him the signal to go ahead, the message is transmitted, inserting the "number" in its proper place, and assigning the next number indicated on the "number sheet." The message is sent in A.R.R.L. sequence.

"HR MSG FM HARTFORD CONN W1MK NR247 NOV 11 CK31 TO FRANK M CORLETT W5ZS 2515 CATHERINE STREET DALLAS TEXAS—...— COMMUNICATIONS DEPARTMENT SUPPLIES AND MEMBERSHIP LIST ARE GOING FORWARD TODAY PLEASE SEND YOUR REACTION TO GENERAL NUMBER 372 OUR ARMY FILE—...— SIG HOUGHTON AR W1MK K.

W9CXX acknowledges the message like this: W1MK DE W9CXX NR 247 R K. Not a single R should be sent unless the whole message has been correctly received.

The operator at W1MK writes in the number of the message, scratches off number 247 on the "number sheet," putting W9CXX after the number. In the "sent" space at the bottom of the message blank he notes the call of the Cedar Rapids station, the date, time, and his own personal "sine." At the same time he concludes with W9CXX something like this: R QRU 73 GB SK W1MK, meaning, "All received OK, I have nothing more for you, see you again, no more now, best regards, good-bye, I am through with you and shall at once listen for other stations who may wish to call me. W1MK is now signing off."

W9CXX will come back with I R GB AR SK W9CXX, meaning "I understand, received you OK, good-bye, I am through." Then he will listen a few minutes to see if anyone is calling him. He will listen particularly for Texas stations and try to put the message through W5ZC or a neighboring station. If he does not hear someone

calling him, he will listen for Texas stations and call them.

Getting Fills

▲ Sometimes parts of a message are not received correctly or perhaps due to fading or interference there are gaps in the copy. The problem is to ask for "fills" or repeats in such a way as to complete the message quickly and with the minimum of transmission.

If the first part of a message is received but substantially all of the latter portions lost, the request for the missing parts is simply *RPT TXT AND SIG*, meaning "Repeat text and signature." *PBL* and *ADR* may be used similarly for the preamble and address of a message. *RPT AL* or *RPT MSG* should not be sent unless nearly all of the message is lost.

Each abbreviation used after a question mark (. . . — . . .) asks for a repetition of that particular part of a message.

When a few word-groups in conversation or message handling have been missed, a selection of one or more of the following abbreviations will enable you to ask for a repeat on the parts in doubt. Phone stations of course request fills by using the full wording specified, without attempt at abbreviation.

Abbreviation	Meaning
?AA	Repeat all after.
?AB	Repeat all before.
?AL	Repeat all that has been sent.
?BN . . . AND	Repeat all between . . . and
?WA	Repeat the word after.
?WB	Repeat the word before.

The good operator will ask for only what fills are needed, separating different requests for repetition by using the break sign or double dash (— . . . —) between these parts. There is seldom any excuse for repeating a whole message just to get a few lost words.

Another interrogation method is sometimes used, the question signal (. . . — . . .) being sent between the last word received correctly and the first word (or first few words) received after the interruption. *RPT FROM TO* is a long, clumsy way of asking for fills which we have heard used by beginners. These have the one redeeming virtue of being understandable.

The figure four (. . . —) is a time-saving abbreviation which deserves popularity with traffic men. It is another of those hybrid abbreviations whose original meaning, "Please start me, where?" has come to us from Morse practice. Of course *?AL* or *RPT AL* will serve the same purpose, where a request for a repetition of parts of a message have been missed. While these latter usages are approved, the earlier practice is still followed by some operators.

Delivering Messages

▲ The only service that we can render anyone by handling a message comes through "delivery."

Every action of ours in sending and relaying messages leads up to this most important duty. Unless a message is delivered, it might as well never have been sent.

There is no reason for anyone to accept a message if he has no intention of relaying it or delivering it promptly. It is not at all discourteous to refuse politely to handle a message when it will be impossible for you to forward it to its destination.

Occasionally message delivery can be made through a third party not able to acknowledge the radiogram he overhears. When a third party happens to be in direct contact with the person addressed in the message he is able to hand him an unofficial confirmation copy and thus to make a delivery much sooner than a delivery could be made otherwise. It is *not* good radio etiquette to deliver such messages without explaining the circumstances under which they were copied, as a direct delivery discredits the operator who acknowledged the message but who through no fault of his own was not able to deliver so promptly. With a suitable note of explanation, such deliveries can often improve A.R.R.L. service and win public commendation.

Provisions of the Radio Act of 1934 make it a misdemeanor to give out information of any sort to any person except the addressee of a message. It is in no manner unethical to deliver an unofficial copy of a radiogram, if you do it to improve the speed of handling a message or to insure certain and prompt delivery. Do not forget that there are heavy fines prescribed by Federal laws for divulging the contents of messages to anyone except the person addressed in a message.

When it is possible to deliver messages in person, that is usually the most effective way. When the telephone does not prove instrumental in locating the party addressed in the message it is usually quickest to mail the message.

To help in securing deliveries, here are some good rules to follow:

Messages received by stations shall be delivered immediately.

Every domestic message shall be relayed within forty-eight (48) hours after receipt or if it cannot be relayed within this time shall be mailed to the addressee.

Messages for points outside North America must not be held longer than half the length of time required for them to reach their destination by mail.

We are primarily a radio organization, and the bulk of our messages should go by radio, not by mail. The point is that messages should not be allowed to fall by the way, and that they should be sent on or delivered just as quickly as possible. When a message cannot be delivered, or if it is unduly delayed, a "service" message should be written and started back to the "office of origin."

Each operator who reads these pages is asked to assume *personal responsibility* for the accuracy and speed of each message handled so that we can

each have reason to take personal pride in our operating work and so that we will have just cause for pride in our League as a whole. Do *your* part that we may approach a 100% delivery figure.

The Service Message

▲ A service message is a message sent by one station to another station relating to the service which we are or are not able to give in message handling. The service message may refer to non-deliveries, to delayed transmission, errors, or to any phase of message handling activity. It is not proper to abbreviate words in the texts of regular messages, but it is quite desirable and correct to use abbreviations in these station-to-station messages relating to traffic-handling work.

In line with the practice outlined above W3CA makes up a service message asking W7GE (station of origin of a message with insufficient address) to "give better address":

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HR SVC FM ROANOKE VA W3CA NR 201 AUG 19
To RADIO W7G
L C MAYBEE
110 SOUTH SEVENTH AVE
PASCO WASHN — . . . —
UR NR 87 AUG 17 TO CUSHING SIG BOB HELD
HR UNDDL PSE GBA — . . . —
                (sig) WOILFORD W3CA
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Counting Messages

▲ So that we can readily keep run of our messages and compare the number originated and delivered each month to learn some facts about the "efficiency" of our work in handling messages, a method of counting is used. Each time a message is *handled by radio* it counts one in the total.

A message received in person, by telephone, by telegraph, or by mail, *filed at the station and transmitted by radio* in proper form, counts as *one originated*.

A message *received by radio and delivered* in person, by telephone, telegraph, or mail, counts as *one delivered*.

A message *received by radio and sent forward by radio* counts as two messages *relayed* (one when received and again one when sent forward).

All messages counted under one of the three classes mentioned must be handled within a 48-hour (maximum) delay period to count as "messages handled." Messages for continents except North America may be held half the length of time it would take them to reach their destination by mail. A "service" message counts the same as any other type of message.

The *message total* shall be the *sum* of the messages originated, delivered and relayed. Each station's message file and log shall be used to determine the report submitted by that particular station. Messages with identical texts (so-called rubber-stamp messages) shall count once only for *each* time the complete text, preamble and signature are sent by radio.

A.A.R.S. and N.C.R. Traffic

▲ Most messages you receive will be in standard A.R.R.L. form. A.A.R.S. nets and N.C.R. drills, conducted in an amateur status by those amateurs voluntarily attached to these services, involve the handling of dispatches in the special procedure followed by these agencies. A.R.R.L. has ruled that all such traffic handled on amateur frequencies, complete with respect to address, preamble, signature (including all information necessary under either A.A.R.S., N.C.R., or A.R.R.L. rules) may be counted in A.R.R.L. traffic totals. Any message completely handled by these standards is countable!

N.C.R. procedure like that of most other services includes cable count check. A.A.R.S. start traffic with "Nr.-St'n.-GR-City-Time-Date" and use a "text" check like W.U. and wire services. It is the correct thing to do to change the preamble to the form *used by the service you are operating in*. This helps both accuracy and speed and proves you a real operator. When not in A.A.R.S. or N.C.R. nets use standard amateur form.

▲ A monthly report should be sent to the local A.R.R.L. S.C.M. The closing date of the "message month" is the 15th of each month (the last of the month in Hawaii and the Philippines). Reports must go forward the next day. Some examples:

Let us assume that on the 15th of the month one operator of a large amateur station receives several messages from another station. (a) Some of these messages are for relaying by radio. (b) Some of them are for local delivery. (c) There are still other messages the disposal of which cannot be accurately predicted. They are for the immediate neighborhood but either can be mailed or forwarded to another amateur by radio. A short-haul toll telephone call will deliver them but the chances of landing them nearer the destination by radio are pretty good. This operator's "trick" ends at midnight on the 15th and he must make the report with some messages "on the hook" to be carried over for the next month's report.

(a) The messages on the hook that are to be relayed have been received and are to be sent. They count as "1 relayed" in the report that is made out now, and they will also count as "1 relayed" in the next month's report (the month during which they were forwarded by radio).

(b) By mailing or 'phoning the messages at once, they count as "1 delivered" for the current report. By holding them until next day they will count in the *next* report as "1 delivered."

(c) The messages in this class should be carried forward into the next month. If they have to be mailed they will count in the next report as "1 delivered." If they are relayed, we count them as "2 relayed"; "1 received" in the preceding month being carried forward and added to "1

sent" makes the "2 relayed." If the operator wishes to count this message at once (for the current month) it must be mailed promptly and counted as "1 delivered."

Some examples of counting:

The operator of Station A gets a message by radio from Station B addressed to himself. This counts as "1 delivered" by himself and by Station A.

The operator of Station A takes a verbal message from a friend for relaying. He gives it to Station B over the telephone. Operator A does not handle the message by radio. Station B and operator B count the message as "1 originated." A cannot count the message in any manner.

The operator and owner of Station A visits Station B and *while operating* there takes a message for relaying. The operator and owner of B cannot operate for a day or two so the message is carried back to Station A by operator A who relays it along within a few hours. The traffic report of both Station A and Station B shows "1 relayed" for this work.

Please note that "handling" a message always includes the transmission and receipt of radio acknowledgment (QSL) of same, and the entry of date, time, and station call on the traffic, as handled, for purposes of record. Only messages properly handled, shall be counted in A.R.R.L. totals.

"Rubber-Stamp" Messages

▲ Because, now and again, our stations fall into the habit of originating quantities of so-called "rubber-stamp" messages with such texts as "Your card received will QSL"; "Greetings by radio" and the like, the identical text being addressed to a large number of addressees, it becomes necessary to reaffirm our policy with respect to such messages. The history of our organization shows the demoralizing effect of an influx of such stereotyped messages in quantity. The net effect is to clog the hooks of traffic-handling stations until they can no longer function. This must be prevented by stopping uncalled for messages right at their source. The handling of traffic must be either fun or constructive, interesting, work. Because such multiple-address messages mean much drudgery for little accomplished they cannot be handled effectively in a hobby like amateur radio.

Obviously, a station in handling a rubber-stamp message has to exert only a small amount of effort in receiving the text and signature once. Then by handling the address to different points *en groupe* a large number of messages (?) can be received and transmitted with little time and effort. The League's system for crediting points for messages handled is based on giving one credit each time a *complete* message is handled by amateur radio, i.e., one credit for each originated message, one credit for each delivered message and two credits for each relayed message (one

credit for the work in receiving it and one for the work in transmitting it). *Only every message handled by radio with a complete preamble, address, text, and signature shall be counted, except in the case of deliveries, each mailed, telephoned or otherwise delivered message shall count "one delivered" regardless of handling in "book" form (with text sent once only).*

Example (showing a claimed and revised count on R.S. messages): A certain station takes an R.S. message to 10 addresses and relays it onward to another station, claiming "relayed 20" for his work. This station shall be credited with "relayed 2"; one for receiving a complete preamble, address, text, and signature, one for sending a complete message on its way. For receiving and relaying to three stations (requiring the complete message to be sent three times) a total of four might be justly claimed in the relayed column. (This should not be construed to mean that any message to a single address should be given to more than a single reliable station.) For receiving and *delivering to three addresses* this work should be credited as "three delivered."

Reporting

▲ Whether the principal accomplishments of the station are in traffic handling or other lines, *what you are doing* is always of interest to A.R.R.L. headquarters. Our magazine, *QST*, covers the entire amateur field, keeping a record of the messages handled in different sections of the country, giving mention of the outstanding work that is done in communicating over great distances using small amounts of power, and summarizing all types of activities in monthly reports.

We have mentioned the Official Relay Stations and the Communications Department organization. A section of *QST* is devoted to Communications Department reports. Form postals are sent the active stations in the relay system for reporting purposes. There is space to tell about the traffic handled, the frequency used during the reporting month, the "DX" worked, and other station records and activities, together with a list of the stations with which schedules are kept. Items of general interest, changes in the set, and addresses of new amateurs also come in on this card.

Every operator of an active amateur station in the United States and Canada is cordially invited to report. Each month on the 16th (the 1st in Hawaii and the Philippines) the active stations send reports to their local officials. These officials forward condensed reports to Headquarters. Representative space is given each section of the country depending on the number reporting. Reports must have the dead material edited out of them to allow room for as much active and interesting news as can be gotten in. The more worth while a report is, the more of it gets in print. Calls of active stations always get full

space. Readers of this Handbook are invited to send in their reports to the local A.R.R.L. official just as soon as they have a station in operation. Write the nearest S.C.M. whose name appears on page 5 of each *QST*. Make your report informative and interesting.

Especially important work having a high news value should be reported direct to League Headquarters at Hartford.

Contributions to *QST* are welcomed by the Editors! Authors must remember that only a small percent of the received material can be printed and that it is impossible for an organization like ours to pay for articles. Ours is a "family" organization supported by and for the amateur. By carefully selecting material the members get the best magazine that can be made. *QST* is noted for its technical accuracy. "Breaking into print" in *QST* is an honor worth working for.

Operating on Schedules

▲ Traffic handling work can be most advantageously carried on by arranging and keeping a few schedules. By arranging schedules and operating the station in a business-like way, using an accurate frequency meter and a clock, it has been proven many times that a maximum amount of business can be moved in a minimum of time and effort. The message "hook" can be cleared in a few minutes of work on schedule and the station will be free for DX or experimental work.

Every brass-pounder is urged to write letters to some of the reliable and regular stations heard, asking if some schedules cannot be kept a few times a week especially for traffic handling. The Route Manager is very frequently able to help in arranging schedules. Write your S.C.M. (see page 5, *QST*) and through him get lined up with your R.M. With reliable schedules in operation it is possible to advertise the fact that messages for certain points can be put through with speed and accuracy, and the traffic problem will take care of itself.

The Five-Point System

▲ To make our relaying more systematic the "five-point system" of arranging schedules was proposed and has worked out very nicely on many cases. After getting the station in good operating condition, each station's operator arranges to work four stations, one north, one east, one south, and one west. These directions are not exact but general. The distances are not too great but they must be distances that can be worked with absolute certainty under any conditions.

A good way to select the four stations is to listen in and to pick out the stations heard most regularly, operating most consistently, and in the

right direction. It is a good scheme to work these stations a few times. Write them letters and get acquainted; then try to arrange some schedules. Short schedules are the best. A half or quarter hour each day is enough. In an hour one can call four stations, clear traffic, and be free to work other groups of "five-pointers."

When there is no traffic, a few pleasantries are in order during the scheduled time of working. Several advantages of handling messages on schedule are evident from whatever angle the situation is approached.

Traffic Handling Develops Skill

▲ The dispatch of messages makes operators keen and alert. The better the individual operator, the better the whole organization. Proper form in handling traffic, getting fills, and in general operating procedure develops operators who excel in "getting results." Station performance depends 90% on operating ability, and 10% on the equipment involved, granting of course that station and operator are always inter-dependent. Experience in message handling develops a high degree of operating "intelligence."

Interest in relaying amateur radiograms has always been the important basic activity around which A.R.R.L. organization revolved. There are several good reasons why. Message handling leads to organization naturally, through the need for schedules and cooperation between operators. It offers systematic training in "real" operating. It leads to planned, useful, unselfish, constructive, work for others at the same time it represents the highest form of operating "skill" and enjoyment to its devotees. Emphasis should be placed on the importance of traffic handling in training operators in the use of procedure — and in general operating reliability. The value of the amateur (as a group), in cases of local or national emergency, depends to a great extent on the *operating ability* of individual operators. This ability is largely developed in message handling work.

Practise in handling traffic familiarizes one with detailed time-saving procedure, and develops general skill and accuracy to a higher extent than obtains in "just rag-chewing" or haphazard work. This work provides a definite aim. Message handling is a vital link in guiding the interest of operators to the point where many accept additional responsibilities in the Signal Corps organization (A.A.R.S.), or the Volunteer Communication Reserve (U.S.N.R.). The interest amateurs show in these services is directly reflected by a full measure of appreciation and important backing by Uncle Sam whenever amateur rights are threatened with encroachment of any kind. Message handling work represents an advanced form of amateur operating activity in which all amateurs sooner or later become interested.

APPENDIX

The "Q" Code

In the regulations accompanying the existing International Radiotelegraph Convention there is a very useful internationally agreed code designed to meet major needs in international radio communication. This code follows. The abbreviations themselves have the meanings shown in the "Answer" column. When an abbreviation is followed by an interrogation mark (?) it assumes the meaning shown in the "question" column.

<i>Abbr- eviation</i>	<i>Question</i>	<i>Answer</i>
QRA	What is the name of your station?	The name of my station is
QRB	How far approximately are you from my station?	The approximate distance between our stations is nautical miles (or kilometres).
QRC	What company (or Government Administration) settles the accounts for your station?	The accounts for my station are settled by the company (or by the Government Administration of).
QRD	Where are you bound and where are you from?	I am bound for from
QRG	Will you tell me my exact frequency (wave-length) in kc/s (or m)?	Your exact frequency (wave-length) is kc/s (or m).
QRH	Does my frequency (wave-length) vary?	Your frequency (wave-length) varies.
QRI	Is my note good?	Your note varies.
QRJ	Do you receive me badly? Are my signals weak?	I cannot receive you. Your signals are too weak.
QRK	Do you receive me well? Are my signals good?	I receive you well. Your signals are good.
QRL	Are you busy?	I am busy (or I am busy with). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by atmospherics?	I am troubled by atmospherics.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster (..... words per minute).
QRS	Shall I send more slowly?	Send more slowly (..... words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Shall I tell that you are calling him on kc/s (or m)?	Please tell that I am calling him on kc/s (or m).
QRX	Shall I wait? When will you call me again?	Wait (or wait until I have finished communicating with) I will call you at o'clock (or immediately).
QRY	What is my turn?	Your turn is No. (or according to any other method of arranging it).
QRZ	Who is calling me?	You are being called by
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSD	Is my keying correct; are my signals distinct?	Your keying is incorrect; your signals are bad.
QSG	Shall I send telegrams (or one telegram) at a time?	Send telegrams (or one telegram) at a time.
QSJ	What is the charge per word for including your internal telegraph charge?	The charge per word for is francs, including my internal telegraph charge.
QSK	Shall I continue with the transmission of all my traffic, I can hear you through my signals?	Continue with the transmission of all your traffic, I will interrupt you if necessary.

Abbreviation	Question	Answer
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Shall I repeat the last telegram I sent you?	Repeat the last telegram you have sent me.
QSO	Can you communicate with direct (or through the medium of)?	I can communicate with direct (or through the medium of).
QSP	Will you retransmit to free of charge?	I will retransmit to free of charge.
QSR	Has the distress call received from been cleared?	The distress call received from has been cleared by
QSU	Shall I send (or reply) on kc/s (or m) and/or on waves of Type A1, A2, A3, or B?	Send (or reply) on kc/s (or m) and/or on waves of Type A1, A2, A3, or B.
QSV	Shall I send a series of VVV?	Send a series of VVV
QSW	Will you send on kc/s (or m) and/or on waves of Type A1, A2, A3 or B?	I am going to send (or I will send) on kc/s (or m) and/or on waves of Type A1, A2, A3 or B.
QSX	Will you listen for (call sign) on kc/s (or m)?	I am listening for (call sign) on kc/s (or m).
QSY	Shall I change to transmission on kc/s (or m) without changing the type of wave? or Shall I change to transmission on another wave?	Change to transmission on kc/s (or m) without changing the type of wave or Change to transmission on another wave.
QSZ	Shall I send each word or group twice?	Send each word or group twice.
QTA	Shall I cancel telegram No. as if it had not been sent?	Cancel telegram No. as if it had not been sent.
QTB	Do you agree with my number of words?	I do not agree with your number of words; I will repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to send?	I have telegrams for you (or for).
QTE	What is my true bearing in relation to you? or What is my true bearing in relation to (call sign)? or What is the true bearing of (call sign) in relation to (call sign)?	Your true bearing in relation to me is degrees or Your true bearing in relation to (call sign) is degrees at (time) or The true bearing of (call sign) in relation to (call sign) is degrees at (time).
QTF	Will you give me the position of my station according to the bearings taken by the direction-finding stations which you control?	The position of your station according to the bearings taken by the direction-finding stations which I control is latitude longitude.
QTG	Will you send your call sign for fifty seconds followed by a dash of ten seconds on kc/s (or m) in order that I may take your bearing?	I will send my call sign for fifty seconds followed by a dash of ten seconds on kc/s (or m) in order that you may take my bearing.
QTH	What is your position in latitude and longitude (or by any other way of showing it)?	My position is latitude longitude (or by any other way of showing it).
QTI	What is your true course?	My true course is degrees.
Q TJ	What is your speed?	My speed is knots (or kilometres) per hour.
QTM	Send radioelectric signals and submarine sound signals to enable me to fix my bearing and my distance.	I will send radioelectric signals and submarine sound signals to enable you to fix your bearing and your distance.
QTO	Have you left dock (or port)?	I have just left dock (or port).

Abbreviation	Question	Answer
QTP	Are you going to enter doek (or port)?	I am going to enter doek (or port).
QTQ	Can you communicate with my station by means of the International Code of Signals?	I am going to communicate with your station by means of the International Code of Signals.
QTR	What is the exact time?	The exact time is
QTU	What are the hours during which your station is open?	My station is open from to
QUA	Have you news of (call sign of the mobile station)?	Here is news of (call sign of the mobile station).
QUB	Can you give me in this order, information concerning: visibility, height of clouds, ground wind for (place of observation)?	Here is the information requested
QUC	What is the last message received by you from (call sign of the mobile station)?	The last message received by me from (call sign of the mobile station) is
QUD	Have you received the urgency signal sent by (call sign of the mobile station)?	I have received the urgency signal sent by (call sign of the mobile station) at (time).
QUF	Have you received the distress signal sent by (call sign of the mobile station)?	I have received the distress signal sent by (call sign of the mobile station) at (time).
QUG	Are you being forced to alight in the sea (or to land)?	I am forced to alight (or land) at (place).
QUH	Will you indicate the present barometric pressure at sea level?	The present barometric pressure at sea level is (units).
QUJ	Will you indicate the true course for me to follow, with no wind, to make for you?	The true course for you to follow, with no wind, to make for me is degrees at (time).

Special abbreviations adopted by the A.R.R.L.:

QST General call preceding a message addressed to all amateurs and A.R.R.L. Members. This is in effect "CQ ARRL."
 QRR Official A.R.R.L. "land SOS." A distress call for emergency use only.

Miscellaneous Abbreviations

Abbreviation	Meaning
C	Yes.
N	No.
P	Indicator of private telegram in the mobile service (to be used as a prefix).
W	Word or words.
AA	All after (to be used after a note of interrogation to ask for a repetition).
AB	All before (to be used after a note of interrogation to ask for a repetition).
AL	All that has just been sent (to be used after a note of interrogation to ask for a repetition).
BN	All between (to be used after a note of interrogation to ask for a repetition).
BQ	A reply to an RQ
CL	I am closing my station.
CS	Call sign (to be used to ask for a call sign or to have one repeated).
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DF	Your bearing at (time) was degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DL	Your bearing at (time) was degrees in the doubtful sector of this station.
DO	Bearing doubtful. Ask for another bearing later, or at (time).
DP	Beyond 50 miles, the possible error of bearing may amount to two degrees.
DS	Adjust your transmitter, the minimum of your signal is too broad.

Abbr- viation	Meaning
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is two-way, what is your approximate direction in degrees in relation to this station?
DZ	Your bearing is reciprocal (to be used only by the control station of a group of direction-finding stations when it is addressing other stations of the same group).
ER	Here (to be used before the name of the mobile station in the sending of route indications).
GA	Resume sending (to be used more specially in the fixed service).
JM	If I may transmit, send a series of dashes. To stop my transmission, send a series of dots [not to be used on 500 kc/s (600 m)].
MN	Minute or minutes (to be used to indicate the duration of a wait).
NW	I resume transmission (to be used more especially in the fixed service).
OK	Agreed.
RQ	Designation of a request.
SA	Indicator preceding the name of an aircraft station (to be used in the sending of particulars of flight).
SF	Indicator preceding the name of an aeronautical station.
SN	Indicator preceding the name of a coast station.
SS	Indicator preceding the name of a ship station (to be used in sending particulars of voyage).
TR	Indicator used in sending particulars concerning a mobile station.
UA	Are we agreed?
WA	Word after (to be used after a note of interrogation to request a repetition).
WB	Word before (to be used after a note of interrogation to request a repetition).
XS	Atmospherics.
YS	Your service message.
ABV	Repeat (or I repeat) the figures in abbreviated form.
ADR	Address (to be used after a note of interrogation to request a repetition).
CFM	Confirm (or I confirm).
COL	Collate (or I collate).
ITP	Stops (punctuation) count.
MSG	Telegram concerning the service of the ship (to be used as a prefix).
NIL	I have nothing for you (to be used after an abbreviation of the Q code to mean that the answer to the question put is negative).
PBL	Preamble (to be used after a note of interrogation to request a repetition).
REF	Referring to (or Refer to).
RPT	Repeat (or I repeat) (to be used to ask for or to give repetition of all or part of the traffic the relative particulars being sent after the abbreviation).
SIG	Signature (to be used after a note of interrogation to request a repetition).
SVC	Indicator of service telegram concerning private traffic (to be used as a prefix).
TFC	Traffic.
TXT	Text (to be used after a note of interrogation to request a repetition).

Ham Abbreviations

▲ In amateur work many of the most commonly used radio and ordinary English words are frequently abbreviated, either by certain generally recognized methods or, as often occurs, on the spur of the moment according to the ideas of the individual operator. Beginning amateurs are likely to be confused by these "ham abbreviations" at first, but will probably pick them up quickly enough in the case of the more or less standard ones, and get the general idea governing the construction of the unusual ones occasionally encountered.

A method much used in short words is to give the first and last letters only, eliminating all intermediate letters. Examples: Now, nw; check, ck; would, wd.

Another method often used in short words employs phonetic spelling. Examples: Some, sum; good, gud; says, sez; night, nite.

A third method uses consonants only, eliminating all vowels. Examples: Letter, ltr; received, red; message, msg.

Replacing parts of a word with the letter "x" is a system occasionally used in abbreviating certain words. Examples: Transmitter, xmtr; weather, wx; distance, dx; press, px.

In listing below a short list of some of the more frequently encountered amateur abbreviations, we want to caution the beginner against making too great an effort to abbreviate or to scatter abbreviations wholesale throughout his radio conversation. A judicious use of certain of the short-cut words is permissible and saves time — the only legitimate object of abbreviations, of course. To abbreviate everything one sends, and to do so in many cases to extremes, is merely ridiculous.

ABT	About
ACCT	Account
AGN	Again

AHD Ahead
 AMP Ampere
 AMT Amount
 ANI Any
 AUSSIE Australian amateur
 BCL Broadcast listener
 BD Bad
 BI By
 BKG Breaking
 BLV Believe
 BN Been, all between
 BPL Brass Pounders' League
 BUG Vibroplex key
 CANS Phones
 CK Check
 CKT Circuit
 CL-CLD Closing station; call; called
 CM Communications Manager
 CONGRATS Congratulations
 CRD Card
 CUD Could
 CUL See you later
 CW Continuous wave
 DH Dead head
 DLD-DLVD Delivered
 DLY Delivery
 DX Distance
 ES And
 FB Fine business, excellent
 FIL Filament
 FM From
 FONES Telephones
 FR For
 FREQ Frequency
 GA Go ahead (resume sending)
 GB Good-bye
 GBA Give better address
 GE Good evening
 GG Going
 GM Good morning
 GN Gone, good night
 GND Ground
 GSA Give some address
 HAM Amateur, brass-pounder
 HI Laughter, high
 HR Here, hear
 HRD Heard
 HV Have
 ICW Interrupted continuous wave
 LID "Lid," a poor operator
 LTR Later, letter
 MA Milliamper
 MG Motor-generator
 MILS Milliamperes
 MO Master oscillator
 ND Nothing doing
 NIL Nothing
 NM No more
 NR Number, near
 NSA No such address
 NW Now
 OB Old Boy, Official Broadcast
 OM Old man
 OO Official Observer
 OPX Operation
 OP-OPR Operator
 ORS Official Relay Station
 OT Old timer, old top
 OW Old woman
 PSE Please
 PUNK Poor operator
 R Are, all right, O.K.
 RAC Rectified alternating current
 RCD Received
 RCVR Receiver
 RI Radio Inspector
 RM Route Manager
 SA Say
 SCM Section Communications Manager
 SED Said
 SEZ Says
 SIG-SG Signature
 SIGS Signals
 SINE Sign, personal initials, signature
 SKED Schedule
 TC Thermocouple
 TKS-TNX Thanks
 TNG Thing
 TMW Tomorrow
 TT That
 U You
 UR Your, you're
 URS Yours

VT Vacuum tube
 VY Very
 WD Would, word
 WCS Words
 WKD Worked
 WKG Working
 WL Will
 WT What, wait, watt
 WUD Would
 WV-WL Wave, wavelength
 WX Weather
 XMTR Transmitter
 YL Young lady
 YR Your
 ZEDDER New Zealander
 73 Best regards
 88 Love and kisses

International Prefixes

▲ The nationality of a radio station is shown by the initial letter or letters of its call signal. The International Radiotelegraph Convention, supplemented by provisional action of the Berne Bureau, allocates the alphabet amongst the nations of the world for that purpose. Every station call of a nation must be taken from the block of letters thus assigned it. The amateur station call commonly consists of one or two initial letters thus chosen (to indicate nationality), a digit (assigned by the local government to indicate the subdivision of the nation in which the station is located), and two or three additional letters (to identify the individual station).

In the list which follows, the first column shows the international allocation of blocks of call signals. This list is useful in identifying the nationality of any call heard, whether amateur or not. In the second column appears the area to which the calls are assigned. In the third column the amateur prefixes, the beginning letters of amateur calls, are listed. In most cases we know these prefixes to have been officially designated by the government concerned, but in some cases we have listed, of our own initiative, the proper prefix when there can be no choice about it. For instance, Haiti is assigned the calls from HHA to HHZ and therefore ever Haitian amateur call must begin with the letters HH, whether that government so proclaims or not. Where a prefix is shown in brackets, it indicates that that government has more than one assignment of initial letters and that the indicated letter will be found assigned, in another part of the list, to that country. The list:

Block	Assigned to	Amateur Prefix
CAA-CEZ	Chile	CE
CFA-CKZ	Canada	[VE]
CLA-CMZ	Cuba	CM
CXA-CNZ	Morocco	[F]
COA-COZ	Cuba	[CM]
CPA-CPZ	Bolivia	CP
CQA-CRZ	Portuguese colonies:	
	Cape Verde Islands	CR4
	Portuguese Guinea	CR5
	Angola	CR6
	Mozambique	CR7
	Portuguese India	CR8
	Macao	CR9
	Timor	CR10
CSA-CUZ	Portugal:	
	Portugal proper	CT1
	Azores Islands	CT2
	Madeira Islands	CT3
CVA-CXZ	Uruguay	CX
CYA-CZZ	Canada	[VE]
D	Germany	D
EAA-EHZ	Spain	EA
EIA-EIZ	Irish Free State	EI

ELA-ELZ	Liberia	EL
EPA-EQZ	Persia	EP
ESA-ESZ	Esthonia	ES
ETA-ETZ	Ethiopia (Abyssinia)	ET
EZA-EZZ	Territory of the Saar	EZ
F	France:	
	France, Algeria, Martinique, Morocco and Tahiti	F3, F8
	Tunis	F4
	French Indo-China	F1
G	United Kingdom:	
	Great Britain except Ireland	G
	Northern Ireland	G1
HAA-HAZ	Hungary	HA
HBA-HBZ	Switzerland	HB
HCA-HCZ	Ecuador	HC
HHA-HHZ	Haiti	HH
HIA-HIZ	Dominican Republic	HI
HJA-HKZ	Colombia	HJ-HK
HPA-HPZ	Republic of Panama	HP
HRA-HRZ	Honduras	HR
HSA-HSZ	Siam	HS
HVA-HVZ	Vatican City	
HZA-HZZ	Hedjaz	HZ
I	Italy and colonies	I
J	Japan	J
K	United States of America:	
	Continental United States	[W]²
	Philippine Islands	KA
	Porto Rico and Virgin Islands	K4
	Canal Zone	K5
	Territory of Hawaii, Guam, Samoa	K6
	Territory of Alaska	K7
LAA-LNZ	Norway	LA
LOA-LWZ	Argentina	LU
LXA-LXZ	Luxembourg	LX
LYA-LYZ	Lithuania	LY
LZA-LZZ	Bulgaria	LZ
M	Great Britain	[G]
N	United States of America	[W]²
OAA-OCZ	Peru	OA
OEA-OEZ	Austria	OE
OFA-OHZ	Finland	OH
OKA-OKZ	Czechoslovakia	OK
ONA-OTZ	Belgium	ON
OUA-OVZ	Denmark	OZ
PAA-PIZ	Netherlands	PA
PJA-PJZ	Curacao	PJ
PKA-POZ	Dutch East Indies	PK
PPA-PYZ	Brazil	PY
PZA-PZZ	Surinam	PZ
R	Union of Soviet Socialist Republics	[U]
SAA-SMZ	Sweden	SM
SOA-SRZ	Poland	SP
STA-SUZ	Egypt	ST
SVA-SVZ	Greece	SV
TAA-TCZ	Turkey	TA
TFA-TFZ	Iceland	TF
TGA-TGZ	Guatemala	TG
TIA-TIZ	Costa Rica	TI
TKA-TZZ	France and colonies and protectorates	[F]
U	Union of Socialist Soviet Republics	[U]
VAA-VGZ	Canada	VE
VHA-VMZ	Australia	VK
VOA-VOZ	Newfoundland	VO
VPA-VSZ	British colonies and protectorates:	
	Gilbert & Ellice Islands, Zanzibar	VP1
	Fiji	VP2
	Malta	VP3
	British Honduras, Trinidad	VP4
	Jamaica	VP5
	Barbados	VP6
	Bermuda	VP9
	Fanning Island	VQ1
	Northern Rhodesia	VQ2
	Tanganyika	VQ3
	Kenya Colony	VQ4
	Uganda	VQ5
	British Guiana	VR
	Malaya	VSI-2-3
	Sarawak	VS5
	Hongkong	VS6
	Ceylon	VS7
	Straits Settlements	VS8
VTA-VWZ	British India	VC
VXA-VYZ	Canada	[VE]
W	United States of America:	
	Continental United States	[W]²
	(For others, see under K)	
XAA-XFZ	Mexico	X³
XGA-XUZ	China	XT-XU⁴
XYA-XZZ	British India	[VU]

YAA-YAZ	Afghanistan	YA
YBA-YHZ	Dutch East Indies	[PK]
YIA-YIZ	Iraq	YI
YJA-YJZ	New Hebrides	YJ
YLA-YLZ	Latvia	YL
YMA-YMZ	Danzig	YM
YNA-YNZ	Nicaragua	YN
YOA-YRZ	Roumania	YR
YSA-YSZ	El Salvador	YS
YTA-YUZ	Jugo-Slavia	YT-YU
YVA-YWA	Venezuela	YV
ZAA-ZAZ	Albania	ZA
ZBA-ZJZ	British colonies and protectorates:	
	Transjordania	ZC1
	Palestine	ZC6
	Nigeria	ZD
	Southern Rhodesia	ZE1
ZKA-ZMZ	New Zealand:	
	Cook Islands	ZK
	New Zealand proper	ZL
	British Samoa	ZM
ZPA-ZPZ	Paraguay	ZP
ZSA-ZUZ	Union of South Africa	ZS-ZT-ZU
ZVA-ZZZ	Brazil	[PY]

¹ A number of Moroccan amateurs use the unofficial prefix CN, although the French government has decreed that F8 must be used by licensed stations.
 ² Some amateur stations licensed to members of the U. S. Naval Reserve are authorized to use the prefix N.
 ³ Improperly assigned by Mexico; it should have two letters to distinguish it from China.
 ⁴ Few Chinese amateurs, on the contrary, use the X-prefix; most of them still use AC, an heritage from the old I.A.R.U. intermediates.

Measuring Distances

▲ Often it is interesting to know just how far away some station is located. In measuring distances it is customary to measure along the shortest path on the surface of the earth. This distance is along the arc of a Great Circle, and for very short distances is practically a straight line. Distances of a thousand miles or so may be measured with sufficient accuracy on an ordinary map with a ruler, using the "scale of miles" indicated on the map.

For longer distances where the curvature of the earth cannot be neglected, the simplest way of measuring distance is by means of a common globe of the type used in school-rooms. The globe should be at least eight inches in diameter for good results. A piece of string should be stretched between the two points in question, and when pulled taut will automatically align itself along the Great Circle route between them. The length of the string between the two points when converted into miles according to the scale of the globe, will be the distance between the two points.

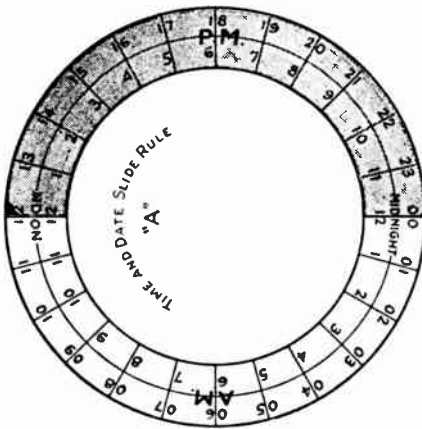
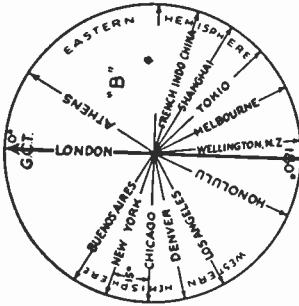
The globe will be found useful in other ways also, as for instance in determining the direction in which a distant spot lies from the station. Flat maps of the world (on Mercator's projection) give a wholly misleading impression of both distance and direction between points widely separated, especially if located in the extremes of latitude.

Circular Time-and-Date Chart

▲ A method of comparing different times with each other and with G.C.T. (Greenwich Civil Time) is necessary to get time, weather, and press schedules, announced in almost every case in local time. In the chart shown, the two discs A and B should be drawn carefully and mounted on cardboard. When centered and pinned together we have a convenient device to use in

working international schedules and in checking QSL-cards. The chart is based on the fact that time changes an hour for each 15° of arc.

To find local time from a given G.C.T., simply set the G.C.T. mark on the given time and read the local time directly at its mark. Let us take an example. Set the G.C.T. mark at 00 G.C.T. Then by direct reading it is 6 p.m. Chicago time or 9 a.m. Tokio time. If we in Tokio wanted to find what time it was in New York at 6 p.m. Tokio time, we would set the Tokio pointer at 6 p.m. and read 4 a.m. for New York time.



Finding dates: Suppose an operator in Los Angeles works a station in Tokio at 11 p.m. P.S.T. on June 10. Then the slide rule shows that it will be 4 p.m. Tokio time. The next thing is to find whether it is *to-day* or *to-morrow* in Tokio, that is, June 10th or 11th. Now with the rule all set we run our eye around it in a *clockwise* direction from Los Angeles to Tokio. If at any point in that space the midnight mark on disc A is encountered it is *to-morrow* in Tokio, i.e. June 11th. If the midnight mark is not encountered in this space it is *to-day* in Tokio. For example: Suppose the Los Angeles station works the station in Tokio at 1 a.m. P.S.T. June 10th. Then the Los Angeles operator will know from the slide rule that it is 6 p.m. June 10th Tokio time.

Let us work from the Eastern Hemisphere back to the Western. Suppose the operator at the Tokio station is doing the figuring. He works the

Los Angeles station, let us say, at 9 p.m. June 15th, Tokio time. He wants to know what time it is in Los Angeles and also what the date is. He sets the rule to 9 p.m. Tokio time and finds at once that it is 4 a.m. in Los Angeles. Now for the date. He reads around disc B from Tokio to Los Angeles in a *clockwise* direction. Notice that it is always clockwise from the local station to the distant station. If at any place in that path the midnight mark is encountered it is *to-day* in Los Angeles, in other words, June 15th.

Suppose the Tokio station works the station in Los Angeles at 1 a.m. Tokio time. It would be 8 a.m. Los Angeles time, and since the midnight mark is not encountered between the two, in a clockwise direction from Tokio to Los Angeles, it is *yesterday* in Los Angeles, e.i. June 14th.

Now to find the difference in dates between two stations in the same hemisphere. Consider that half of the disc B and disregard the other half altogether. If the midnight mark does not come between them, within that semicircle, they are both *to-day*. If, however, the midnight mark comes in between them the one to the right is one day ahead of the one to the left, or inversely, the one to the left is a day behind the one to the right.

Good Books

▲ Every amateur should maintain a carefully selected bookshelf; a few good books, consistently read and consulted, will add immeasurably to the interest and knowledge of the owner. We suggest a selection among the following works, all of which have been gone over carefully and are recommended in their various fields.

Principles of Radio, by Keith Henney, is an excellent book for the amateur who wants to acquire a better understanding of the fundamentals of radio transmission and reception. The book is thoroughly modern and, generally speaking, is a "non-mathematical" treatment. Recommended to every amateur. Price, \$3.50.

Radio Engineering, by Prof. F. E. Terman, is written from the viewpoint of the practical engineer engaged in design and experimental work on modern transmitters and receivers, and covers all phases of radio communication with the thoroughness of a complete reference book. A knowledge of advanced mathematics is helpful, but not necessary. Price, \$5.00.

An excellent theoretical work, requiring some knowledge of mathematics (algebra, at least) is *Elements of Radio Communication*, by Prof. J. H. Morecroft, price \$3.00. This is in the "first-year" student class. Perhaps the best known of all theoretical works is *Principles of Radio Communication*, by Morecroft, priced at \$7.50, but a familiarity with mathematics is essential to anyone who expects to derive much benefit from this book. The *Manual of Radio Telegraphy and Telephony*, by Admiral S. S. Robison, U.S.N., and published by the Naval Institute, covers both the theoretical and practical fields.

A monumental work on vacuum tubes has been made available recently in Dr. E. L. Chaffee's *Theory of Thermionic Vacuum Tubes*, based on his research and study at Harvard University. This book is of an advanced nature, but is particularly recommended because of its exhaustive and competent presentation.

Two valuable books cover the general field of electricity and communications, with fitting emphasis on the radio aspects. *Electricity — What It Is and How It Acts*, by A. W. Kramer, is an easily understood treatment of modern electrical theory, including comprehensive discussions of vacuum-tube and electro-magnetic wave phenomena. It is written in two volumes, price \$2.00 each. *Communication Engineering*, by Prof. W. L. Everitt, is a thorough treatment of all types of communications networks. A certain amount of training in d.c. and a.c. current theory as well as mathematics through calculus is needed for fullest appreciation of this work. The price is \$5.00.

For the experimenter, there is Prof. R. R. Ramsey's *Experimental Radio*, price \$2.75, which describes in detail 128 experiments designed to bring out the principles of radio theory, instruments and measurements. There are two excellent books on high frequency measurements, intended primarily for serious experimenters and engineers. *Radio Frequency Electrical Measurements*, by H. A. Brown, is priced at \$4.00, while *High Frequency Measurements* by August Hund costs \$5.00.

Radio Data Charts, an English publication by R. T. Beatty, is a series of abacs (graphic charts) which enables most of the problems connected with radio design to be solved easily without recourse to mathematical calculations.

For practical handbooks covering just about the entire field of radio, we recommend either *Radio Theory and Operating*, by Loomis, price \$4.25, *The Radio Manual*, by Sterling, at \$6.00, or *Radio Telegraphy and Telephony*, by Duncan and Drew, at \$7.50. All of these are over 900 pages and are of the type used as texts in radio schools; while they contain a moderate amount of theory, they are essentially practical handbooks for commercial and broadcast operators. Any one of them is well worth having.

Amateurs who are interested in studying for commercial operators' licenses will be interested in the following, in conjunction with the volumes listed in the preceding paragraph: *How to Pass U. S. Government Radio License Examinations*, by Duncan and Drew, price \$2.00, which is written to supplement the other work by the same authors, mentioned above; and *Radio Operating Questions and Answers*, by Nilson and Hornung, \$2.50, which is intended to supplement *Practical Radio Telegraphy* (by the same authors, price \$3.00) in preparation for commercial licenses. This book is the only one in the current list which has been revised to incorporate the new regulations. Revisions of other operating texts are believed to be in progress, but are not yet completed. In addition, there is also the *Radio Traffic Manual and Operating Regulations*, by Duncan and Drew, which carries the new commercial licensee right into the practical operating field.

Any of the above books may be obtained from the Book Department of the A.R.R.L. at the prices stated. Readers are referred to the Book Department's advertisement, in the advertising section of this Handbook, for a list which includes additional volumes of interest to amateurs.

QST is the official organ of the American Radio Relay League. It is published monthly, containing up-to-date information on amateur activities

and describing the latest developments in amateur radio. It is a magazine devoted exclusively to the radio amateur. Written by and for the amateur, it contains knowledge supplementary to the books we have mentioned. *QST* is found on the bookshelves of earnest amateurs and experimenters everywhere. Good books are a worth-while investment. A subscription to *QST* is equally valuable.

The Decibel

▲ The decibel (abbreviated *db*) is a convenient unit for the measurement of electrical or acoustic power ratios on a logarithmic scale. The number of decibels equivalent to the ratio between two amounts of power is

$$db = 10 \log_{10} \frac{P_1}{P_2}$$

Since the decibel is a logarithmic unit, successive gains and losses expressed in *db* can be added algebraically. If the ratio of the two power values is greater than 1 there is a power gain; if the ratio is less than 1 there is a loss of power. A gain is expressed in "plus *db*"; a loss in "minus *db*."

The decibel also can be used to express ratios between voltages and currents provided the circuit conditions are the same for the two quantities whose magnitudes are being compared; i.e., if the impedances and power factors of the circuits are the same.

The decibel is primarily a unit which specifies gains or losses with reference to the power value at some point in a system regardless of the actual value of the reference power. In telephone and radio work, however, it is convenient to assume a reference power level and express the power at a point in a circuit in terms of "plus *db*" or "minus *db*" above or below this reference level. A standard reference level in radio work is .006 watts, or 6 milliwatts.

Standard Letter Symbols for Electrical Quantities

Admittance	<i>Y, y</i>
Angular velocity ($2\pi f$)	ω
Capacitance	<i>C</i>
Conductance	<i>G, g</i>
Current	<i>I, i</i>
Difference of potential	<i>E, e</i>
Dielectric constant	<i>K</i> or ϵ
Energy	<i>W</i>
Frequency	<i>f</i>
Impedance	<i>Z, z</i>
Inductance	<i>L</i>
Magnetic intensity	<i>H</i>
Magnetic flux	Φ
Magnetic flux density	<i>B</i>
Mutual inductance	<i>M</i>
Number of conductors or turns	<i>N</i>
Permeability	μ
Phase displacement	θ or ϕ
Power	<i>P, p</i>
Quantity of electricity	<i>Q, q</i>
Reactance	<i>X, x</i>
Resistance	<i>R, r</i>
Susceptance	<i>b</i>
Speed of rotation	<i>n</i>

Voltage	E, e
Work	W
Letter Symbols for Vacuum Tube Notation	
Grid potential	E_g, e_g
Grid current	I_g, i_g
Grid conductance	g_g
Grid resistance	r_g
Grid bias voltage	E_c
Plate potential	E_p, e_p
Plate current	I_p, i_p
Plate conductance	g_p
Plate resistance	r_p
Plate supply voltage	E_b
Emission current	I_s
Mutual conductance	g_m
Amplification factor	μ
Filament terminal voltage	E_f
Filament current	I_f
Filament supply voltage	E_a
Grid-plate capacity	C'_{gp}
Grid-filament capacity	C'_{gf}
Plate-filament capacity	C'_{pf}
Grid capacity ($C'_{gp} + C'_{gf}$)	C'_g
Plate capacity ($C'_{gp} + C'_{pf}$)	C'_p
Filament capacity ($C'_{gf} + C'_{pf}$)	C'_f

NOTE.—Small letters refer to instantaneous values.

Abbreviations Commonly Used in Radio

Alternating current	a.c.
Antenna	ant.
Audio frequency	a.f.
Continuous waves	c.w.
Cycles per second	~
Decibel	db.
Direct current	d.c.
Electromotive force	e.m.f.
Frequency	f.
Ground	gnd.
Henry	h.
Intermediate frequency	i.f.
Interrupted continuous waves	i.c.w.
Kilocycles (per second)	kc.
Kilowatt	kw.
Megohm	MΩ
Microfarad	μfd.
Microhenry	μh.
Micronicrofarad	μμfd.
Microvolt	μv.
Microvolt per meter	μv/m.
Milliamperere	ma.
Milliwatt	mw.
Ohm	Ω
Power factor	p.f.
Radio frequency	r.f.
Volt	v.

Metric Prefixes Often Used with Radio Quantities

μ	$\frac{1}{1,000,000}$	One-millionth	micro-
m	$\frac{1}{1,000}$	One-thousandth	milli-
c	$\frac{1}{100}$	One hundredth	centi-
d	$\frac{1}{10}$	One-tenth	deci-

1	One	uni-
10	Ten	deka-
100	One hundred	hekto-
1,000	One thousand	kilo-
10,000	Ten thousand	myria-
1,000,000	One million	mega-

Greek Alphabet

▲ Since Greek letters are used to stand for many electrical and radio quantities, the names and symbols of the Greek alphabet with the equivalent English characters are given.

Greek Letter	Greek Name	English Equivalent
A α	Alpha	a
B β	Beta	b
Γ γ	Gamma	g
Δ δ	Delta	d
E ε	Epsilon	e
Z ζ	Zeta	z
Η η	Eta	ē
Θ θ	Theta	th
I ι	Iota	i
K κ	Kappa	k
Λ λ	Lambda	l
M μ	Mu	m
N ν	Nu	n
Ξ ξ	Ni	x
Ο ο	Omicron	ō
Π π	Pi	p
Ρ ρ	Rho	r
Σ σ	Sigma	s
T τ	Tau	t
Υ υ	Upsilon	u
Φ φ	Phi	ph
Χ χ	Chi	ch
Ψ ψ	Psi	ps
Ω ω	Omega	ō

Inductance Calculation

▲ The lumped inductance of coils for transmitting and receiving is fairly easy to calculate:

$$L = \frac{0.2 A^2 N^2}{3.1 + 9B + 10C}$$

where *L* is the inductance in microhenrys
A is the mean diameter of the coil in inches
B is the length of winding in inches
C is the radial depth of winding in inches
N is the number of turns.

The quantity *C* may be neglected if the coil is a single-layer solenoid, as is nearly always the case with coils for high frequencies.

For example, assume a coil having 35 turns of No. 30 d.s.c. wire on a receiving coil form having a diameter of 1.5 inches. Consulting the wire table, we find that 35 turns of No. 30 d.s.c. will occupy a length of one-half inch. Therefore,

$$\begin{aligned} A &= 1.5 \\ B &= .5 \\ N &= 35 \end{aligned}$$

and

Appendix

$$L = \frac{0.2 \times (1.5)^2 \times (35)^2}{(3 \times 1.5) + (9 \times 1.5)}$$

or 61.25 microhenrys.

Figuring the Capacitance of a Condenser

$$C = \frac{kA(n-1)}{4\pi d \times 9 \times 10^5}$$

$$= .0088 \frac{kA}{d} (n-1) 10^{-5} \mu\text{fds.}$$

where A = area of one side of one plate (sq. cm.)
 n = total number of plates
 d = separation of plates (cm.)
 k = specific inductive capacity of dielectric.

The Specific Inductive Capacity (k) is a property of the dielectric used in a condenser. It determines the quantity of charge which a given separation and area of plates will accumulate for

Table of Dielectric Constants

Dielectric	"k"	Puncture voltage	
		Kilovolts per cm.	Kilovolts per inch.
Air (normal pressure)	1.00	7.8-9.0	19.8-22.8
Flint Glass	6.6 to 10	900	2280
Mica	4.6 to 8	1500	3810
Paraffin Wax (solid)	2.0 to 2.5	400	1017
Sulphur	3.9 to 4.2	—	—
Castor Oil	4.7	150	381
Porcelain	4.4	—	—
Quartz	4.5	—	—
Resin	2.5	—	—
Olive Oil	3.1	120	305
Gutta Percha	3.3 to 4.9	80-200	203-508
Shellac	3.1	—	—
Common Glass	3.1 to 4.0	300-1500	762-3810
Turpentine	2.23	110-160	280-406
Dry Oak Wood	2.5 to 6.8	—	—
Formica, Bakelite, etc.	5 to 6	—	—

a given applied voltage. The "inductivity" of the dielectric varies as in the above table. "k" is the ratio of the capacitance of a condenser with a given dielectric to the capacitance of the same instrument with air dielectric.

When the air dielectric in a variable condenser is replaced with some other fluid dielectric its maximum and minimum capacitance values are multiplied by "k" and the "sparking" potential is increased.

Fluid dielectrics repair themselves after a breakdown unless an arc is maintained that carbonizes the oil. Dry oil is a good dielectric with quite low losses. When solid dielectric is used it should be borne in mind that dielectric strength (breakdown voltage) becomes lower as temperature rises. Breakdown is a function of time as well as voltage. A condenser that stands up under several thousand volts for a few seconds might break down when connected to a 2000-volt line for a half-hour.

Example of finding condenser capacitance: We have 3 plates, 3" x 5", in air. The plates are separated 1/8". 1" = 2.54 centimeters.

$$k = 1. A = 7.62 \times 12.70 = 96.8 \text{ sq. cm. } d = .3175 \text{ cm. } n - 1 = 2.$$

$$C = .0088 \frac{1 \times 96.8}{.32} 2 \times 10^{-5} = .00005325 \mu\text{fd. or } 53\frac{1}{4}$$

micromicrofarads.

The capacity formula becomes as follows, when A is the area of one side of one plate in square inches and d is the separation of the plates in inches.

$$C = .02235 \frac{kA}{d} (n-1) 10^{-5} \mu\text{fd.}$$

If we put the condenser of our example in castor oil the increase in capacitance, owing to the greater value of k , will make our condenser have a capacitance of

$$53\frac{1}{4} \times 4.7 = 250 \text{ micromicrofarads.}$$

The air condenser might spark over at about $7.8 \times .3175 \text{ cm.} = 2.475 \text{ kv. (2,475 volts)}$.

In oil (castor oil) it would have $150/7.8$ (or $381/19.8$) times the breakdown voltage of air.

$$\frac{150}{7.8} = 19.25$$

$$19\frac{1}{4} \times 2475 = 47,600 \text{ volts}$$

We can find the same value directly:
 $150 \times .3175 \text{ cm.} = 47,600 \text{ volts (peak)}$.

Using the formulas for "reactance" we can find what the voltage drop across this condenser will be when carrying current at a specified high frequency.

$$E_x = X_c I \quad X_c = \frac{1}{2\pi f c}$$

where E_x is the reactance voltage drop, C is the capacitance of the condenser (farads),

f is the frequency (cycles per second), X_c is the reactance of the condenser in ohms.

Suppose we are using the 3-plate fixed air condenser in our antenna circuit, and that a radio-frequency ammeter is in series with it. We are operating on an 80-meter wavelength (3,750,000 cycles) and the meter right next the condenser reads 1.3 amperes. What is the voltage drop across the air condenser?

$$X_c = \frac{1}{2 (3.1416) (3,750,000) (53.25) 10^{-12}}$$

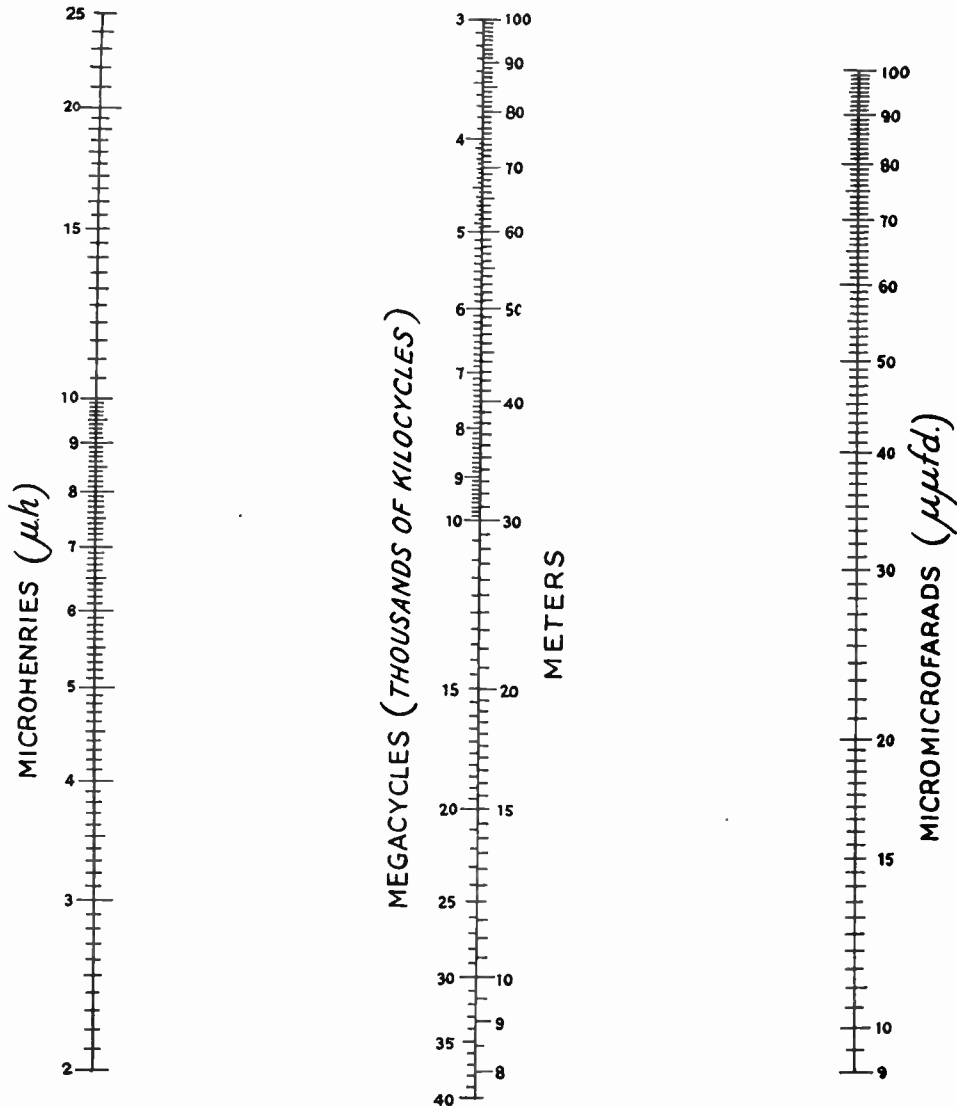
$$= \frac{1}{1257 \times 10^{-6}} = \frac{10^6}{1257} = 797 \text{ ohms}$$

$$E_x = (797)(1.3) = 1034 \text{ volts (root mean square value)}$$

If the wave is a sine wave, this value multiplied by 1.414 will give the "peak" or maximum value

$$1034 \times 1.414 = 1462 \text{ volts (peak)}$$

Our radio-frequency ammeter measures the heating effect of all the instantaneous values of current during the radio-frequency cycle. The direct current, the square of which equals the average of the squares of all the values of alternating current over a whole cycle, produces the same heat as the alternating current. Alternating current meters generally used for a.c. switchboard work read the effective or root mean square values which we mention above.



RELATION BETWEEN INDUCTANCE, CAPACITY AND FREQUENCY

With this chart and a straight-edge any of the above quantities can be determined if the other two are known. For example, if a condenser has a minimum capacity of 15 $\mu\mu fd.$ and a maximum capacity of 50 $\mu\mu fd.$, and it is to be used with a coil of 10 $\mu h.$ inductance, what frequency range will be covered? The straight-edge is connected between 10 on the left-hand scale and 15 on the right, giving 13 mc. as the high-frequency limit. Keeping the straight-edge at 10 on the left-hand scale, the other end is swung to 50 on the right-hand scale, giving a low-frequency limit of 7.1 mc. The tuning range would, therefore, be from 7.1 mc. to 13 mc., or 7100 kc. to 13,000 kc. The center scale also serves to convert frequency to wavelength.

COPPER WIRE TABLE

Gauge No. B. & S.	Diam. in Mils ¹	Circular Mil Area	Turns per Linear Inch ²				Turns per Square Inch ²			Feet per Lb.		Ohms per 1000 ft. 250 C.	Current-Carrying Capacity at 1500 C.M. per Amp. ³	Diam. in mm.	Nearest British S.W.G. No.
			Enamel	S.S.C.	D.S.C. or S.C.C.	D.C.C.	S.C.C.	Enamel S.C.C.	D.C.C.	Bare	D.C.C.				
1	289.3	82690	—	—	—	—	—	—	—	3.947	—	.1264	55.7	7.348	1
2	257.6	66370	—	—	—	—	—	—	—	4.977	—	.1593	44.1	6.544	3
3	229.4	52640	—	—	—	—	—	—	—	6.276	—	.2009	35.0	5.827	4
4	204.3	41740	—	—	—	—	—	—	—	7.914	—	.2533	27.7	5.189	5
5	181.9	33100	—	—	—	—	—	—	—	9.980	—	.3195	22.0	4.621	7
6	162.0	26250	—	—	—	—	—	—	—	12.58	—	.4028	17.5	4.115	8
7	144.3	20820	—	—	—	—	—	—	—	15.87	—	.5080	13.8	3.665	9
8	128.5	16510	7.6	—	7.4	7.1	—	—	—	20.01	19.6	.6405	11.0	3.264	10
9	114.4	13090	8.6	—	8.2	7.8	—	—	—	25.23	24.6	.8077	8.7	2.906	11
10	101.9	10390	9.6	—	9.3	8.9	87.5	84.8	80.0	31.82	30.9	1.018	6.9	2.588	12
11	90.74	8234	10.7	—	10.3	9.8	110	105	97.5	40.12	38.8	1.284	5.5	2.305	13
12	80.81	6530	12.0	—	11.5	10.9	136	131	121	50.59	48.9	1.619	4.4	2.053	14
13	71.96	5178	13.5	—	12.8	12.0	170	162	150	63.80	61.5	2.042	3.5	1.828	15
14	64.08	4107	15.0	—	14.2	13.3	211	198	183	80.44	77.3	2.575	2.7	1.628	16
15	57.07	3257	16.8	—	15.8	14.7	262	250	223	101.4	97.3	3.247	2.2	1.450	17
16	50.82	2583	18.9	—	17.9	16.4	321	306	271	127.9	119	4.094	1.7	1.291	18
17	45.26	2048	21.2	—	19.9	18.1	397	372	329	161.3	150	5.163	1.3	1.150	18
18	40.30	1624	23.6	—	22.0	19.8	493	454	399	203.4	188	6.510	1.1	1.024	19
19	35.89	1288	26.4	—	24.4	21.8	592	553	479	256.5	237	8.210	.86	.9116	20
20	31.96	1022	29.4	—	27.0	23.8	775	725	625	323.4	298	10.35	.68	.8118	21
21	28.46	810.1	33.1	—	29.8	26.0	940	895	754	407.8	370	13.05	.54	.7230	22
22	25.35	642.4	37.0	—	34.1	30.0	1150	1070	910	514.2	461	16.46	.43	.6438	23
23	22.57	509.5	41.3	—	37.6	31.6	1400	1300	1080	648.4	584	20.76	.34	.5733	24
24	20.10	404.0	46.3	—	41.5	35.6	1700	1570	1260	817.7	745	26.17	.27	.5106	25
25	17.90	320.4	51.7	—	45.6	38.6	2060	1910	1510	1031	903	33.00	.21	.4547	26
26	15.94	254.1	58.0	—	50.2	41.8	2500	2300	1750	1300	1118	41.62	.17	.4049	27
27	14.20	201.5	64.9	—	55.0	45.0	3030	2780	2020	1639	1422	52.48	.13	.3606	29
28	12.64	159.8	72.7	—	60.2	48.5	3670	3350	2310	2067	1759	66.17	.11	.3211	30
29	11.26	126.7	81.6	—	65.4	51.8	4300	3900	2700	2607	2207	83.44	.084	.2859	31
30	10.03	100.5	90.5	—	71.5	55.5	5040	4660	3020	3287	2534	105.2	.067	.2546	33
31	8.928	79.70	101.	—	77.5	59.2	5920	5280	—	4145	2768	132.7	.053	.2268	34
32	7.950	63.21	113.	—	83.6	62.6	7060	6250	—	5227	3137	167.3	.042	.2019	36
33	7.080	50.13	127.	—	90.3	66.3	8120	7360	—	6591	4697	211.0	.033	.1798	37
34	6.305	39.75	143.	—	97.0	70.0	9600	8310	—	8310	6168	266.0	.026	.1601	38
35	5.615	31.52	158.	—	104.	73.5	10900	8700	—	10480	6737	335.0	.021	.1426	38-39
36	5.000	25.00	175.	—	111.	77.0	12200	10700	—	13210	7877	423.0	.017	.1270	39-40
37	4.453	19.83	198.	—	118.	80.3	—	—	—	16660	9309	533.4	.013	.1131	41
38	3.965	15.72	224.	—	126.	83.6	—	—	—	21010	10666	672.6	.010	.1007	42
39	3.531	12.47	248.	—	133.	86.6	—	—	—	26500	11907	848.1	.008	.0897	43
40	3.145	9.88	282.	—	140.	89.7	—	—	—	33410	14222	1069	.006	.0799	44

¹ A mill is 1/1000 (one thousandth) of an inch.² The figures given are approximate only, since the thickness of the insulation varies with different manufacturers.³ The current-carrying capacity at 1000 C.M. per ampere is equal to the circular-mil area (Column 3) divided by 1000.

Numbered Drill Sizes

Number	Diameter (mils)	Will Clear Screw	Drilled for Tapping Iron, Steel or Brass*
1	225.0	—	—
2	221.0	12-24	—
3	213.0	—	14-24
4	209.0	12-20	—
5	205.5	—	—
6	204.0	—	—
7	201.0	—	—
8	199.0	—	—
9	196.0	—	—
10	193.5	10-32	—
11	191.0	10-24	—
12	189.0	—	—
13	185.0	—	—
14	182.0	—	—
15	180.0	—	—
16	177.0	—	12-24
17	173.0	—	—
18	169.5	8-32	—
19	166.0	—	12-20
20	161.0	—	—
21	159.0	—	10-32
22	157.0	—	—
23	154.0	—	—
24	152.0	—	—
25	149.5	—	10-24
26	147.0	—	—
27	144.0	—	—
28	140.5	6-32	—
29	136.0	—	8-32
30	128.5	—	—
31	120.0	—	—
32	116.0	—	—
33	113.0	4-36 4-40	—
34	111.0	—	—
35	110.0	—	6-32
36	106.5	—	—
37	104.0	—	—
38	101.5	—	—
39	99.5	3-48	—
40	98.0	—	—
41	96.0	—	—
42	93.5	—	4-36 4-40
43	89.0	2-56	—
44	86.0	—	—
45	82.0	—	3-48
46	81.0	—	—
47	78.5	—	—
48	76.0	—	—
49	73.0	—	2-56
50	70.0	—	—
51	67.0	—	—
52	63.5	—	—
53	59.5	—	—
54	55.0	—	—

* Use one size larger drill for tapping bakelite and hard rubber.

Extracts from the Radio Law

▲ The complete text of the Communications Act of June 19, 1934, would occupy many pages. Only those parts most applicable to amateur radio station licensing and regulation in this country (with which every amateur should be familiar) are given. Note particularly Secs. 324, 325, 326 and 605 and the penalties provided in Secs. 501 and 502.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a commission to be known as the "Federal Communications Commission," which shall be constituted as

hereinafter provided, and which shall execute and enforce the provisions of this Act.

SEC. 2. (a) The provisions of this Act shall apply to all interstate and foreign communication by wire or radio and all interstate and foreign transmission of energy by radio, which originates and/or is received within the United States, and to all persons engaged within the United States in such communication or such transmission of energy by radio, and to the licensing and regulating of all radio stations as hereinafter provided; but it shall not apply to persons engaged in wire or radio communication or transmission in the Philippine Islands or the Canal Zone, or to wire or radio communication or transmission wholly within the Philippine Islands or the Canal Zone. . . .

SEC. 3. For the purposes of this Act, unless the context otherwise requires—

(b) "Radio communication" or "communication by radio" means the transmission by radio of writing, signs, signals, pictures, and sounds of all kinds, including all instrumentalities, facilities, apparatus, and services (among other things, the receipt, forwarding, and delivery of communications) incidental to such transmission.

(c) "Licensee" means the holder of a radio station license granted or continued in force under authority of this Act.

(d) "Transmission of energy by radio" or "radio transmission of energy" includes both such transmission and all instrumentalities, facilities, and services incidental to such transmission.

(e) "Interstate communication" or "interstate transmission" means communication or transmission (1) from any State, Territory, or possession of the United States (other than the Philippine Islands and the Canal Zone), or the District of Columbia, to any other State, Territory, or possession of the United States (other than the Philippine Islands and the Canal Zone), or the District of Columbia, (2) from or to the United States to or from the Philippine Islands or the Canal Zone, insofar as such communication or transmission takes place within the United States, or (3) between points within the United States but through a foreign country; but shall not include wire communication between points within the same State, Territory, or possession of the United States, or the District of Columbia, through any place outside thereof, if such communication is regulated by a State commission.

(f) "Foreign communication" or "foreign transmission" means communication or transmission from or to any place in the United States to or from a foreign country, or between a station in the United States and a mobile station located outside the United States.

(g) "United States" means the several States and Territories, the District of Columbia, and the possessions of the United States, but does not include the Philippine Islands or the Canal Zone. . . .

(q) "Amateur station" means a radio station operated by a duly authorized person interested in radio technique solely with a personal aim and without pecuniary interest.

SEC. 4. (a) The Federal Communications Commission (in this Act referred to as the "Commission") shall be composed of seven commissioners appointed by the President, by and with the advice and consent of the Senate, one of whom the President shall designate as chairman. . . .

SECTION 301. It is the purpose of this Act, among other things, to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio (a) from one place in any Territory or possession of the United States or in the District of Columbia to another place in the same Territory, possession, or District; or (b) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (c) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (d) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (e) upon any vessel or aircraft of the United States; or (f) upon any other mobile stations within the jurisdiction of the United States, except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

SEC. 303. Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest, or necessity requires, shall—

- (a) Classify radio stations;
- (b) Prescribe the nature of the service to be rendered by each class of licensed stations and each station within any class;
- (c) Assign bands of frequencies to the various classes of stations, and assign frequencies for each individual station and determine the power which each station shall use and the time during which it may operate;
- (d) Determine the location of classes of stations or individual stations;
- (e) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein;
- (f) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act: *Provided, however, That changes in the frequencies, authorized power, or in the times of operation of any station, shall not be made without the consent of the station licensee unless, after a public hearing, the Commission shall determine that such changes will promote public convenience or interest or will serve public necessity, or the provisions of this Act will be more fully complied with;*
- (g) Study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest; . . .
- (i) Have authority to make general rules and regulations requiring stations to keep such records of programs, transmissions of energy, communications, or signals as it may deem desirable; . . .
- (l) Have authority to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as the Commission finds qualified;
- (m) Have authority to suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy the Commission that the licensee (1) has violated any provision of any Act or treaty binding on the United States which the Commission is authorized by this Act to administer or any regulation made by the Commission under any such Act or treaty; . . . or (3) has willfully damaged or permitted radio apparatus to be damaged; or (4) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (5) has willfully or maliciously interfered with any other radio communications or signals;
- (n) Have authority to inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements of this Act, the rules and regulations of the Commission, and the license under which it is constructed or operated;
- (o) Have authority to designate call letters of all stations;
- (p) Have authority to cause to be published such call letters and such other announcements and data as in the judgment of the Commission may be required for the efficient operation of radio stations subject to the jurisdiction of the United States and for the proper enforcement of this Act; . . .

SEC. 309. (a) If upon examination of any application for a station license or for the renewal or modification of a station license the Commission shall determine that public interest, convenience, or necessity would be served by the granting thereof, it shall authorize the issuance, renewal, or modification thereof in accordance with said finding. In the event the Commission upon examination of any such application does not reach such decision with respect thereto, it shall notify the applicant thereof, shall fix and give notice of a time and place for hearing thereon, and shall afford such applicant an opportunity to be heard under such rules and regulations as it may prescribe.

(b) Such station licenses as the Commission may grant shall be in such general form as it may prescribe, but each license shall contain, in addition to other provisions, a statement of the following conditions to which such license shall be subject:

- (1) The station license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies designated in the license beyond the term thereof nor in any other manner than authorized therein.
- (2) Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of this Act. . . .

SEC. 310. (a) The station license required hereby shall not be granted to or held by—

- (1) Any alien or the representative of any alien; . . .

SEC. 312. (a) Any station license may be revoked for false statements either in the application or in the statement of fact which may be required by section 308 hereof, or because

of conditions revealed by such statements of fact as may be required from time to time which would warrant the Commission in refusing to grant a license on an original application, or for failure to operate substantially as set forth in the license, or for violation of or failure to observe any of the restrictions and conditions of this Act or of any regulation of the Commission authorized by this Act or by a treaty ratified by the United States: *Provided, however, That no such order of revocation shall take effect until fifteen days' notice in writing thereof, stating the cause for the proposed revocation, has been given to the licensee. Such licensee may make written application to the Commission at any time within said fifteen days for a hearing upon such order, and upon the filing of such written application said order of revocation shall stand suspended until the conclusion of the hearing conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of revocation.*

(b) Any station license hereafter granted under the provisions of this Act or the construction permit required hereby and hereafter issued, may be modified by the Commission either for a limited time or for the duration of the term thereof, if in the judgment of the Commission such action will promote the public interest, convenience, and necessity, or the provisions of this Act or of any treaty ratified by the United States will be more fully complied with: *Provided, however, That no such order of modification shall become final until the holder of such outstanding license or permit shall have been notified in writing of the proposed action and the grounds or reasons therefor and shall have been given reasonable opportunity to show cause why such an order of modification should not issue.*

SEC. 318. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission.

SEC. 321. . . . (b) All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

SEC. 324. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

SEC. 325. (a) No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station. . . .

SEC. 326. Nothing in this Act shall be understood or construed to give the Commission the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the Commission which shall interfere with the right of free speech by means of radio communication. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

SEC. 328. This title shall not apply to the Philippine Islands or to the Canal Zone. In international radio matters the Philippine Islands and the Canal Zone shall be represented by the Secretary of State.

SEC. 329. The Commission is authorized to designate any officer or employee of any other department of the Government on duty in any Territory or possession of the United States other than the Philippine Islands and the Canal Zone, to render therein such services in connection with the administration of the radio laws of the United States as the Commission may prescribe; *Provided, That such designation shall be approved by the head of the department in which such person is employed.*

SEC. 501. Any person who willfully and knowingly does or causes to be done any act, matter, or thing, in this Act prohibited or declared to be unlawful, or who willfully and knowingly omits or fails to do any act, matter, or thing in this Act required to be done, or willfully and

knowingly causes or suffers such omission or failure, shall, upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided herein, by a fine of not more than \$10,000 or by imprisonment for a term of not more than two years, or both.

Sec. 502. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than \$500 for each and every day during which such offense occurs.

Sec. 505. The trial of any offense under this Act shall be in the district in which it is committed; or if the offense is committed upon the high seas, or out of the jurisdiction of any particular State or district, the trial shall be in the district where the offender may be found or into which he shall be first brought. Whenever the offense is begun in one jurisdiction and completed in another it may be dealt with, inquired of, tried, determined, and punished in either jurisdiction in the same manner as if the offense had been actually and wholly committed therein.

Sec. 605. No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception, to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, contents, substance, purport, effect, or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided*, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

United States Amateur Regulations

▲ Pursuant to the basic communications law, general regulations for amateurs have been drafted by the Federal Communications Commission. The number before each regulation is its official number in the complete book of regulations for all classes of radio stations as issued by the Commission; since the amateur regulations are not all in one group, the numbers are not necessarily consecutive. The number of each regulation is of no consequence to the amateur, except as a means of reference.

Every amateur should be *thoroughly familiar* with these regulations and their effect, although, of course, it is not necessary to know the exact wording from memory.

RULES AND REGULATIONS GOVERNING AMATEUR RADIO STATIONS

1. Each application for an instrument of authorization shall be made in writing on the appropriate form prescribed by the Commission for the purpose. Separate application shall be filed for each instrument of authorization. The required forms except as provided in Rule 408 for amateur applicants, may be obtained from the Commission or from

the office of any Inspector. For a list of such offices and related geographical districts, see paragraph 30.

2. (h) Each application for amateur facilities shall be filed in accordance with the following instructions:

(1) Applications for amateur station and/or operators' licenses from applicants residing within 125 miles of Washington, D. C., a radio district office of the Commission, or an examining city (see Rule 30): One copy to the Inspector-in-Charge of the Radio District in which the applicant resides.

(2) Applications for amateur station and/or operators' licenses from applicants residing more than 125 miles from Washington, D. C., a radio district office of the Commission, or an examining city (see Rule 30): One copy direct to the Federal Communications Commission, Washington, D. C., in accordance with the instructions specifically set forth on the application form.

14. Each application for new license, where a construction permit is not prerequisite thereto, shall be filed at least 60 days prior to the contemplated operation of the station.

16. Unless otherwise directed by the Commission, each application for renewal of license shall be filed at least 60 days prior to the expiration date of the license sought to be renewed.

20. The transfer of a radio station license, or the rights granted thereunder, without consent of the Commission shall be sufficient ground for the revocation of such license or denial of any application for its renewal. Amateur station licenses and call signals are not transferable.

22. The Commission may grant special authority to the licensee of an existing station authorizing the operation of such station for a limited time in a manner, to an extent, or for a service other or beyond that authorized in the license.

24. Any licensee receiving official notice of a violation of Federal laws, the Commission's rules and regulations, or the terms and conditions of a license, shall within three days from such receipt send a written reply direct to the Federal Communications Commission at Washington, D. C. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. If the notice relates to some violation that may be due to the physical or electrical characteristics of the transmitting apparatus, the answer shall state fully what steps, if any, are taken to prevent future violations, and if any new apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery.

26. If the notice of violation relates to some lack of attention or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

27. All station licenses will be issued so as to expire at the hour of 3 a. m., eastern standard time. The normal license periods and expiration dates are as follows:

(e) The licenses for amateur stations will be issued for a normal license period of three years from the date of expiration of old license or the date of granting a new license or modification of a license.

28. Insofar as practicable, call signals of radio stations will be designated in alphabetical order from groups available for assignment, depending upon the class of station to be licensed. Because of the large number of amateur stations, calls will be assigned thereto in regular order and requests for particular calls will not be considered.

29. Call signals of stations will be deleted in each of the following cases:

(a) Where an existing instrument of authorization has expired and no application for renewal or extension thereof has been filed.

(b) Where a license has been revoked.

(c) Where a license is surrendered or cancelled.

(d) Other cause, such as death, loss of citizenship, or adjudged insanity of the station licensee. Such occurrences coming to notice should be reported to the Commission, preferably accompanied by the station license for cancellation, if available.

30. The following list of the radio districts gives the address of each field office of the Federal Radio Commission and the territory embraced in each district. [This list is reproduced on the last page of this appendix. — Ed.]

(a) The following is a list of the cities where examinations will be held for radio operators' licenses in addition to Washington, D. C., and the radio district offices of the Commission. Other cities may also be designated from time to time for the purpose of conducting commercial operators' examinations only: (See Rules 2, 404, and 408.)

Schenectady, N. Y.	St. Louis, Mo.
Winston-Salem, N. C.	Pittsburgh, Pa.
Nashville, Tenn.	Cleveland, Ohio
San Antonio, Tex.	Cincinnati, Ohio
Oklahoma City, Okla.	Columbus, Ohio
Des Moines, Iowa	

Examinations for commercial and Class A amateur privileges will be conducted not more than twice per year in the following cities, which are not to be construed as examining cities under the rules which apply for Class B and C amateur privileges:

Albuquerque, New Mexico	Jacksonville, Florida
Billings, Montana	Little Rock, Arkansas
Bismarck, North Dakota	Phoenix, Arizona
Boise, Idaho	Salt Lake City, Utah
Butte, Montana	Spokane, Washington

188. The term "station" means all of the radio-transmitting apparatus used at a particular location for one class of service and operated under a single instrument of authorization. In the case of every station other than broadcast, the location of the station shall be considered as that of the radiating antenna.

192. The term "portable station" means a station so constructed that it may conveniently be moved about from place to place for communication and that is in fact so moved about from time to time, but not used while in motion.

(a) The term "portable-mobile station" means a station so constructed that it may conveniently be moved from one mobile unit to another for communication, and that is, in fact, so moved about from time to time and ordinarily used while in motion.

204. Allocations of bands of frequencies to services, such as mobile, fixed, broadcast, amateur, etc., are set forth in Article 7 of the General Regulations annexed to the International Radiotelegraph Convention and in the North American Radio Agreement. These allocations will be adhered to in all assignments to stations capable of causing international interference.

207. Licenses shall use radio transmitters, the emissions of which do not cause interference, outside the authorized band, that is detrimental to traffic and programs of other authorized stations.

210. Radio communications or signals relating to ships or aircraft in distress shall be given absolute priority. Upon notice from any station, Government or commercial, all other transmission shall cease on such frequencies and for such time as may, in any way, interfere with the reception of distress signals or related traffic.

213. One or more licensed operators, of grade specified by these regulations, shall be on duty at the place where the transmitting apparatus of each station is located and whenever it is being operated; provided, however, that for a station licensed for service other than broadcast, and remote control is used, the Commission may modify the foregoing requirement upon proper application and showing being made, so that such operator or operators may be on duty at the control station in lieu of the place where the transmitting apparatus is located. Such modification shall be subject to the following conditions:

(a) The transmitter shall be capable of operation and shall be operated in accordance with the terms of the station license.

(b) The transmitter shall be monitored from the control station with apparatus that will permit placing the transmitter in an inoperative condition in the event there is a deviation from the terms of the license, in which case the radiation of the transmitter shall be suspended immediately until corrective measures are effectively applied to place the transmitter in proper condition for operation in accordance with the terms of the station license.

(c) The transmitter shall be so located or housed that it is not accessible to other than duly authorized persons.

214. The person manipulating the transmitting key of a manually operated radiotelegraph, mobile or amateur transmitting station shall be a regularly licensed operator. The licensees of other stations operated under the constant supervision of duly licensed operators may permit any per-

son or persons, whether licensed or not, to transmit by voice or otherwise, in accordance with the types of emission specified by the respective licenses.

220. Licensees of stations other than broadcast stations are authorized to carry on such routine tests as may be required for the proper maintenance of the stations, provided, however, that these tests shall be so conducted as not to cause interference with the service of other stations.

221. The original of each station license, except amateur, portable and portable-mobile stations shall be posted by the licensee in a conspicuous place in the room in which the transmitter is located. In the case of amateur, portable, and portable-mobile stations the original license, or a photostat copy thereof, shall be similarly posted or kept in the personal possession of the operator on duty.

(a) The original license of each station operator, except amateur and aircraft radio station operators, and operators of portable and portable-mobile stations, shall be posted in a conspicuous place in the room occupied by such operator while on duty. In the case of an amateur or aircraft radio operator, and operators of portable or portable-mobile stations, the original operator's license shall be similarly posted or kept in his personal possession and available for inspection at all times while the operator is on duty.

(b) When an operator's license cannot be posted because it has been mailed to an office of the Federal Communications Commission for endorsement or other change, such operator may continue to operate stations in accordance with the class of license held, for a period not to exceed sixty days, but in no case beyond the date of expiration of the license.

361. The term "amateur service" means a radio service carried on by amateur stations.

362. The term "amateur station" means a station used by an "amateur," that is, a duly authorized person interested in radio technique solely with a personal aim and without pecuniary interest.

364. The term "amateur radio operator" means a person holding a valid license issued by the Federal Communications Commission who is authorized under the regulations to operate amateur radio stations.

365. The term "amateur radiocommunication" means radiocommunication between amateur radio stations solely with a personal aim and without pecuniary interest.

366. An amateur station license may be issued only to a licensed amateur radio operator who has made a satisfactory showing of ownership or control of proper transmitting apparatus; provided, however, that in the case of a military or naval reserve radio station located in approved public quarters and established for training purposes, but not operated by the United States Government, a station license may be issued to the person in charge of such station who may not possess an amateur operator's license.

(a) An amateur operator's license may be granted to a person who does not desire an amateur station license, provided such applicant waives his right to apply for an amateur station license for ninety days subsequent to the date of application for operator's license.

367. Amateur radio station licenses shall not be issued to corporations, associations, or other organizations; provided, however, that in the case of a bona fide amateur radio society, a station license may be issued to a licensed amateur radio operator as trustee for such society.

368. Licenses for mobile stations and portable-mobile stations will not be granted to amateurs for operation on frequencies below 56,000 kilocycles. However, the licensee of a fixed amateur station may operate portable amateur stations (Rule 192) in accordance with the provisions of Rules 384, 386 and 387; and also portable and portable-mobile amateur stations (Rules 192 and 192a) on authorized amateur frequencies above 56,000 kilocycles in accordance with Rules 384 and 386, but without regard to Rule 387.

369. (Deleted. Rule 213 applies.)

370. Amateur stations shall be used only for amateur service, except that in emergencies or for testing purposes they may be used also for communication with commercial or Government radio stations. In addition, amateur stations may communicate with any mobile radio station which is licensed by the Commission to communicate with amateur stations, and with stations of expeditions which may also be authorized to communicate with amateur stations.

371. Amateur stations shall not be used for broadcasting any form of entertainment nor for the simultaneous retransmission by automatic means of programs or signals emanating from any class of station other than amateur.

372. Amateur stations may be used for the transmission of music for test purposes of short duration in connection with the development of experimental radiotelephone equipment.

373. Amateur radio stations shall not be used to transmit or receive messages for hire, nor for communication for

material compensation, direct or indirect, paid or promised.

374. The following bands of frequencies are allocated exclusively for use by amateur stations:

1,715 to 2,000 kc.	28,000 to 30,000 kc.
3,500 to 4,000 "	56,000 to 60,000 "
7,000 to 7,300 "	400,000 to 401,000 "
14,000 to 14,400 "	

374a. The licensee of an amateur station may, subject to change upon further order, operate amateur stations on any frequency above 110,000 kilocycles, without separate licenses therefor, provided:

- (1) That such operation in every respect complies with the Commission's rules governing the operation of amateur stations in the amateur service.
- (2) That records are maintained of all transmissions in accordance with the provisions of Rule 386.

375. All bands of frequencies so assigned may be used for radiotelegraphy, type A-1 emission. Type A-2 emission may be used in the following bands of frequencies only:

28,000 to 30,000 kc.
56,000 to 60,000 "
400,000 to 401,000 "

376. The following bands of frequencies are allocated for use by amateur stations using radiotelephony, type A-3 emission:

1,800 to 2,000 kc.	56,000 to 60,000 kc.
28,000 to 28,500 "	400,000 to 401,000 "

377. Provided the stations shall be operated by a person who holds an amateur operator's license endorsed for class A privileges, an amateur radio station may use radiotelephony, type A-3 emission, in the following additional bands of frequencies:

3,900 to 4,000 kc.	14,150 to 14,250 kc.
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378. The following bands of frequencies are allocated for use by amateur stations for television, facsimile, and picture transmission:

1,715 to 2,000 kilocycles
56,000 to 60,000 kilocycles

379. Transmissions by an amateur station may be on any frequency within an amateur band above assigned.

380. An amateur radio station shall not be located upon premises controlled by an alien.

381. The frequency of the waves emitted by amateur radio stations shall be as constant and as free from harmonics as the state of the art permits. For this purpose, amateur transmitters shall employ circuits loosely coupled to the radiating system or devices that will produce equivalent effects to minimize keying impacts and harmonics. Conductive coupling to the radiating antenna, even though loose, is not permitted, but this restriction does not prohibit the use of transmission-line feeder systems.

382. Licensees of amateur stations using frequencies below 14,400 kilocycles, shall use adequately filtered direct-current power supply for the transmitting equipment, to minimize frequency modulation and to prevent the emission of broad signals.

383. Licensees of amateur stations are authorized to use a maximum power input of one kilowatt to the plate circuit of the final amplifier stage of an oscillator-amplifier transmitter or to the plate circuit of an oscillator transmitter.

384. An operator of an amateur station shall transmit its assigned call at least once during each fifteen minutes of operation and at the end of each transmission. In addition, an operator of an amateur portable or portable-mobile radiotelegraph station shall transmit immediately after the call of the station, the break sign (BT) followed by the number of the amateur call area in which the portable or portable-mobile amateur station is then operating, as for example:

Example 1. Portable or portable-mobile amateur station operating in the third amateur call area calls a fixed amateur station: W1ABC W1ABC W1ABC DE W2DEF BT3 W2DEF BT3 W2DEF BT3 AR.

Example 2. Fixed amateur station answers the portable or portable-mobile amateur station: W2DEF W2DEF W2DEF DE W1ABC W1ABC W1ABC K.

Example 3. Portable or portable-mobile amateur station calls a portable or portable-mobile amateur station: W3GHI W3GHI W3GHI DE W4JKL BT4 W4JKL BT4 W4JKL BT4 AR.

If telephony is used, the call sign of the station shall be followed by an announcement of the amateur call area in which the portable or portable-mobile station is operating.

384a. In the case of an amateur licensee whose station is licensed to a regularly commissioned or enlisted member of the United States Naval Reserve, the Commandant of the naval district in which such reservist resides may authorize in his discretion the use of the call letter prefix "N," in lieu of the prefix "W," or "K," assigned in the license issued by the Commission, provided that such "N" prefix shall be used only when operating in the frequency bands 1715-2000

kilocycles and 3500-4000 kilocycles in accordance with instructions to be issued by the Navy Department.

385. In the event that the operation of an amateur radio station causes general interference to the reception of broadcast programs with receivers of modern design, that amateur station shall not operate during the hours from 8 o'clock p.m. to 10:30 p.m., local time, and on Sundays from 10:30 a.m. until 1 p.m., local time, upon such frequency or frequencies as cause such interference.

386. Each licensee of an amateur station shall keep an accurate log of station operation to be made available upon request by authorized Government representatives, as:

a. The date and time of each transmission. (The date need only be entered once for each day's operation. The expression "time of each transmission" means the time of making a call and need not be repeated during the sequence of communication which immediately follows; however, an entry shall be made in the log when "signing off" so as to show the period during which communication was carried on.)

b. The name of the person manipulating the transmitting key of a radiotelegraph transmitter or the name of the person operating a transmitter of any other type (type A-3 or A-4 emission) with statement as to type of emission. (The name need only be entered once in the log provided the log contains a statement to the effect that all transmissions were made by the person named except where otherwise stated. The name of any other person who operates the station shall be entered in the proper space for his transmissions.)

c. Call letters of the station called. (This entry need not be repeated for calls made to the same station during any sequence of communication provided the time of "signing off" is given.)

d. The input power to the oscillator, or to the final amplifier stage where an oscillator-amplifier transmitter is employed. (This need be entered only once provided the input power is not changed.)

e. The frequency band used. (This information need be entered only once in the log for all transmissions until there is a change in frequency to another amateur band.)

f. The location of a portable or portable-mobile station at the time of each transmission. (This need be entered only once, provided the location of the station is not changed. However, suitable entry shall be made in the log upon changing location, showing the type of vehicle or mobile unit in which the station is operated, and the approximate geographical location of the station at the time of operation.)

g. The message traffic handled. (If record communications are handled in regular message form, a copy of each message sent and received shall be entered in the log or retained on file for at least one year.)

387. Advance notice of all locations in which portable amateur stations will be operated shall be given by the licensee to the Inspector in Charge of the district in which the station is to be operated. Such notices shall be made by letter or other means prior to any operation contemplated and shall state the station call, name of licensee, the date of proposed operation and the approximate locations, as by city, town, or county. An amateur station operating under this rule shall not be operated during any period exceeding thirty days without giving further notice to the Inspector in Charge of the radio district in which the station will be operated. This rule does not apply to the operation of portable or portable-mobile amateur stations on frequencies above 56,000 kilocycles authorized to be used by amateur stations. (See Rule 368.)

400. An amateur station may be operated only by a person holding a valid amateur operator's license, and then only to the extent provided for by the class of privileges for which the operator's license is endorsed.

401. Amateur operators' licenses are valid only for the operation of licensed amateur stations, provided, however, any person holding a valid radio operator's license of any class may operate stations in the experimental service licensed for, and operating on, frequencies above 30,000 kilocycles.

402. Amateur station licenses and/or amateur operator licenses may, upon proper application, be renewed provided: (1) the applicant has used his station to communicate by radio with at least three other amateur stations during the three-month period prior to the date of submitting the application, or (2) in the case of an applicant possessing only an operator's license, that he has similarly communicated with amateur stations during the same period. Proof of such communication must be included in the application by stating the call letters of the stations with which communication was carried on and the time and date of each communication. Lacking such proof, the applicant will be ineligible for a license for a period of ninety days.

403. There shall be but one main class of amateur operator's license to be known as "amateur class" but each such license shall be limited in scope by the signature of the examining officer opposite the particular class or classes of privileges which apply, as follows:

Class A. Unlimited privileges.

Class B. Unlimited radiotelegraph privileges. Limited in the operation of radiotelephone amateur stations to the following bands of frequencies: 1800 to 2000 kilocycles; 28,000 to 28,500 kilocycles; 56,000 to 60,000 kilocycles; 400,000 to 401,000 kilocycles.

Class C. Same as Class B privileges, except that the Commission may require the licensee to appear at an examining point for a supervisory written examination and practical code test during the license term. Failing to appear for examination when directed to do so, or failing to pass the supervisory examination, the license held will be cancelled and the holder thereof will not be issued another license of the Class C privileges.

404. The scope of examinations for amateur operators' licenses shall be based on the class of privileges the applicant desires, as follows:

Class A: To be eligible for examination for the Class A amateur operator's privileges, the applicant must have been a licensed amateur operator for at least one year and must personally appear at one of the Commission's examining offices, and take the supervisory written examination and code test. (See Rules 2 (2) a, 30 and 408.) Examinations will be conducted at Washington, D. C., on Thursday of each week, and at each radio district office of the Commission on the days designated by the Inspector-in-Charge of such offices. In addition, examinations will be held quarterly in the examining cities listed in Rule 30 on the dates to be designated by the Inspector-in-Charge of the radio district in which the examining city is situated. The examination will include the following:

(a) Applicant's ability to send and receive in plain language messages in the Continental Morse Code (5 characters to the word) at a speed of not less than 10 words per minute.

(b) Technical knowledge of amateur radio apparatus, both telegraph and telephone.

(c) Knowledge of the provisions of the Communications Act of 1934, subsequent acts, treaties, and rules and regulations of the Federal Communications Commission, affecting amateur licenses.

Class B: The requirements for Class B amateur operator's privileges are similar to those for the Class A, except that no experience is required and the questions on radiotelephone apparatus are not so comprehensive in scope.

Class C: The requirements for Class C amateur operator's privileges shall be the same as for the Class B except the examination will be given by mail. To be eligible for this class of privileges, an applicant must reside more than 125 miles (airline) from Washington, D. C., a radio district office of the Commission, or an examining city. (See Rules 2 (2) b, 30, and 408.)

405. An applicant for any class of amateur operator's privileges who has held a radiotelephone second class operator's license or higher, or an equivalent commercial grade license, or who has been accorded unlimited amateur radiotelephone privileges, within five years of the date of application may only be required to submit additional proof as to code ability and/or knowledge of the laws, treaties, and regulations affecting amateur licenses.

406. An applicant for the Class B or C amateur operator's privileges who has held a radiotelegraph third class operator's license or higher, or an equivalent commercial grade

license, or who has held an amateur extra first class license within five years of the date of application may be accorded a license by passing an examination in laws, treaties, and regulations affecting amateur licensees.

407. An applicant for Class C amateur operator's privileges must have his application signed in the presence of a person authorized to administer oaths, by (1) a licensed radiotelegraph operator other than an amateur operator possessing only the Class C privileges or former temporary amateur class license, or (2) by a person who can show evidence of employment as a radiotelegraph operator in the Government service of the United States. In either case the radiotelegraph code examiner shall attest to the applicant's ability to send and receive messages in plain language in the Continental Morse Code (5 characters to the word) at a speed of not less than 10 words per minute. The code certification may be omitted if the applicant can show proof of code ability in accordance with the preceding rule.

408. Forms for amateur station and/or operator license shall be obtained by calling or writing to the Inspector-in-Charge of the radio inspection district in which the applicant resides. Upon completion of the forms they shall be sent back to the same office where the final arrangements will be made for the examination: *Provided*, however, in the case of applicants for the Class C amateur operator's privileges, the forms and examination papers when completed shall be mailed direct to the Federal Communications Commission, Washington, D. C.

409. The percentage that must be obtained as a passing mark in each examination is 75 out of a possible 100. No credit will be given in the grading of papers for experience or knowledge of the code. If an applicant answers only the questions relating to laws, treaties, and regulations by reason of his right to omit other subjects because of having held a recognized class of license, a percentage of 75 out of a possible 100 must be obtained on the questions answered.

410. An amateur station license shall be issued so as to run concurrently with the amateur operator's license and both licenses shall run for three years from the date of issuance. If either the station license or the operator's license is modified during the license term, both licenses shall be reissued for the full three-year term, provided, however, if an operator's license is modified only with respect to the class of operator's privileges, the old license may be endorsed in which case the expiration date will not change.

411. No applicant who fails to qualify for an operator's license will be reexamined within ninety days from the date of the previous examination.

412. Any attempt to obtain an operator's license by fraudulent means or by attempting to impersonate another, or copying or divulging questions used in examinations, or, if found unqualified or unfit, will constitute a violation of the regulations for which the licensee may suffer suspension of license or debarment from further examination for a period not exceeding two years at the discretion of the licensing authority.

413. Any licensee applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed, shall submit an affidavit to the Commission attesting to the facts regarding the manner in which the original was lost. Duplicates will be issued in exact conformity with the original, and will be marked "duplicate" on the face of the license.

414. Licenses are not valid until the oath of secrecy has been executed and the signature of the licensee affixed thereto.

415. All examinations, including the code test, must be written in longhand by the applicant.

U. S. RADIO DISTRICTS

District	Territory	Address, Radio Inspector in Charge
No. 1	The States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.	Customhouse, Boston, Mass.
No. 2	The counties of Albany, Bronx, Columbia, Delaware, Dutchess, Greene, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Schenectady, Suffolk, Sullivan, Ulster and Westchester of the State of New York; and the counties of Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Passaic, Somerset, Sussex, Union and Warren of the State of New Jersey.	Federal Building, 641 Washington St., New York, N. Y.
No. 3	The counties of Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton, Perry, Philadelphia, Schuylkill and York of the State of Pennsylvania; and the counties of Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Ocean and Salem of the State of New Jersey; and the county of Newcastle of the State of Delaware.	Gimbel Building, 35 South Ninth St., Philadelphia, Pa.
No. 4	The State of Maryland; the District of Columbia; the counties of Arlington, Clark, Fairfax, Fauquier, Frederick, Loudoun, Page, Prince William,	Fort McHenry, Baltimore, Md.

- Rappahannock, Shenandoah and Warren of the State of Virginia; and the counties of Kent and Sussex of the State of Delaware.
- No. 5 The State of Virginia except that part lying in District 4, and the State of North Carolina except that part lying in District 6. Customhouse, Norfolk, Va.
- No. 6 The States of Alabama, Georgia, South Carolina, and Tennessee; and the counties of Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Cleveland, Graham, Haywood, Henderson, Jackson, McDowell, Macon, Madison, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga and Yancey of the State of North Carolina. 528 Post Office Building, Atlanta, Ga.
- No. 7 The State of Florida, Puerto Rico, and the Virgin Islands. 228 Post Office Building, Miami, Fla.
- No. 8 The States of Arkansas, Louisiana and Mississippi; and the city of Texarkana in the State of Texas. Customhouse, New Orleans, La.
- No. 9 The counties of Aransas, Brazoria, Brooks, Calhoun, Cameron, Chambers, Fort Bend, Galveston, Goliad, Harris, Hidalgo, Jackson, Jefferson, Jim Wells, Kenedy, Kleberg, Matagorda, Nueces, Refugio, San Patricio, Victoria, Wharton and Willacy of the State of Texas. 209 Prudential Building, Galveston, Tex.
- No. 10 The State of Texas except that part lying in District 9 and in the city of Texarkana; and the States of Oklahoma and New Mexico. 464 Federal Building, Dallas, Tex.
- No. 11 The State of Arizona; the county of Clarke in the state of Nevada; and the counties of Imperial, Kern, Kings, Los Angeles, Monterey, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Tulare and Ventura of the State of California. 1105 Rives-Strong Building, Los Angeles, Calif.
- No. 12 The State of California except that part lying in District 11; the State of Nevada except the county of Clarke; the Hawaiian Islands, Guam and American Samoa. Customhouse, San Francisco, Calif.
- No. 13 The State of Oregon; and the State of Idaho except that part lying in District 14. 227 New Post Office Building, Portland, Ore.
- No. 14 The Territory of Alaska; the State of Washington; the counties of Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce and Shoshone of the State of Idaho; the counties of Beaverhead, Broadwater, Cascade, Deerlodge, Flathead, Gallatin, Glacier, Granite, Jefferson, Lake, Lewis & Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Pondera, Powell, Ravalli, Sanders, Silver Bow, Teton and Toole of the State of Montana. 808 Federal Office Building, Seattle Wash.
- No. 15 The States of Colorado, Utah and Wyoming; and the State of Montana except that part lying in District 14. 538 Customhouse, Denver, Colo.
- No. 16 The States of North Dakota, South Dakota and Minnesota; the counties of Alger, Baraga, Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon and Schoolcraft of the State of Michigan; and the State of Wisconsin except that part lying in District 18. 413 Federal Building, St. Paul, Minn.
- No. 17 The States of Nebraska, Kansas and Missouri; and the State of Iowa except that part lying in District 18. 231 Federal Building, Kansas City, Mo.
- No. 18 The States of Indiana and Illinois; the counties of Allamakee, Buchanan, Cedar, Clayton, Clinton, Delaware, Des Moines, Dubuque, Fayette, Henry, Jackson, Johnson, Jones, Lee, Linn, Louisa, Muscatine, Scott, Washington and Winneshiek of the State of Iowa; the counties of Columbia, Crawford, Dane, Dodge, Grant, Green, Iowa, Jefferson, Kenosha, Lafayette, Milwaukee, Ozaukee, Racine, Richland, Rock, Sauk, Walworth, Washington and Waukesha of the State of Wisconsin. 2022 Engineering Building, Chicago, Ill.
- No. 19 The State of Michigan except that part lying in District 16; the States of Ohio, Kentucky and West Virginia. Room 1025, New Federal Building, Detroit, Mich.
- No. 20 The State of New York except that part lying in District 2, and the State of Pennsylvania except that part lying in District 3. 514 Federal Building, Buffalo, N. Y.

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FOR members who hold amateur licenses, who are interested in radio activities and Communications Department operating work (explained fully, Chap. XIV, XV, XVI), here is an application blank which may be filled out for appointment as either Official Relay Station (for telegraphing members) or Official Phone Station (for voice operated member-stations). Copy this, or cut and fill it out, and send it direct to your Section Communications Manager (address on page 5 of QST) or to A.R.R.L. Headquarters, 38 LaSalle Road, West Hartford, Conn. for routing to the proper S.C.M. for attention if you are interested.

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APPLICATION FOR APPOINTMENT AS OFFICIAL.....STATION (Relay or Phone?)

To: Section Communications Manager.....Section, A.R.R.L.

Name.....Call.....

Street and Number.....Date.....

City.....State.....County.....

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to.....kilocycles. Actual frequency in use.....kilocycles.

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— to obey the radio communication laws and regulations of the country under which this station is licensed, particularly with respect to quiet hours and observance of our frequency allocations.

— to send monthly reports of station activities to the Section Communications Manager under whose jurisdiction this station comes.

— to handle messages in accordance with good operating procedure, delivering messages within forty-eight (48) hours when possible, mailing to destination when ever impossible to relay to the next station in line within a 48-hour period.

— to participate in every A.R.R.L. communication activity to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code."

In making application for appointment as Official Phone Station, I agree:

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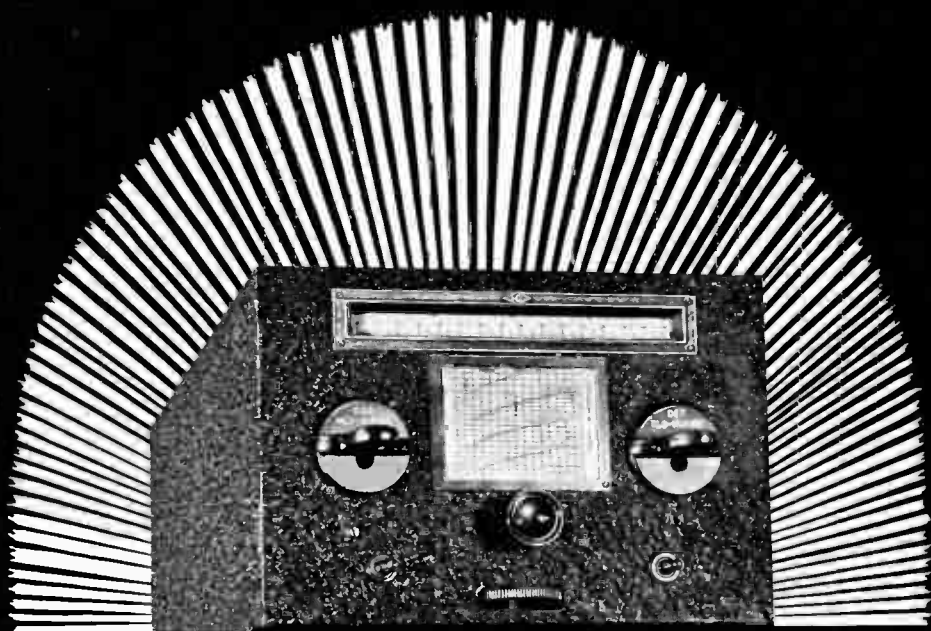
— to participate in all amateur communication activities to the best of my ability, always trying to live up to those ideals set forth in "The Amateur's Code" and to carry on amateur operation in a constructive and unselfish spirit.

— to use circuits and adjustments that avoid frequency modulation and over modulation by proper transmitter adjustment (accomplished by use of proper indicating devices) to avoid causing interference unnecessarily.

I understand that this appointment requires annual endorsement, and also may be suspended or cancelled at the discretion of the Section Communications Manager for violation of the agreement set forth above

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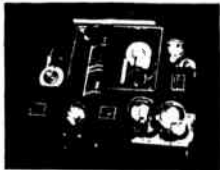


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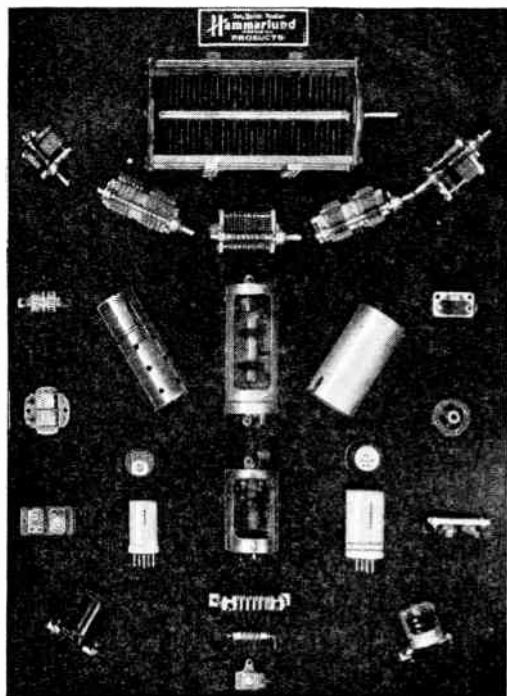
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