FUNDAMENTALS OF SINGLE SIDE BAND

COLLINS RADIO COMPANY

$5.00

FUNDAMENTALS OF Single Side Band

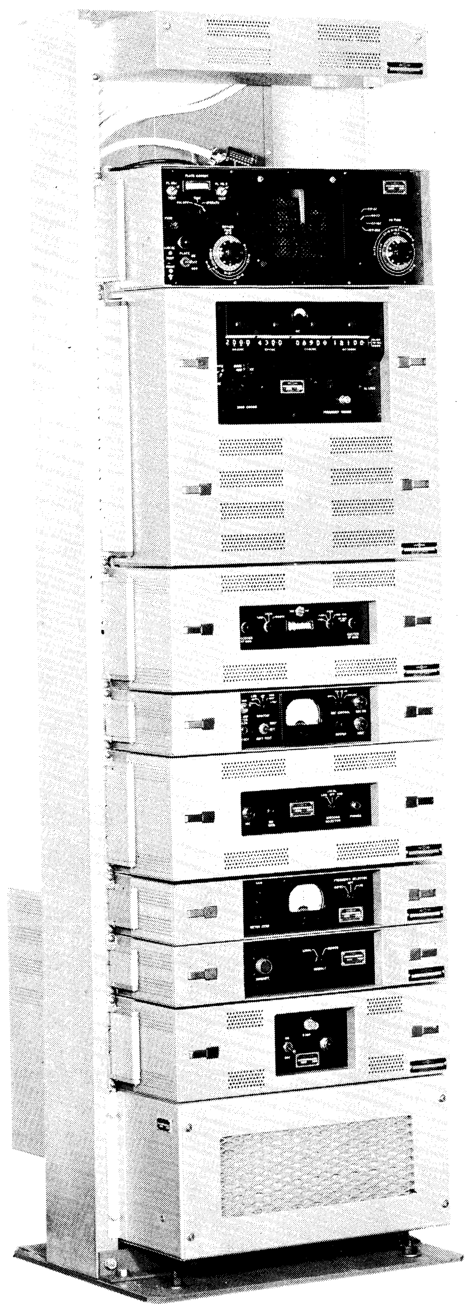
COLLINS

597 0331 00

2nd EDITION, 1 SEPTEMBER 1959

PRINTED IN THE UNITED STATES OF AMERICA

CEDAR RAPIDS, IOWA U.S.A.



Collins Designed AN/URC-32 Fixed Station SSB Communnications System Provides Transmission and Reception in the 2 to 30 Mc Range, with 500 Watts PEP

TABLE OF CONTENTS (CONT)

Chapter		Page
	a. Selectivity	3-6
	b. Amplification	3-7
	c. Automatic Gain Control	3-7
	4. Audio Section	3-9
	a. The Product Demodulator	3-9
4	**STABILIZED MASTER OSCILLATORS**	**4-1**
	1. Technical Requirements	4-1
	2. AFC vs Absolute Frequency Control	4-1
	3. Development of Frequency Control	4-1
	4. Frequency Synthesizers	4-2
	a. Harmonic Generators	4-2
	b. Harmonic Frequency Selectors	4-3
	5. The Stabilized Master Oscillator	4-3
	a. Frequency Discriminator	4-4
	b. Reactance Control	4-4
	c. Basic SMO Operation	4-6
	d. Multiple Frequency SMO Operation	4-8
5	**FREQUENCY STANDARDS**	**5-1**
	1. Introduction	5-1
	2. Deterioration of Generated Frequency	5-2
	a. Effect of Doppler Shift	5-2
	b. Effect of Propagation Characteristics	5-3
	c. Effects of Equipment Circuitry	5-3
	3. Measurement Techniques	5-3
	a. Time Comparison	5-3
	b. Frequency Intercomparison	5-5
	c. Phase Intercomparison	5-5
	4. Quartz Resonator Theory	5-7
	a. Construction and Operation	5-7
	b. Characteristics	5-8
	c. Construction of Precision Resonators	5-10
	5. Oscillator Theory	5-10
	a. General Theory	5-10
	b. Typical Oscillator Circuits	5-11
	c. Precision Crystal-Controlled Oscillators	5-13
	6. Oven Theory	5-15
	a. General Theory	5-15
	b. Typical Precision Oven	5-15
	7. Frequency Divider Theory	5-16
	8. System Considerations	5-17
6	**PRINCIPLES OF SERVOMECHANISMS**	**6-1**
	1. Definitions	6-1
	2. A Typical Position Servo System	6-1
	3. Servo Stability Requirements	6-3
	4. Components and Circuits	6-6

TABLE OF CONTENTS

Chapter		Page
1	**INTRODUCTION TO SINGLE SIDEBAND**	**1-1**
	1. Need for Single Sideband	1-1
	2. What Single Sideband Means	1-1
	3. Historical Development of Single-Sideband Communication Systems	1-1
	4. Basic Functional Units of a Single-Sideband Transmitting System	1-2
	5. Basic Functional Units of a Single-Sideband Receiving System	1-5
	6. Comparison of SSB with AM.	1-5
	a. Power Comparison of SSB and AM..	1-5
	b. Antenna Voltage Comparison of SSB and AM.	1-6
	c. Advantage of SSB with Selective Fading Conditions.	1-8
	d. Comparison of SSB with AM. under Limiting Propagating Conditions	1-8
	e. Comparison of Airborne High-Frequency Systems.	1-10
	f. Summary	1-11
	7. Comparison of SSB with FM	1-11
	8. Nature of Single-Sideband Signals	1-11
	a. Introduction	1-11
	b. The SSB Generator	1-12
	c. Generating the Single-Tone SSB Waveform	1-12
	d. Generating the SSB Waveform of a Single Tone with Carrier	1-13
	e. Generating the Two-Tone SSB Waveform	1-14
	f. Generating the Square Waveform	1-15
	g. Generating the Voice Waveform	1-16
	9. Mechanical Filters	1-17
2	**SINGLE-SIDEBAND EXCITERS**	**2-1**
	1. Single-Sideband Exciter Considerations	2-1
	a. Filter System	2-1
	b. Phase Shift System	2-1
	2. The Single-Sideband Generator	2-2
	a. Input Signal Processing	2-2
	b. Modulators for Single Sideband	2-5
	c. Suppressing the Carrier	2-7
	d. Sideband Selection	2-7
	3. Translation to the Operating Frequency	2-10
	a. Spurious Mixer Products	2-10
	b. Oscillator Requirements	2-14
	4. Amplification	2-15
	a. Tuned Circuits	2-15
	b. Linear Amplification	2-15
	5. Summary	2-16
3	**SINGLE-SIDEBAND RECEIVERS**	**3-1**
	1. Single-Sideband Receiver Considerations	3-1
	2. R-F Section.	3-2
	a. Noise Sources.	3-2
	b. R-F Selectivity	3-5
	c. Mixers	3-5
	3. I-F Section	3-6

TABLE OF CONTENTS (CONT)

Chapter		Page
7	**R-F LINEAR POWER AMPLIFIER**	**7-1**
	1. Introduction	7-1
	2. Power Amplifier Classification	7-1
	3. R-F Power Amplifier Tubes	7-2
	4. Basic Linear Power Amplifier Circuits	7-4
	a. General	7-4
	b. Grid Driven Triode Power Amplifier	7-4
	c. Cathode Driven Triode Power Amplifier	7-4
	d. Grid Driven Tetrode Power Amplifier	7-5
	5. Power Amplifier Output Networks	7-5
	a. Tank Circuit Considerations	7-5
	b. Circuit Losses	7-6
	c. Tank Coil and Capacitor Requirements	7-6
	6. Neutralization	7-7
	a. Effects of Plate-to-Grid Capacitance	7-7
	b. Neutralizing Circuits	7-7
	c. Testing for Proper Neutralization	7-8
	7. R-F Feedback Circuits	7-8
	a. Introduction	7-8
	b. Feedback Around One Stage	7-8
	c. Feedback Around Two Stages	7-9
	8. Automatic Load Control	7-10
	9. Linear Power Amplifier Tuning	7-11
	a. Introduction	7-11
	b. Phase Comparison Tuning	7-11
	c. Loading Comparator Circuit	7-12
	d. Antenna Tuning and Loading	7-13
	10. Power Supplies for Power Amplifiers	7-14
	11. Control Circuits	7-14
	12. Tube Operating Conditions for R-F Linear Power Amplifiers	7-15
	a. General	7-15
	b. Class A R-F Linear Amplifiers	7-15
	c. Class AB R-F Linear Amplifiers	7-15
	d. Estimating Tube Operating Conditions	7-16
	13. Distortion	7-17
	a. Causes of R-F Linear Power Amplifier Distortion	7-17
	b. Distortion Reduction	7-18
	c. Linearity Tracer	7-19
8	**TEST EQUIPMENT AND TECHNIQUES**	**8-1**
	1. General	8-1
	2. Frequency Measurement	8-1
	3. Signal Level	8-2
	4. Undesired Power Output	8-5
	5. Panoramic Spectrum Analyzer 478R-1	8-8
	6. Angle Modulation Measurements	8-12
	7. Compression Measurement	8-12
	8. Intermodulation Measurements with Built-In Monitor	8-13
	9. Linearity Measurement with Noise Loading	8-13
	10. Delay Distortion	8-14
	11. Field Test Set for Intermodulation Distortion Measurements	8-14
	12. Summary	8-19

TABLE OF CONTENTS (CONT)

Chapter		Page
9	**HIGH-FREQUENCY ANTENNAS**	**9-1**
	1. Introduction	9-1
	2. Antenna Fundamentals	9-1
	a. Radiation Characteristics of a Linear Conductor	9-1
	b. Polarization	9-3
	c. Reciprocity	9-3
	d. Image Antennas	9-3
	e. Mutual Impedance	9-3
	f. Antenna Directivity	9-4
	3. Typical High-Frequency Antennas	9-6
	a. The Practical Half-Wave Dipole	9-6
	b. Electrically Short Antennas	9-9
	c. Long Wire Antenna	9-10
	d. Phased Dipole Arrays with Parasitic Elements	9-11
	e. The Folded Dipole	9-12
	f. Reflector Type Antennas (Billboard)	9-12
	4. Logarithmically Periodic Antennas	9-14
	a. Principles of Operation	9-14
	b. Unidirectional HF Rotable Antennas	9-16
	c. Point to Point Unidirectional Antenna	9-17
	d. Horizontally Polarized Omnidirectional Antennas	9-18
10	**ANTENNA FEED SYSTEMS**	**10-1**
	1. Introduction	10-1
	2. Types of R-F Lines	10-1
	3. Transmission Line Properties	10-1
	4. Typical R-F Transmission Lines	10-2
	a. Two-Wire Balanced Lines--Air Dielectric	10-2
	b. Four-Wire Balanced Lines--Air Dielectric	10-3
	c. Two-Wire Balanced Lines--Solid Dielectric	10-3
	d. Air Dielectric Coaxial Lines	10-4
	e. Solid Dielectric Coaxial Lines	10-4
	f. Two Conductor Shielded Cables	10-5
	g. Single Wire Line	10-5
	5. Transmission Line Sections as Circuit Elements	10-5
	a. Line Sections as Parallel Resonant Circuits	10-5
	b. Line Sections as Series Resonant Circuits	10-7
	c. Line Sections as Low-Loss Reactances	10-7
	d. Line Sections as Impedance Transformers	10-8
	e. Line Sections as Balancing Devices	10-9
	6. Methods of Coupling to the Antenna	10-12
	a. Direct Feeding	10-12
	b. Resonant Line Feeding	10-12
	c. Nonresonant Line Feeding	10-13
	d. Typical Antenna Feeds	10-16
	7. Measurements	10-16

TABLE OF CONTENTS (CONT)

Chapter		Page
11	**RADIO WAVE PROPAGATION**	**11-1**
	1. Introduction	11-1
	2. Formation of the Ionosphere	11-1
	3. Ionospheric Absorption	11-1
	4. Structure of the Ionosphere	11-2
	5. Natural Phenomena Which Affect Ionic Layers	11-5
	a. Sunspots	11-5
	b. Sudden Ionospheric Disturbances	11-5
	c. Magnetic Storms	11-5
	d. Sporadic E Layer	11-5
	6. Sky Wave Transmission	11-5
	a. Sky Wave Reflection	11-5
	b. Sky Wave Absorption	11-7
	c. Sky Wave Field Intensity	11-8
	d. Lowest Useful High Frequency	11-11
	e. Maximum Usable Frequency	11-11
	f. Lowest Effective Power	11-11
	7. Ground Wave Propagation	11-11
	8. Charts and Graphs	11-13
	9. Sample Propagation Analysis	11-63
	a. Introduction	11-63
	b. Sky Wave Propagation Analysis	11-63
	c. Ground Wave Propagation Analysis	11-67
	d. Final Analysis	11-68
12	**KINEPLEX DATA TRANSMISSION**	**12-1**
	1. Introduction	12-1
	2. Codes Used for Data Transmission	12-1
	3. Telegraph Signaling	12-2
	4. Frequency Shift Keying	12-2
	5. Predicted Wave Signaling	12-2
	6. Kineplex	12-3
13	**SINGLE SIDEBAND FOR THE RADIO AMATEUR**	**13-1**
	1. Introduction	13-1
	2. 75S-1 Receiver	13-3
	a. R-F Circuits	13-3
	b. Frequency-Conversion Data	13-4
	c. I-F Circuits	13-7
	d. A-F Circuits	13-7
	e. Oscillator Circuits	13-7
	f. Power Supply	13-7
	3. 32S-1 Transmitter	13-7
	a. Frequency-Conversion Data	13-8
	b. A-F Circuits	13-8
	c. Balanced Modulator and Low-Frequency I-F Circuits	13-10
	d. Balanced Mixers	13-10
	e. R-F Circuits	13-10
	f. Control Circuits	13-10
	g. Oscillators	13-10
	h. Sync Operation	13-13
	i. Transceiver Operation with the 75S-1 Receiver	13-13

TABLE OF CONTENTS (CONT)

Chapter		Page
4.	KWM-1 Transceiver	13-13
	a. Receive-Transmit Common Circuits	13-14
	b. Receive Circuits	13-14
	c. Transmit Circuits	13-14
	d. Control Circuits	13-14
	e. Oscillator Circuits	13-18
5.	KWM-2 Transceiver	13-18
	a. Frequency-Conversion Data	13-18
	b. Transmitter Circuits	13-22
	c. Receiver Circuits	13-22
6.	30S-1 Linear Amplifier	13-28
	a. R-F Circuit Description	13-31
	b. Power Supply	13-31
7.	312B-4 Station Control	13-31
8.	Noise Blankers	13-31
9.	Directional Wattmeters	13-36
	a. R-F Circuit	13-37
	b. D-C Circuit	13-37
	c. Frequency Linearity	13-37
	d. Real Power	13-37
10.	Power Supplies	13-37
	a. 516E-1 12-Volt D-C Power Supply	13-37
	b. 516E-2 28-Volt D-C Power Supply	13-38
	c. 516F-2 A-C Power Supply	13-38

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Location of SSB Signal in R-F Spectrum	1-1
1-2	Functional Units of an SSB Transmitting System	1-3
1-3	Generation of the Twin-Channel Sideband Signal	1-4
1-4	Generation of Two Channel SSB Signal	1-4
1-5	Functional Units of an SSB Receiving System	1-5
1-6	SSB and AM. Comparison with Equal Signal-to-Noise Ratio	1-7
1-7	Deterioration of an AM. Signal with Selective Fading	1-9
1-8	Relative Advantage of SSB over AM. with Limiting Propagating Conditions	1-10
1-9	AN/ARC-38 and AN/ARC-58 Comparison	1-10
1-10	SSB Performance Compared with FM	1-11
1-11	Filter-Type SSB Generator	1-12
1-12	Single-Tone, Balanced Modulator Output	1-13
1-13	Single-Tone Balanced Modulator Output After Filtering Out the LSB	1-13
1-14	Single-Tone SSB Signal with Carrier--Carrier Equal in Amplitude to Tone	1-13
1-15	Single-Tone SSB Signal with Carrier--Carrier 10 DB Below Tone	1-13
1-16	Two-Tone SSB Signal-Tones of Equal Amplitude	1-14
1-17	Two-Tone SSB Signal with Small Reinserted Pilot Carrier	1-14
1-18	Power Measurements from Two-Tone SSB Test Signal	1-14
1-19	Square Wave SSB Signal--All Frequency Components Present	1-15
1-20	SSB Envelope Developed from 300 CPS, Clipped Sine-Wave (Harmonics above 9th Attenuated)	1-15
1-21	Voice Signal at Audio Frequency--ā Sound	1-16
1-22	SSB Voice Signal--ā Sound	1-16
1-23	Power Distribution in Speech Frequencies--Low and High Frequencies Removed	1-16
1-24	Elements of a Mechanical Filter	1-18
1-25	Electrical Analogy of a Mechanical Filter	1-18
1-26	Mechanical Filter Characteristic Curve	1-19
1-27	Size Comparison Between a Mechanical Filter and a Miniature Tube	1-19
2-1	Typical Single-Sideband Exciter, Functional Diagram	2-1
2-2	Basic Single-Sideband Generator, Block Diagram	2-2
2-3	Peak-to-Average Level Variations of Speech	2-3
2-4	Compressor Circuit	2-3
2-5	Clipper Circuit	2-4
2-6	Basic Ring Modulator Circuits	2-6
2-7	Basic Shunt Modulator Circuits	2-6
2-8	Basic Series Modulator Circuits	2-6
2-9	Vacuum Tube Balanced Modulators	2-8
2-10	Ring Modulator Carrier Current Paths	2-9
2-11	Selectivity Considerations in Frequency Translators	2-13
3-1	Typical Single-Sideband Receiver, Functional Diagram	3-1
3-2	Noise Sources in R-F Section of Single-Sideband Receiver	3-3
3-3	Generalized Selectivity Curve	3-4
3-4	Typical Receiver Mixer Spurious Response	3-5
3-5	Receiver Mixer Crossover Response	3-5
3-6	Selectivity Comparison	3-7
3-7	AGC Circuit	3-8
3-8	Product Demodulator	3-8
4-1	Multiple Crystal Frequency Synthesizer	4-2
4-2	Single Crystal Frequency Synthesizer	4-2
4-3	Harmonic Generator	4-3
4-4	Harmonic Frequency Selector	4-4
4-5	Simple Stabilized Master Oscillator with Frequency Discriminator	4-5
4-6	Frequency Discriminator	4-5

LIST OF ILLUSTRATIONS (CONT)

Figure		Page
4-7	Variable Inductor Response Curve	4-6
4-8	Discriminator Frequency Response Curve	4-6
4-9	Simple Stabilized Master Oscillator with Phase Discriminator	4-7
4-10	Block Diagram of Basic Stabilized Master Oscillator	4-7
5-1	Multiple-Crystal Frequency Synthesizer	5-2
5-2	Single-Crystal Frequency Synthesizer	5-2
5-3	Typical Long-Term Stability	5-2
5-4	Typical Short-Term Stability	5-2
5-5	Doppler Frequency Shift in Aircraft	5-3
5-6	Time Comparison System, Aural Indication	5-4
5-7	Time Comparison System, Visual Indication, Chronoscope	5-4
5-8	Frequency Intercomparison System Using Frequency Counter	5-5
5-9	Frequency Intercomparison System Using Power Line Frequency Recorder	5-5
5-10	Phase Intercomparison System	5-5
5-11	Quartz Crystal Showing Types of Cuts	5-6
5-12	Modes of Vibration	5-7
5-13	Quartz Resonator Equivalent Circuit	5-8
5-14	Impedance Versus Frequency Curve	5-8
5-15	Frequency Versus Temperature Characteristics	5-9
5-15.1	Quartz Resonators, Aging Rate versus Temperature	5-10
5-16	Precision Quartz Resonator, Construction and Mode of Vibration of 5th Overtone AT Cut	5-10
5-17	Equivalent Circuit of a Crystal-Controlled Oscillator	5-11
5-18	Calculation of Resonator Power Dissipation	5-11
5-19	Basic Crystal Oscillator Operating the Resonator at Series Resonance	5-12
5-20	Basic Pierce Oscillator	5-12
5-21	Meacham Oscillator	5-13
5-22	Precision Pierce Oscillator	5-14
5-23	Oven Operation Equivalent Electrical Circuit	5-15
5-24	Typical Oven Construction	5-16
5-25	Oven Control Oscillator	5-16
5-26	8U-1 Frequency Divider, Block Diagram	5-17
5-27	Typical Secondary Frequency Standard, Covers Removed	5-18
5-28	Collins Radio Company Primary Frequency Standard	5-19
6-1	Position Follow-Up Servomechanism	6-1
6-2	Voltage Regulator	6-2
6-3	Idealized Torque versus Voltage Curve	6-2
6-4	Servo Loop Block Diagram	6-3
6-5	Response of Motor and Amplifier to Step Input	6-4
6-6	Response of Follow-Up Servo to Step Input	6-4
6-7	Effect of Rate Generator on Response Time	6-5
6-8	Lead Network	6-5
6-9	Effect of Lead Network on Response Time	6-5
6-10	Motor-Generator Schematic Diagram	6-6
6-11	Electromechanical Chopper Circuit	6-7
6-12	Synchro Error Circuit	6-7
7-1	Class A Tube Operation	7-1
7-2	Class B Tube Operation	7-2
7-3	Class C Tube Operation	7-3
7-4	Grid Driven, Plate Neutralized Triode Power Amplifier	7-4
7-5	Cathode Driven Triode Power Amplifier	7-4
7-6	Grid Driven Tetrode Power Amplifier	7-5
7-7	Tuning Controls for Pi-L Output Network	7-6
7-8	Circuit Losses in Pi-L Network	7-6

LIST OF ILLUSTRATIONS (CONT)

Figure		Page
7-9	Conventional Grid-Neutralized Amplifier	7-7
7-10	Modified Grid-Neutralized Amplifier	7-8
7-11	One-Stage Feedback with Neutralization	7-8
7-12	Two-Stage Feedback with Neutralization	7-9
7-13	Vector Relationship of Voltages for Two-Stage Feedback	7-10
7-14	Automatic Load Control Circuit	7-10
7-15	Automatic Load Control Performance Curve	7-11
7-16	Phase Discriminator for PA Tuning	7-11
7-17	Coarse Discriminator for PA Tuning	7-12
7-18	Discriminator Output Curves for PA Tuning	7-12
7-19	Loading Comparator for PA Loading	7-13
7-20	Output Network Tuning and Loading Controls	7-13
7-21	Optimum Static Plate Current for Linear Operation	7-16
7-22	Graphical Determination of Tube Operating Conditions	7-16
7-23	Efficiency and Plate Dissipation for Class AB Operation	7-17
7-24	Typical PA Tube Transfer Characteristic Curve	7-17
7-25	Spectrum Distribution of Products Generated in PA Stage	7-18
7-26	Odd-Order Intermodulation Products Causing SSB Distortion	7-18
7-27	Linearity Tracer, Block Diagram	7-19
7-28	Envelope Detector, Schematic Diagram	7-19
7-29	Typical Linearity Traces	7-19
8-1	Directional Wattmeter, SWR Chart	8-4
8-2	Receiver/Signal Generator Substitution, Block Diagram	8-5
8-3	Idealized Panoramic Spectrum Analyzer Pattern	8-8
8-4	Practical Panoramic Spectrum Analyzer Pattern	8-8
8-5	Panoramic Spectrum Analyzer 478R-1, Block Diagram	8-9
8-6	Two-Tone Generator, Source Isolation	8-10
8-7	Intermodulation Products in a Noise Loaded System	8-13
8-8	Audio Two-Tone Test Generator, Block Diagram	8-15
8-9	Audio Distortion Analysis Filter, Block Diagram	8-16
8-10	R-F to Audio Converter, Block Diagram	8-17
8-11	Test of Intermodulation in Transmitter	8-18
8-12	Test of Intermodulation in Receiver	8-18
8-13	Test of Intermodulation in Audio Amplifier	8-18
8-14	System Test for Intermodulation Distortion	8-18
8-15	Transmitter Monitor, Block Diagram	8-18
8-16	Test of Two-Tone Audio Generator	8-19
8-17	Test of Intermodulation in R-F to Audio Converter	8-19
9-1	Sinusoidal Voltage and Current Distribution on Resonant Wires	9-2
9-2	Lumped Circuit Analogy for Half-Wave Radiators	9-2
9-3	Image Antennas	9-3
9-4	Polar Diagram of Radiation Patterns of an Isotropic Radiator, Elementary Dipole, and Half-Wave Dipole, in Free Space	9-4
9-5	Image Antenna and Ground Effect	9-5
9-6	Angles of Ground Reflection Factor Maxima and Minima for Antenna Heights up to Two Wave Lengths	9-5
9-7	Variation of the Radiation Resistance of a Theoretical Half-Wave Dipole with Height above a Perfectly Conducting Earth	9-6
9-8	Vertical Radiation Pattern of a Vertical Dipole at the Surface of an Earth of Finite Conductivity	9-6
9-9	Vertical Radiation of a Vertical Dipole a Quarter Wave Length Above an Earth of Finite Conductivity	9-6

LIST OF ILLUSTRATIONS (CONT)

Figure		Page
9-10	Vertical Radiation Pattern of a Vertical Dipole a Half Wave Length above an Earth of Finite Conductivity	9-7
9-11	Vertical Radiation (in the plane perpendicular to the axis of the dipole) of a Horizontal Dipole a Quarter Wave Length above an Earth of Finite Conductivity.	9-7
9-12	Vertical Radiation Pattern (in the plane perpendicular to the axis of the dipole) of a Horizontal Dipole a Half Wave Length above an Earth of Finite Conductivity	9-7
9-13	Common Methods of Exciting High-Frequency Antennas	9-7
9-14	Radiation Patterns of Center-Fed Vertical Dipoles.	9-8
9-15	Experimental Patterns of Wire Antennas with Different Feed Points	9-8
9-16	Top-Loaded Antennas	9-9
9-17	Current Distribution for Short Vertical Antennas	9-9
9-18	(a) Theoretical Current Distribution and (b) Radiation Pattern of a Two-Wave Length End-Fed Antenna	9-10
9-19	Radiation Pattern for Terminated Long Wire Antenna	9-10
9-20	V Antenna	9-11
9-21	Rhombic Antenna	9-11
9-22	Three Element Parasitic Array	9-11
9-23	Half-Wave Folded Dipole	9-12
9-24	Impedance Step-Up Ratio	9-13
9-25	Billboard Antenna.	9-13
9-26	High-Frequency, Broad-Band, Billboard Antenna	9-13
9-27	Steerable Beam Antenna	9-13
9-28	Log Periodic Antenna Showing Design Parameters	9-14
9-29	Effect of Angle ψ on Pattern Characteristics for Antenna with $\alpha = 60°$ $\tau = .6$	9-15
9-30	Effect of Angle α on Pattern Characteristics for Antenna with $\psi = 30°$	9-15
9-31	Collins Unidirectional Antenna 237A-2	9-16
9-32	Logarithmically Periodic Antenna for Use in Point to Point Communications	9-17
9-33	Horizontally Polarized Omnidirectional Antenna	9-18
10-1	Approximate Representation of a Two-Wire Transmission Line by Means of Lumped Constants	10-1
10-2	Effect of SWR on Line Loss	10-2
10-3	Cross Section of Two-Wire Balanced Line.	10-3
10-4	Characteristic Impedances for Typical Values of Conductor Size and Spacing (Two-Wire Balanced Lines)	10-3
10-5	Cross Section of Four-Wire Balanced Lines	10-4
10-6	Characteristic Impedances of Four-Wire Balanced Line with Typical Values of Conductor Size and Spacing.	10-4
10-7	Cross Section of Air Dielectric Coaxial Line.	10-5
10-8	Cross Section of Solid Dielectric Coaxial Line	10-5
10-9	Lumped Circuit Analogy for Quarter-Wave Section of Transmission Line Terminated in a Short Circuit	10-6
10-10	Lumped Circuit Analogy of Transmission Line Sections of Various Lengths	10-6
10-11	Quarter-Wave Open Transmission Line Section and its Equivalent Circuit	10-7
10-12	Effect of Shorted Stub on SWR Between Stub and Generator	10-7
10-13	Universal Reactance Curves for Open or Shorted Lines Less than a Quarter-Wave in Length.	10-8
10-14	Line Sections as Reactive Elements.	10-8
10-15	Quarter-Wave Line Section as Transformer	10-8
10-16	Bazooka Type Balun	10-9
10-17	Double Bazooka Type Balun	10-9
10-18	Parallel-Conductor Type Balun with 1:1 Impedance Transfer	10-10
10-19	Simple Balun Impedance Transformer	10-10
10-20	Half-Wave Balun with 4:1 Impedance Transfer	10-11

LIST OF ILLUSTRATIONS (CONT)

Figure		Page
10-21	Broad Band Coil Balun with 1:1 Impedance Transfer	10-11
10-22	Coupling the Directly Fed Antenna Through a Pi Network	10-12
10-23	Current and Voltage Feed in Antennas Operated at One, Two, and Three Times Fundamental Frequency	10-12
10-24	Coupling Networks for Resonant Feedlines	10-13
10-25	Coupling to Nonresonant Balanced and Unbalanced Lines	10-13
10-26	Typical Coupling to Center-Fed Half-Wave Dipoles	10-14
10-27	Typical Applications of Matching Stubs. The curves shown apply only if the characteristic impedance of the line and the stub are the same and the load is resistive. When applicable, modify lengths of A and B by the appropriate velocity factor. Where coaxial lines are used, the same principles apply	10-15
10-28	Typical Applications of Practical Transmission Lines	10-16
10-29	Relationship of SWR to Incident and Reflected Power	10-18
10-30	VSWR Correction Curves for Attenuation on Transmission Line	10-19
10-31	Attenuation Data for Common Types of Transmission Lines	10-20
11-1	Formation of an Ionixed Layer by a Single-Frequency Ultraviolet Wave	11-2
11-2	Typical Ionospheric Record	11-3
11-3	Geomagnetic Co-ordinates as Related to East, West, Intermediate, and Auroral Zone	11-4
11-4	Distance Limitations for Single Reflection Transmission (A) and Modes of Transmission (B)	11-6
11-5	Refraction of a Radio Wave	11-6
11-6	Ray Path for a Curved Earth and a Curved Ionosphere	11-7
11-7	Geometric Length of 1-Hop E Layer Sky Wave Propagation Path; Length Equals 190 Km	11-10
11-8	World Map Showing Zones Covered by Predicted Charts, and Auroral Zones	11-15
11-9	Great Circle Chart Centered on Equator; Solid Lines Represent Great Circles; Numbered Dot-Dash Lines Indicate Distances in Thousands of Kilometers	11-16
11-10	Median F_2-Zero-MUF, in Mc, W Zone, Predicted for April 1957	11-17
11-11	Median F_2-4000-MUF, in Mc, W Zone, Predicted for April 1957	11-18
11-12	Median E-2000-MUF, in Mc, Predicted for April 1957	11-19
11-13	Median fE_s, in Mc, Predicted for April 1957	11-20
11-14	Gains of Spaced Diversity Receiving Antennas for Rapidly Fading Signals	11-21
11-15	Rapid Variation of Sky Wave Field Intensity	11-22
11-16	Slow Variation of Sky Wave Intensity	11-23
11-17	Slow Variation of Atmospheric Noise	11-24
11-18	Radiation Angle Versus Great Circle Distance Curves	11-25
11-19	Nomogram for Transforming E-2000 MUF to Equivalent MUF's and Optimum Working Frequencies Due to Combined Effect of E Layer and F_1 Layer at Other Transmission Distances	11-26
11-20	E Layer MUF and Penetration Nomogram	11-27
11-21	Nomogram from Transforming F_2 ZERO MUF and F_2 4001 MUF to Equivalent MUF's at Intermediate Transmission Distances; Conversion Scale for Obtaining Optimum Working Frequencies	11-28
11-22	Absorption Index Chart (Excluding Auroral Absorption) for April	11-29
11-23	Auroral Absorption Chart	11-30
11-24	K_d Nomogram, Transmission Path Entirely in the Day Region	11-31
11-25	K or K_d Correction Factors	11-32
11-26	Table of Service Gains, Sky Wave Communications, Fading Signal	11-33
11-27	Median Incident Sky Wave Intensity, 0 to 200 km, 1-hop-F_2	11-34
11-28	Median Incident Sky Wave Field Intensity, 0 to 200 km, 2-hop-F_2	11-35
11-29	Median Incident Sky Wave Intensity, 0 to 200 km, 1-hop-E	11-36
11-30	Median Incident Sky Wave Field Intensity, 400 km, 1-hop-F_2	11-37
11-31	Median Incident Sky Wave Field Intensity, 400 km, 2-hop-F_2	11-38

LIST OF ILLUSTRATIONS (CONT)

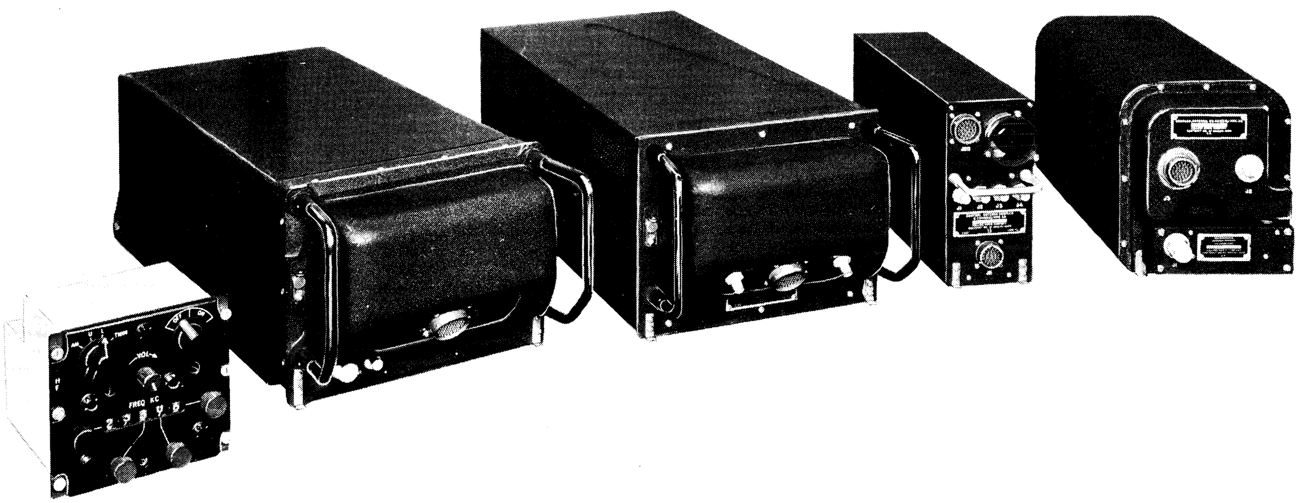
Figure		Page
11-32	Median Incident Sky Wave Field Intensity, 400 km, 1-hop-E	11-39
11-33	Median Incident Sky Wave Field Intensity, 800 km, 1-hop-F_2	11-40
11-34	Median Incident Sky Wave Field Intensity, 800 km, 2-hop-F_2	11-41
11-35	Median Incident Sky Wave Field Intensity, 800 km, 1-hop-E	11-42
11-36	Noise Distribution Chart for March, April, and May	11-43
11-37	Minimum Required Incident Field Intensities, Noise Grade 2.5, Summer	11-44
11-38	Minimum Required Incident Field Intensities, Noise Grade 2.5, Winter	11-45
11-39	Minimum Required Incident Field Intensities, Noise Grade 2.5, Equinox	11-46
11-40	Minimum Required Incident Field Intensities and Discriminator Gain, 15-foot Whip Antenna	11-47
11-41	Minimum Required Incident Field Intensities and Discrimination Gain, 1/4-Wave Grounded Vertical Antenna	11-48
11-42	Minimum Required Incident Field Intensities and Discrimination Gain, 1/2-Wave Grounded Vertical Antenna, Transmission Line Fed from Base of Antenna	11-49
11-43	Gain Curves, 15-foot Whip Antenna Erected Above Poor Ground	11-50
11-44	Gain Curves, 1/4-Wave Vertical Antenna Erected Above Poor Ground	11-51
11-45	Gain Curves, 1/2-Wave Vertical Antenna Erected Above Poor Ground	11-52
11-46	World Map Showing Various Types of Terrain	11-53
11-47	Ground-Wave Field Intensity Versus Distance Curves for Various Frequencies in Mc, for Vertical Polarization, 1-2,000 miles--Poor Ground	11-54
11-48	Ground-Wave Field Intensity Versus Distance Curves for Various Frequencies in Mc, for Vertical Polarization, 1-2,000 miles--Good Ground	11-55
11-49	Ground-Wave Field Intensity Versus Distance Curves for Various Frequencies in Mc, for Vertical Polarization, 1-2,000 miles--Sea Water	11-56
11-50	Minimum Required Field Intensity in the Presence of Set Noise, and Discrimination Gains in the Presence of Atmospheric Noise, for Various Antennas	11-57
11-51	Service Gains, Ground-Wave Communication, Nonfading Signal	11-58
11-52	Inverse Distance Field Intensity Expressed as an Antenna Gain in Respect to 186.3 Millivolts per Meter at 1 mile, Grounded Vertical Antenna	11-59
11-53	Inverse Distance Field Intensity Expressed as an Antenna Gain in Respect to 186.3 Millivolts per Meter at 1 Mile, 15-foot Vertical Whip Antenna	11-60
11-54	Inverse Distance Field Intensity Expressed as an Antenna Gain in Respect to 186.3 Millivolts per Meter at 1 Mile, Half-Wave Vertical Antenna Erected Above Perfect Earth at a Height of H/λ	11-61
11-55	Line of Sight Distance for Elevated Antennas (For Smooth Spherical Earth with an Effective Radius of 4/3 the Actual Values), Antenna Heights from 0 to 5,000	11-62
11-56	Overlay on World Map	11-63
11-57	Overlay on Great Circle Chart	11-65
11-58	Overlay on F_2 Zero MUF, W Zone Chart	11-65
11-59	Tabulated Sky Wave Propagation Analysis	11-69/11-70
11-60	Tabulated Ground Wave Propagation Analysis	11-71/11-72
12-1	Basic Telegraph Circuit	12-2
12-2	Predicted Wave Detection	12-2
12-3	Phase Modulation Vector Diagrams	12-3
12-4	Keyed Filter Pair, Quench-Drive-Ring Sequence	12-4
12-5	Energy Versus Frequency Distribution of Transmitted Pulses and Infinite Q Resonator Responses	12-5
12-6	Timing Pulse Relation	12-7
12-7	Channel Allocation at 100 WPM	12-8
12-8	Kineplex (Frequency Division) Block Diagram	12-9

LIST OF ILLUSTRATIONS (CONT)

Figure		Page
13-1	75S-1 Receiver	13-3
13-2	75S-1 Block Diagram	13-4
13-3	75S-1 Schematic Diagram	13-5/6
13-4	32S-1 Transmitter	13-8
13-5	32S-1 Block Diagram	13-9
13-6	32S-1 Schematic Diagram	13-11/12
13-7	KWM-1 Transceiver	13-13
13-8	KWM-1 Block Diagram	13-15
13-9	KWM-1 Vacuum-Tube Control Circuits	13-16
13-10	KWM-1 Relay and Switch Control Circuits	13-17
13-11	KWM-1 Antenna Switching Circuit	13-18
13-12	KWM-1 Schematic Diagram	13-19/20
13-13	KWM-2 Transceiver	13-21
13-14	KWM-2 Block Diagram	13-23/24
13-15	KWM-2 Schematic Diagram	13-25/26
13-16	30S-1 Linear Amplifier	13-28
13-17	30S-1 Block Diagram	13-28
13-18	30S-1 Schematic Diagram	13/29/30
13-19	312B-4 Station Control	13-31
13-20	312B-4 Schematic Diagram	13-32
13-21	136A-1 Noise Blanker Installed in 75S-1	13-33
13-22	136B-1 Noise Blanker Installed in KWM-1	13-33
13-23	136A-1 Block Diagram	13-34
13-24	136A-1 Schematic Diagram	13-35
13-25	302C-1 Directional Wattmeter	13-36
13-26	302C-1 Directional Wattmeter, Simplified Schematic Diagram	13-36
13-27	516E-1 12-Volt D-C Power Supply	13-37
13-28	516E-2 28-Volt D-C Power Supply	13-38
13-29	616F-2 A-C Power Supply (Removed from Case)	13-38
13-30	516E-1 Schematic Diagram	13-39
13-31	516E-2 Schematic Diagram	13-40
13-32	516F-2 Schematic Diagram	13-41

LIST OF TABLES

Table		Page
2-1	Calculated Frequency Products Contained in the Plate Current of a 12AU7 Triode Mixer	2-11
2-2	Spurious Response Chart	2-12
2-3	Typical Oscillator Long-Term Frequency Error	2-14
2-4	Typical Oscillator Short-Term Frequency Error	2-15
3-1	Equivalent Tube Noise Resistance	3-3
5-1	Frequency Range of Quartz Resonators	5-9
8-1	Comparative Meter Readings 1 to 16 Equal Tones Amplifier Output Held Constant on VU Meter	8-2
8-2	Comparative Meter Readings 16 to 1 Equal Tones Amplifier Output Set to +3 VU With 16 Equal Tones	8-3
8-3	Single-Sideband Distortion Products	8-7
12-1	Kineplex Phase Relationships	12-4
12-2	Timing Frequencies and Pulse Widths	12-6



Collins Designed Radio Set AN/ARC-58, Single Sideband High-Frequency Communications System, Providing 28,000 Directly Selectable Frequency Channels and 1000 Watts PEP