



**HANDBOOK OF  
SERVICE INSTRUCTIONS**

**AUTOMATIC ANTENNA TUNER**

**1801-2**



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**15 July 1953**





HANDBOOK OF  
SERVICE INSTRUCTIONS

for

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SUPPLEMENT TO  
HANDBOOK OF SERVICE INSTRUCTIONS  
FOR  
AUTOMATIC ANTENNA TUNER  
180L-2

The following revisions should be made, as indicated, in this Handbook:

In TABLE OF CONTENTS, page 1, revise as follows:

3-15 Receiver-Transmitter 618S-1 . . . . . 3-7

In TABLE 1-2, page 1-2 revise as follows:

R-F Connectors	<u>CPH 49195 (PL-259A)</u> CPN 357 9006 00	P-101. Connects to J-101. Also connects R-F Input Cable to Receiver-Transmitter
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In Paragraph 3-12, page 3-5, revise as follows:

No internal modification is required, with exception of a few equipments in this group, which must be modified in according with paragraph 3-13.h. of the following text. No additional parts are required for this modification, which provides for connection of Circuit Control Relay K-204 so that its coil is in parallel with the coil of Antenna Change Relay K-203.

In the tabular matter following Paragraph 3-12, FUNCTION AFTER RE-CONNECTION, revise as follows:

Chopper control circuit  
ground through P-102.7,  
K-204.6, K-204.7 with  
transmitter keyed.

In Paragraph 3-13, page 3-6, revise as follows:

for operation with Antenna Tuner 180L-2, and modification of connections to Delay Relay K-105, to add a transmitter interlock circuit. The kit of parts for modification includes the following:

In Paragraph 3-13.c., revise as follows:

c. Remove the coil connection of Microphone Relay K-101 from the control circuit leaf of the microphone jack, J-107.T, and re-connect the lead to Relay K-105.4. Connect K-105.5 to the control circuit leaf, J-107.T.



In Paragraph 3-13.h., page 3-7, revise as follows:

h. Extend the #22 AWG miniature JAN wires (red, and white with red tracer) from the coil of Antenna Change Relay K-203 to the coil of Relay K-204, placing the two coils in parallel. Check polarity to make certain that both relays close when the transmitter is keyed.

In Paragraph 3-14, revise as follows:

This relay is supplied upon request as an additional item in the kit of parts for modification of the receiver-transmitters noted.

In Paragraph 3-15, revise as follows:

3-15. RECEIVER-TRANSMITTER 618S-1. Receiver-Transmitter 618S-1 is designed

In Figure 4-5, revise as follows:

Reverse polarity of CR-203 and CR-204.

In Paragraph 4-36, page 4-22, revise as follows:

operates either K-704 (INDUCTIVE ERROR) or K-703 (CAPACITIVE ERROR), to correct

In Figures 4-23 and 4-24, revise as follows:

Make S-402B contact numeral identifications read 4, 8, 10, 12 (one higher than indicated in drawing in each case)

In Paragraph 4-43.c., page 4-28, revise as follows:

S-402B.4 and S-402B.10. K-705 is held because K-705.4 is grounded through

K-705.6 and K-705.12, K-703.5 and K-703.12, P-401.3, S-402B.4, P-401.8 and

In TABLE 4-1, page 4-31, INDUCTIVE ERROR (To Minimum) K-704, revise as follows:

Terminal 9      Not used. Reserved for future use.

In TABLE 6-1, page 6-13, Symptom 9., revise as follows:

9. L-401 runs to maximum,  
fails to reverse toward  
minimum

In Paragraph 6-31, page 6-17, revise as follows:

r-f transmission line from the transmitter to J-101, and connect the antenna



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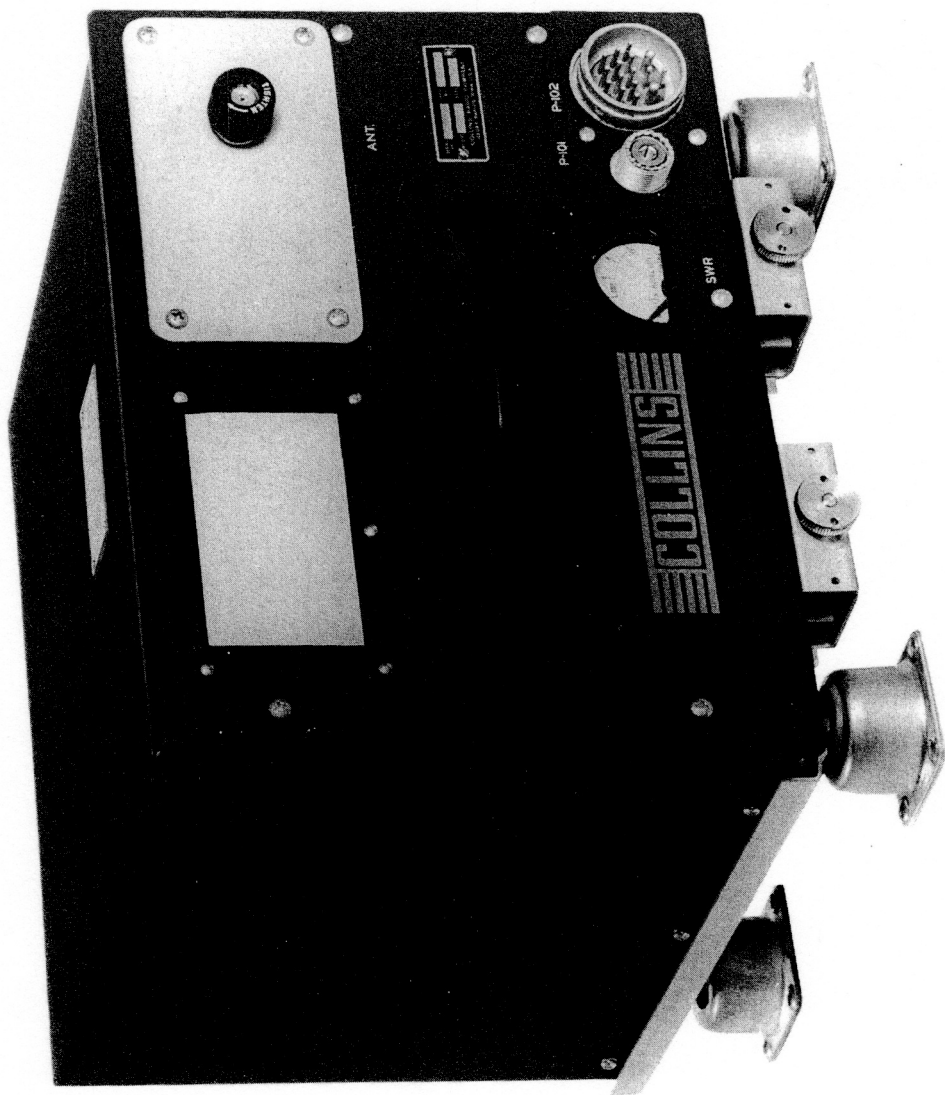
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SECTION I  
DESCRIPTION AND LEADING PARTICULARS

1-1. PURPOSE OF HANDBOOK.

1-2. This Handbook is published to aid in the installation, operation, and maintenance of Automatic Antenna Tuner 180L-2 (see figure 1-1). It includes description of the Antenna Tuner, test equipment and tools required, installation procedure, theory of operation, operators' and technicians' maintenance, and diagrams.

1-3. PURPOSE OF EQUIPMENT.

1-4. Antenna Tuner 180L-2 is designed for automatic tuning of open, fixed wire antennas of length between 45 and 100 feet, and the coupling of the 52 ohm output circuit of an aircraft transmitter of 150 watts power output or less to such antennas over a frequency range of 2 to 25 megacycles. Most grounded-end antennas of similar length are also fully tunable, but in some instances may require a different shunt capacitance at frequencies in the 2 to 4 megacycle range.

1-5. EQUIPMENT SUPPLIED.

TABLE 1-1

EQUIPMENT SUPPLIED

Name of Unit	Type Designation Collins Part Number (CPN)	Overall Dimensions (Inches)	Weight (Pounds)
Antenna Tuner 180L-2	CPN 506 1199 004	10 3/16W x 7 11/16H x 11 1/4 D	17.3
Mounting 350D-3	CPN 505 2782 002	10 3/8W x 1 1/2H x 10 5/8D	1.25

1-6. EQUIPMENT REQUIRED BUT NOT SUPPLIED.

1-7. The following equipment is required for installation and operation of Antenna Tuner 180L-2. All or the majority of items listed may be available as existing facilities on the aircraft, or existing accessories of the transmitter concerned.

TABLE 1-2

EQUIPMENT REQUIRED BUT NOT SUPPLIED

Name of Unit	Type Designation	Required Characteristics
	Collins Part Number (CPN)	
Primary Power		Lead-acid storage battery, engine-driven generator, 28 VDC at 2 amperes continuous (in addition to transmitter requirements).
A-C Power		115 V, 400 cps, 15 watts.
Antenna		Fixed-wire, general 45 to 100 foot length.
R-F Input Cable	RG-8/U	Coaxial cable, 28 VDC, or equal.
Indicator	CPN 424 0006 00	
Power, Control Cable	*-WM-3/U	*-Eight #22 AWG conductors (Maximum), two #16 AWG conductors.
	CPN 425 0006 00	
R-F Connectors	CPH 49195	P-101. Connects to J-101.
	CPN 357 9006 00	
Power, Control Cable Connector	SK-C16-23 1/2AC	P-102. Connects to J-102.
	CPN 371 0012 00	
Remote Tuneup Indicator		Lamp, Pilot, 28VDC, or equal.
<p>*-Eighteen conductors, including two #16 AWG, are available in the cable listed; this cable is a standard installation accessory for Receiver-Transmitter 18S-4. Refer to Table 3-2, paragraph 3-12.</p>		



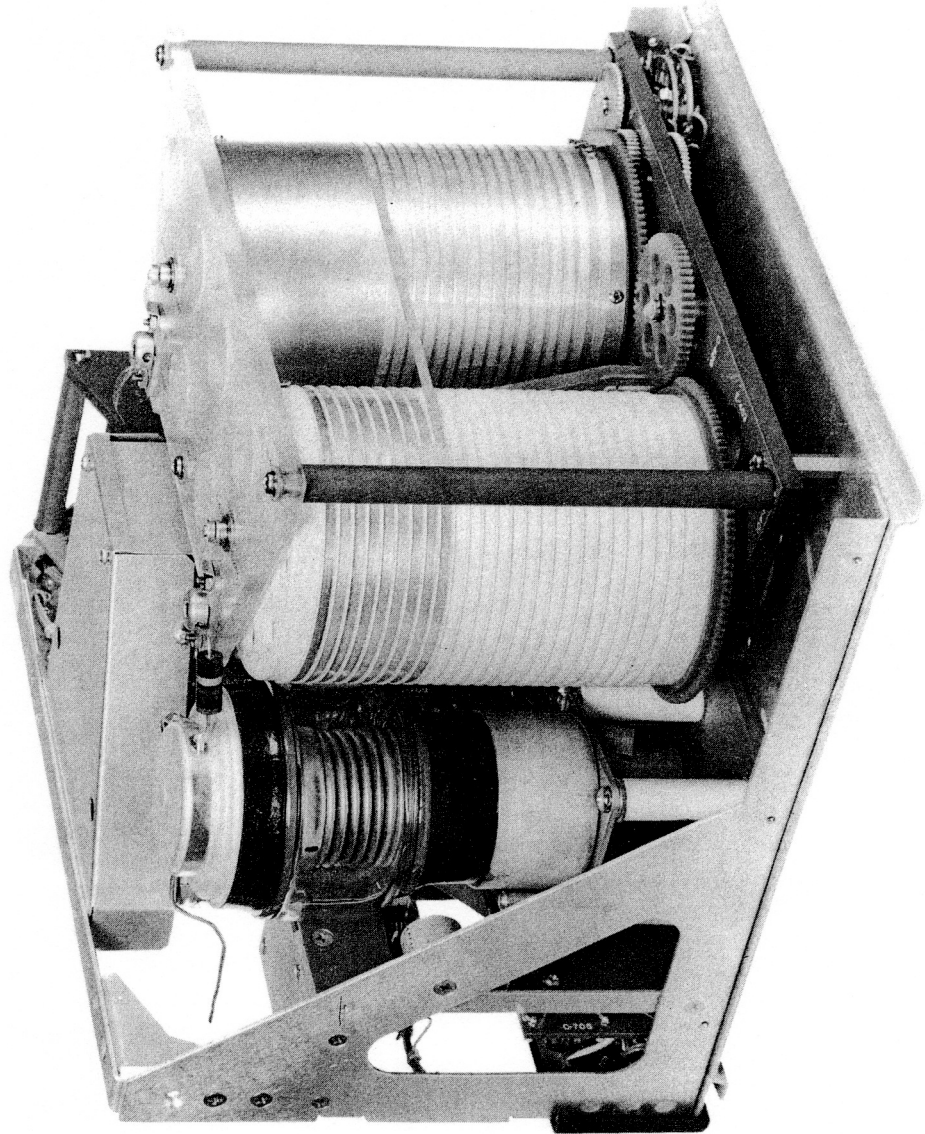


Figure 1-2. Antenna Tuner 180L-2, Rear View, Case Removed

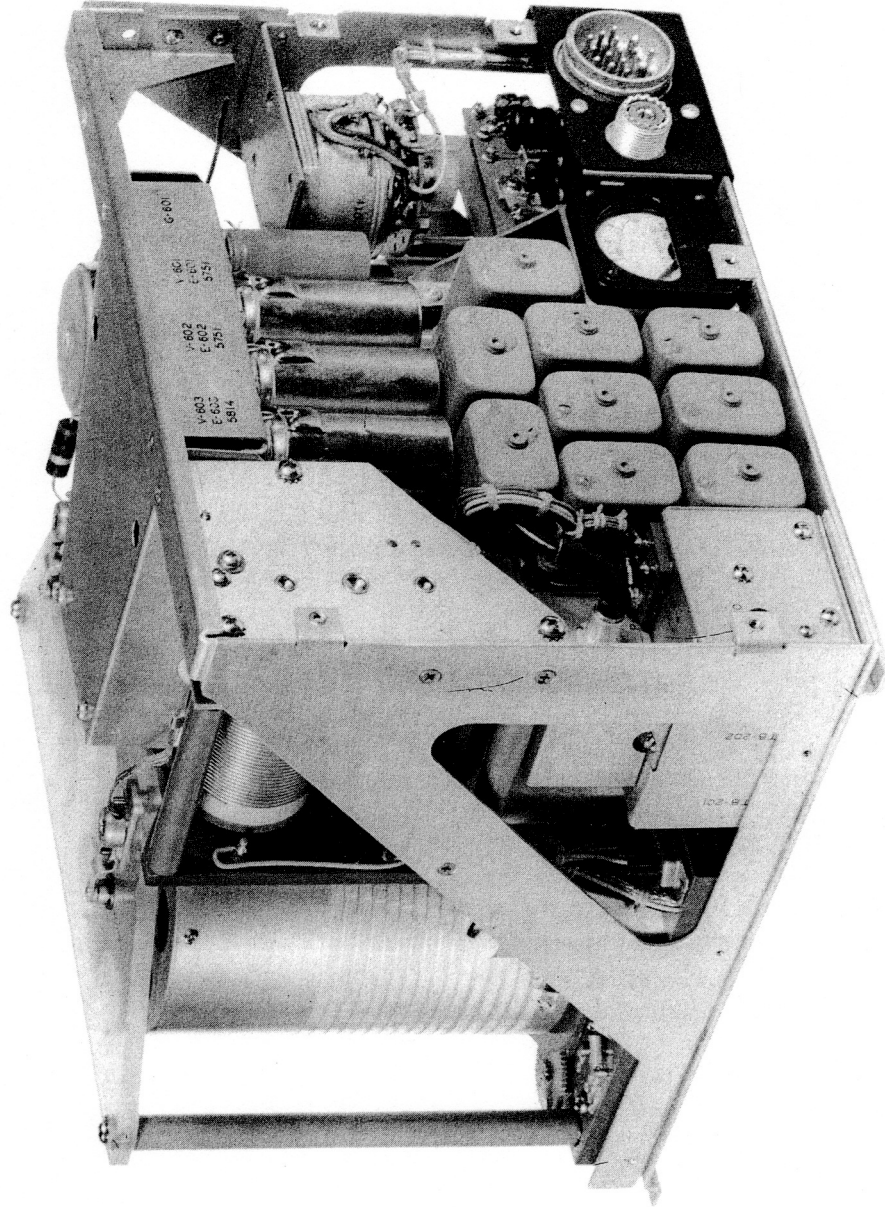


Figure 1-3. Antenna Tuner 180L-2, Front View, Panel and Case Removed

1-8. GENERAL DESCRIPTION.

1-9. Antenna Tuner 180L-2 is enclosed in a single aluminum case, secured to the main mounting frame by machine screws, (see figure 1-1). Power and control cable connections are made through a multi-contact fixed plug at the lower right of the mounting frame. The plug extends through a front panel cutaway area, as does the 52 ohm radio-frequency line connection which is adjacent at left. An SWR indicator is adjacent to the r-f line connector, and is viewed through a cutaway area. The antenna connector is located on a ceramic plate at upper right of the front panel. Viewed from the top, rear (see figure 1-2) with the case removed, the main chassis contains a series variable capacitor unit, servo amplifier assembly, r-f autotransformer and variable inductor assembly. Viewed from the front (see figure 1-3) with the panel and case removed, the main chassis contains plug-in assemblies including discriminator, r-f autotransformer, control circuit relay panel, three vacuum tubes and a d-c to a-c chopper. The entire Antenna Tuner assembly is retained in Mounting 350D-3. Knurled fasteners at the front of the Mounting tighten clamps into a flange on the base plate of the Antenna Tuner case, bringing pressure against mating fixed flanges at the rear of the base plate and Mounting. The knurled fasteners are secured by safety wire. Vibration isolators and grounding straps are provided by the Mounting. Attachment or removal of the Antenna Tuner is accomplished without use of special tools.

1-10. ELECTRICAL DESCRIPTION.

1-11. Antenna Tuner 180L-2 contains components and assemblies capable of producing electrical configurations which will tune out inductive or capacitive reactances encountered in standard fixed-wire aircraft antennas within a



general range of 45 to 100 feet in length, at frequencies between 2 and 25 megacycles. Antennas of shorter dimensions may not be fully tunable in frequency regions below 4 megacycles; the limiting factor is the maximum available inductance for series-resonating the reactance of the antenna. Use of extremely short antennas is not recommended, since efficiency of the equipment and the associated transmitter will be reduced. The Antenna Tuner also contains apparatus to match the antenna resistance to the 52 ohm output impedance of the transmitter. Phasing and loading operations are completely automatic after an r-f signal is received from the transmitter. The control circuits consist of two discriminator circuits which determine the course of action to follow in phasing and loading the antenna circuit; two servo amplifiers to build up information received from the discriminators, and suitable relays and switches to control the phasing system motors. The Antenna Tuner receives its power from the primary power supply (28 volts), a B+ source of 400 or 250 volts such as the transmitter plate supply circuits, and 115 volts, 400 cycles per second, from an aircraft source, or from a transmitter power unit.

1-12. MECHANICAL DESCRIPTION.

1-13. Both inductive and capacitive series elements of the antenna resonating circuits in Antenna Tuner 180L-2 are variable. The inductor consists of a ceramic cylinder upon which a silver ribbon is wound from an aluminum short-circuiting cylinder. The two cylinders are driven by a d-c motor. The series capacitor of the capacitive element is driven by a d-c motor; the shunt capacitor is connected by a relay circuit. The impedance matching element of the r-f system is a roller coil (autotransformer) which is driven by an a-c motor.

Several gear trains are employed between motors and driven elements to produce correct shaft speeds. The detailed parts of the overall assembly are arranged in logical groups on several removable chassis to facilitate servicing. Plug-in connections are used between sub-assemblies in nearly all cases.

1-14. PRINCIPLE OF OPERATION.

1-15. After the operator selects a new frequency by setting the channel selector switch of a radio set control panel, keying the transmitter places the Antenna Tuner in operation. The transmitter carrier is held on during the tuning process, which is completed in 15 seconds or less under normal conditions. (Refer to paragraph 3-16). The variable inductor and variable capacitor (plus the shunt capacitor, in some cases) act to produce resonance of the antenna circuit. Then the r-f autotransformer acts to match the obtained impedance, which automatically produces proper loading of the transmitter (assuming the latter has been properly adjusted to operate into a 52 ohm load). When the tuning cycle is complete, the transmitter carrier is turned off. The Antenna Tuner thereafter automatically compensates for changing antenna characteristics at any time the transmitter emits a signal.

1-16. OPERATING AND ADJUSTMENT CONTROLS.

1-17. Since Antenna Tuner 180L-2 is an automatic tuning device, there are no operating and adjustment controls. Operation of the equipment is normally performed as a function of radio set control, and initiated by use of the radio set control panel. (Refer to paragraph 3-16).

1-18. ELECTRICAL CHARACTERISTICS.

1-19. Frequency Coverage: 2 through 25 megacycles.

Sources of Power: Primary power supply, 27.5 VDC; transmitter plate supply, 400 VDC, and aircraft supply, 115 V, 400 cps, single phase.

Power Requirements: Primary power supply, 2 amperes average; 400 VDC, 20 milliamperes maximum; 115 V, 400 cps, 12 watts.

Input Impedance: 52 ohms.

Output Power:  $P_{\text{INPUT}} \times 0.75 \times \frac{275}{275 + QA}$  ( $QA = \frac{\text{Antenna Reactance}}{\text{Antenna Resistance}}$ )

1-20. VACUUM TUBE COMPLEMENT.

Symbol Designation	Tube Quantity, Tube Type	Circuit Function
V-601A (1/2 of)	1-5751	First loading amplifier
V-601B (1/2 of)		First phasing amplifier
V-602A (1/2 of)	1-5751	Second loading amplifier
V-602B (1/2 of)		Second phasing amplifier
V-603A (1/2 of)	1-5814	Third loading amplifier
V-603B (1/2 of)		Third phasing amplifier

1-21. FUSE COMPLEMENT.

1-22. There are no fuses in Antenna Tuner 180L-2.



SECTION II

TEST EQUIPMENT AND SPECIAL TOOLS

2-1. GENERAL.

2-2. The following test equipment is required or recommended for complete bench testing and maintenance servicing of Antenna Tuner 180L-2. No special tools are furnished with the equipment.

TABLE 2-1

REQUIRED AND RECOMMENDED TEST EQUIPMENT, TOOLS

ITEM	IDENTIFICATION, REQUIRED CHARACTERISTICS
Transmitter, fully operative (Receiver-Transmitter 18S-4, modifications per paragraphs 3-12, 3-13; or Receiver- Transmitter 618S-1, or equal)	Frequency range within 2 to 25 mega- cycles, output up to 150 watts, 52 ohm output impedance.
Dummy Antenna Load	Termaline (Bird Model 62) Coaxial Resistor or equal, 52 ohm non- inductive resistance.
Connecting Cables	Refer to Table 3-2, paragraph 3-8.
Power Sources	28.0 VDC at 2 amperes (in addition to transmitter requirements) and 115 V, 400 cps, 15 watts.
Electron Tube Test Set	TV-7/U or equal.
Voltmeter, Ohmmeter	TS-352/U or equal, 20,000 ohms/volt.
Vacuum Tube Voltmeter	ME-25A/U or equal.
Crystal Rectifier Test Set	TS-268C/U or equal.
Test Battery	1.5 VDC, dry cell.

ITEM	IDENTIFICATION, REQUIRED CHARACTERISTICS
Patch cords	Clip leads.
Relay contact tools	Adjustment, burnishing tools.
Wrench	Bristol #4
Bench tools	Soldering iron, pliers, screwdrivers.
Lubricants	Refer to Table 6-4, paragraph 6-27.

SECTION III  
PREPARATION FOR USE AND RESHIPMENT

3-1. GENERAL.

3-2. Remove Automatic Antenna Tuner 180L-2 and Mounting 350D-3 from their cartons. Inspect the tuner and mounting externally. If there is no apparent damage, proceed with a bench test, according to steps described below. If there is apparent damage, preserve packing material. Any claims for shipping damage should be filed promptly with the transportation agency concerned.

3-3. BENCH TEST.

3-4. EQUIPMENT REQUIRED. The following equipment is required for bench testing:

TABLE 3-1

BENCH TEST EQUIPMENT REQUIRED

Name of Unit	Required Characteristics
Transmitter, fully operative (Receiver-Transmitter 18S-4, 618S-1, or equivalent)	Frequency range within 2 to 25 mega- cycles, output up to 150 watts, 52 ohm output impedance.
Dummy Antenna Load	52 ohm, non-inductive resistance.
Connecting Cables	Refer to Table 3-2, paragraph 3.8.
Power Sources	28.0 VDC at 2 amperes (in addition to transmitter requirements), and 115 V, 400 cps, 15 watts.

3-5. PROCEDURE. a. Connect Antenna Tuner 180L-2 to transmitter and power sources, according to specifications of paragraph 3-8. Make certain that all power control switches and circuit breakers are in "OFF" positions.



b. Connect the antenna load or an antenna of appropriate length to the output terminal, E-102 (ANT).

NOTE

It is assumed that the transmitter has been tuned for several appropriate channels or frequencies within the range of 2 to 25 mc, according to instructions for the type of equipment in use. Modifications of certain Receiver-Transmitters 18S-4 must also have been completed. Refer to paragraph 3-12, 3-13 and 3-14.

c. Place the primary power circuit breaker or line switch in the 28 volt d-c circuit in the "ON" position. Place the 115 volt, 400 cycle circuit breaker in the "ON" position. Allow time for tubes to warmup.

d. Select an appropriate frequency, using the channel selector of the radio set control unit; key the transmitter, if necessary. (Refer to paragraph 3-16). Antenna Tuner 180L-2 should begin to tune as soon as r-f current appears in the input cable, and complete its phasing and loading operation within 15 seconds after it starts to tune. The transmitter power amplifier should load to the normal extent indicated by instructions for the type of equipment in use. The SWR (standing wave ratio) indicator of Antenna Tuner 180L-2 should come to rest at an indication of 2 or lower on its scale.

e. Select other appropriate frequencies and observe for normal power amplifier loading and SWR indications.

3-6. INSTALLATION.

3-7. a. SITING. Since Antenna Tuner 180L-2 requires no adjustment after installation, it may be mounted at a distance from the associated transmitter, in a space which is convenient to the antenna feed-through insulator, or mast, and will allow easy removal of the unit from the mounting. Clearance of four inches from all surfaces and areas is recommended for the antenna connection. (See figure 7-1 for outline and mounting dimensions.)

b. MOUNTING 350D-3. Four 9/64 inch bolts are used to attach each foot of Mounting 350D-3 to the aircraft structure. Grounding straps should be attached at the isolator feet, and the structural surface spot-faced to insure a good electrical bond.

c. SECURING EQUIPMENT. Place Antenna Tuner 180L-2 within the side rails of Mounting 350D-3 and push it to the rear to engage the fixed flanges on the base of equipment and mounting. Place the two clamps below the front panel so they engage the fixed flange at that position. Tighten the knurled fasteners on both clamps. Secure the knurled fasteners with safety wire through holes in the clamps and fasteners.

3-8. CONNECTIONS. No. 22 AWG conductors may be used for all power and control cable connections except those from pins 13 and 15 of J-102, which should be #16 AWG. The continuous current through any conductor will be less than 6.0 amperes.

TABLE 3-2

CABLE INTERCONNECTIONS

Function	Antenna Tuner 180L-2 J-102/P-102	CONNECT TO	
		18S-4 Terminal Board, Mounting 350C-5	618S-1 Terminal Board, Mounting 350S-1 (TB-1801)
Remote Tuneup Indicator	1		
	2		
	3		
Not Used	4		
	5		
	6		
Chopper Control	7	76	9
115V, 400 cps	8	#-75	#-45
Transmitter Keying	9	40	38
Retune Information	10	74	8

Function	Antenna Tuner 180L-2 J-102/P-102	CONNECT TO	
		18S-4 Terminal Board Mounting 350C-5	618S-1 Terminal Board Mounting 350S-1 (TB-1801)
28 VDC, Control	*-11	37	Not Used
Keying Relay	12	36	10
28 VDC, Filament	*-13	70	24
400 VDC	*-14	64	11
Ground	15	31	4
400 VDC	*-16	63	Not Used
<p>*-Terminals 14-16 are interconnected at J-102. Terminals 11 and 13 may require interconnection (refer to paragraph 4-47).                      #-400 cps supply is obtained from aircraft sources when 18S-4 equipment is in use, or from Terminal 14 of Power Supply 416W-1 when 618S-1 equipment is in use.</p>			

3-9. ANTENNA CONNECTIONS. Antenna connections include both those from antenna feed-through insulator or mast to Antenna Tuner 180L-2 and from the latter to the transmitter. The antenna lead-in should be flexible, should clear all surrounding surfaces and areas by four inches, and should have slack enough to permit free movement of the Antenna Tuner on Mounting 350D-3.

3-10. The transmitter is connected to the Antenna Tuner by 52 ohm coaxial cable (Type RG-8/U) terminated in connectors Type CPH 49195 (P-101). The cable is connected to J-101 of Antenna Tuner 180L-2, and to J-105 of Receiver-Transmitter 18S-4, or to J-109 of Receiver-Transmitter 618S-1.

3-11. ADJUSTMENT. Since Antenna Tuner 180L-2 is an automatic tuning device, there are no adjustments to be performed after installation.

3-12. MODIFICATION OF RECEIVER-TRANSMITTER 18S-4 (Serial 801 and Higher). Receiver-Transmitters 18S-4 with serial numbers 801 and higher are designed to operate with Antenna Tuner 180L-2. No internal modification is required. Modification of cable connections to Mounting 350C-5 and aircraft wiring are required when Antenna Tuner 180L-2 replaces Antenna Matching Network 180K-3 as a component of Radio Set 18S-4. The existing power and control cable (Type WM-3/U), used to interconnect terminals of Mounting 350C-5 and P-503 of Antenna Network 180K-3, must be re-connected as specified below. (P-503 of Antenna Network 180K-3 and P-102 of Antenna Tuner 180L-2 are identical connectors, both Type SK-C16-23 1/2AC, and their termination is equal to that of J-102, Antenna Tuner 180L-2.)

P-503/P-102 <u>TERMINALS</u> J-102 TERMINALS	CONNECTED TO 350C-5 TERMINALS (With 180K-3)	CHANGE TO 350C-5 TERMINALS (With 180L-2)	FUNCTION AFTER RE-CONNECTION
J-102.7	48	76	Chopper control circuit ground through P-102.7, K-204.6, K-204.7 with transmitter in CW function, or in PH function with microphone control button closed.
J-102.8	49	#-75	115 V, 400 cps supply line.
J-102.9	50	40	Transmitter keying line, to J-107.7 of transmitter through P-101.6
J-102.10	62	74	Retune information circuit ground through P-102.19, K-105.6, K-105.7 during channel selection.
J-102.13	33	70	Circuit protection.
#-Connect the aircraft source of 115 V, 400 cps to terminal 75 of Mounting 350C-5, using a #22 AWG conductor.			



3-13. MODIFICATION OF RECEIVER-TRANSMITTERS 18S-4 (Serial 601-800). In addition to the re-connection of the power and control cable as shown in paragraph 3-12 above, Receiver-Transmitters 18S-4 with serial numbers 601 through 800 require internal installation of Circuit Control Relay K-204 for operation with Antenna Tuner 180L-2, and modification of connections to Delay-Interlock Relay K-105. The kit of parts for modification includes the following:

QUANTITY	ITEM	COLLINS PART NUMBER
1	Relay K-204, Circuit Control	972 1295 00
1	Mounting Bracket	506 7326 002
2	Binder Head Screws, 4-40 x 3/16	343 0132 00
2	Lock Washers	373 8010 00

Make the modification as follows (J-102 and P-102 references in the text apply to those parts of Receiver-Transmitter 18S-4):

- a. Attach Relay K-204 to the mounting bracket using the binder head screws and lock washers.
- b. Remove the two front mounting screws of the exciter assembly, located on the exciter assembly housing flange, underside of the main chassis, in the forward area of the transmitter section. Position the relay and bracket assembly so the bracket mounting holes align with holes in the exciter assembly housing flange and re-install the two screws.
- c. Connect terminal 4 of Relay K-105 to the coil of microphone Relay K-101. Break the connection of the K-101 coil to the control circuit leaf of the microphone jack, J-107.T, and re-connect to terminal 4 of Relay K-105. Connect terminal 5 of Relay K-105 to the control circuit leaf, J-107.T.
- d. Connect terminal 6 of Relay K-105 to P-102.19, using a #22 AWG conductor. If a connection is not provided, connect J-102.19 to terminal 74 of Mounting 350C-5, using a #22 AWG conductor.

- e. Connect terminal 7 of Relay K-105 to ground at contact 2 of S-201, using #18 AWG copper bus wire.
- f. Connect terminal 6 of Relay K-204 to ground at the chassis lug located near C-222, using #18 AWG copper bus wire.
- g. Connect terminal 7 of Relay K-204 to P-102.7, using #22 miniature JAN wire or equivalent.
- h. Extend the #22 AWG miniature JAN wires (red, and red with white tracer) from the coil of Filament Control Relay K-202 to the coil of Relay K-204, placing the two coils in parallel. Check polarity to make certain that both relays close when the transmitter is placed in CW function, or the microphone control button is pressed, in PH function.
- i. Provide a connection from J-102.7 to terminal 76 in Mounting 350C-5, using a #22 AWG conductor.

3-14. MODIFICATION OF RECEIVER-TRANSMITTERS 18S-3 and 18S-4 of Serial 600 and Lower. All steps performed in paragraph 3-12 and 3-13 are necessary for the modification of Receiver-Transmitters 18S-3 and 18S-4 with serial numbers 600 and lower. In addition, SPDT Relay K-105 must be replaced with a suitable delay-interlock relay, connected as in sub-paragraphs c., d. and e., above. This relay is supplied as an additional item in the kit of parts for modification of the receiver-transmitters noted. The relay is identical to K-204, and is listed under Collins Part Number 972 1295 00.

3-15. RECEIVER-TRANSMITTER 618S-4. Receiver-Transmitter 618S-4 is designed to operate with Antenna Tuner 180L-2. No modification is required.

3-16. MODIFICATION FOR "RADIO SILENCE" OPERATION.

3-17. Antenna Tuner 180L-2 is designed so that operation of the channel

selector of the radio set control provides fully automatic keying of the transmitter during the equipment's tuning cycle, over a period of 15 seconds or less. If it is desirable to maintain "radio silence" during the period of channel selection, the Antenna Tuner may be modified for manual-start transmitter keying. Thus, the transmitting channel may be selected in advance by operation of the radio set control, but the Antenna Tuner will not begin its tuning cycle and an on-the-air signal will not be transmitted until the transmitter microphone button or key are closed. Refer to the schematic diagram, figure 7-2.

a. For normal operation, providing automatic keying of the transmitter when a new channel is selected, wire A is connected to terminal 8 of Relay K-708.

b. For "radio silence" operation, providing manual-start keying of the transmitter after a new channel is selected, wire A is connected to terminal 9 of Relay K-708.

3-18. MODIFICATION FOR 250 VOLT OPERATION. Antenna Tuner 180L-2 is designed for operation with 400 volt plate supply, obtained from the associated transmitter. The Antenna Tuner may also be operated with 250 volt plate supply, by short-circuiting R-713 and R-714 (see figure 7-3) or replacing the resistors with a bus connection. R-715 may also be removed from the circuit, or its ground connection opened.

3-19. REMOTE TUNEUP INDICATOR. If remote tuneup indication is desired, a 28.0 volt pilot lamp and its power source may be connected across terminals 2-3 of J-102, using #22 AWG conductors. The pilot lamp will be lighted during the entire phasing and loading cycle of Antenna Tuner 180L-2. It will

be extinguished by completion of the automatic keying function and release of Relay K-708, indicating that the radio set is ready for operation on a selected frequency. This indication is correct for either fully automatic keying or manual-start keying of the transmitter. An additional indicating lamp may also be placed across terminals 1-2 of J-102, and will remain lighted while the Antenna Tuner is not in its operating cycle. Any alternate system of indication that will operate on a three-wire circuit, with terminal 2 as the common lead, may be substituted for the indicator lamps.

3-20. PREPARATION FOR RESHIPMENT.

3-21. No special provisions need be made for reshipment of the Antenna Tuner. Remove equipment from the aircraft by the reverse of installation procedure, and return it to the shipping cartons or their equivalent.



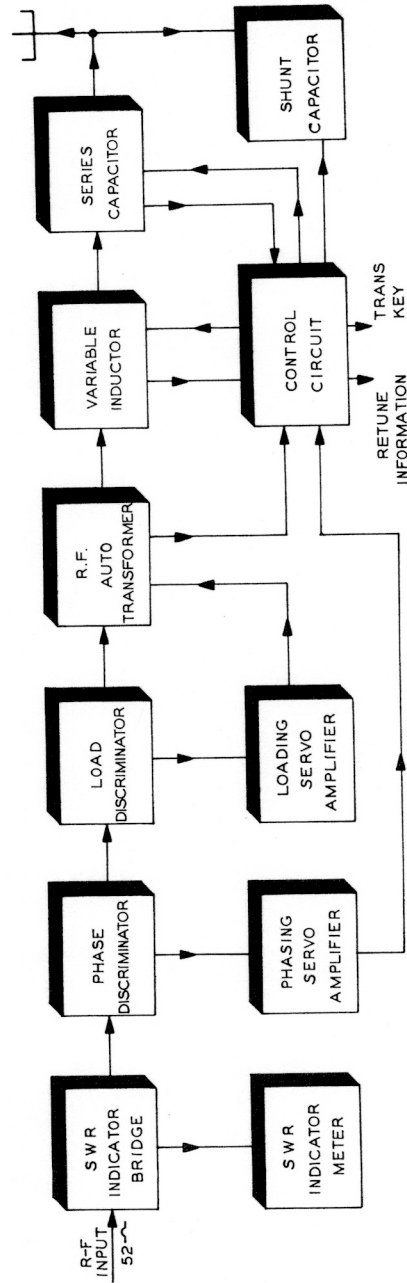


Figure 4-1. Block Diagram, Antenna Tuner 180L-2

SECTION IV  
THEORY OF OPERATION

4-1. GENERAL.

4-2. Automatic Antenna Tuner 180L-2 contains all components needed for the fully automatic coupling of a medium-powered aircraft transmitter with a 52 ohm output impedance to an open, fixed-wire antenna of length between 45 and 100 feet, over a frequency range of 2 to 25 megacycles. Most grounded-end antennas of similar length are also fully tunable, but in some instances may require a larger shunt capacitance than that furnished at frequencies in the 2 to 4 megacycle range.

4-3. Refer to figure 4-1, the block diagram of Antenna Tuner 180L-2. The Antenna Tuner consists of series reactive elements for tuning (a variable inductor and a series vacuum capacitor, also variable), a variable r-f autotransformer for loading, analyzing circuits for tuning and loading, and an SWR indicator bridge. The analyzing or sense information circuits consist of discriminator circuits that determine whether antenna impedance as viewed from the input of the tuner is more or less than 52 ohms (loading discriminator) and whether the antenna is capacitive or inductive in reactance (phasing discriminator). The phasing discriminator also provides information to the series elements' servo system and the loading discriminator provides information to the r-f autotransformer servo system.

4-4. The loading discriminator consists of two germanium diodes with associated circuits. It is in balance when the ratio of voltage across the

r-f transmission line to the antenna is 52 ohms. If the ratio is more than 52 ohms, the error voltage output is negative; if it is less than 52 ohms, error voltage output is positive. The phasing discriminator consists of two germanium diodes with associated circuits. It is in balance when the voltage and current of the transmission line are in phase. If the current leads the voltage, a negative error voltage results; if the current lags the voltage, a positive error voltage results.

4-5. Information from the discriminator circuits goes to the input circuits of the two-phase servo amplifiers. The d-c error voltages are fed to a chopper which transforms them into 400 cps signals, proportional to the d-c errors. The resulting voltages are amplified and the loading error signal is fed to a two phase, 400 cps motor which drives the r-f autotransformer directly. The phasing error signal is applied to a motor which operates a switch. The switch provides information to a relay system which controls driving of the series reactive or phasing elements.

4-6. A modified Schering bridge circuit is used in the SWR (standing wave ratio indicator) element. One pair of bridge arms is resistive, the other capacitive. The bridge is balanced when the input impedance of the Antenna Tuner is 52 ohms resistive, and zero indication results on the SWR Indicator (M-701). Capacitive arms of the bridge include C-701 through C-704 (refer to figure 7-2), and the resistive arms consist of R-701 through R-710, ten 10-ohm resistors in parallel. The bridge detector is CR-701. M-701 is an r-f voltmeter, with a scale of arbitrary units. Indications will normally be less than 2 units under all antenna tuning conditions.

4-7. ELECTRICAL DESCRIPTION, ANALYZING CIRCUITS.

4-8. FUNCTION OF DISCRIMINATORS. The discriminator circuits are capable of

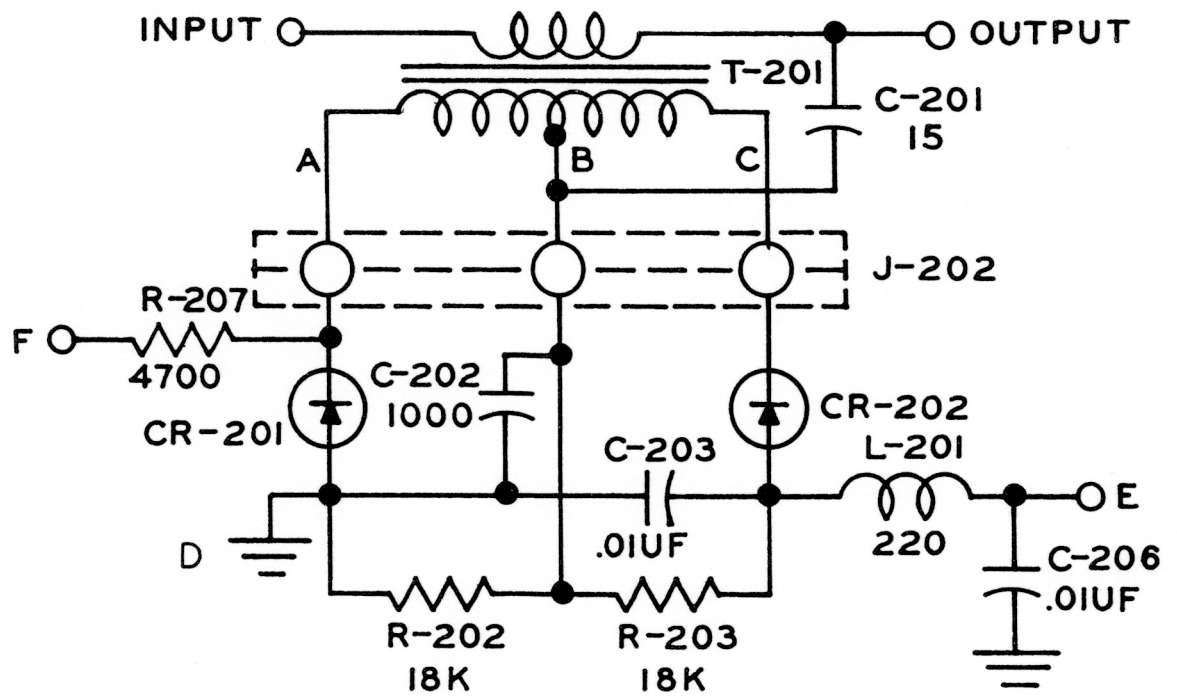


Figure 4-2. Phasing Discriminator, Simplified Schematic Diagram



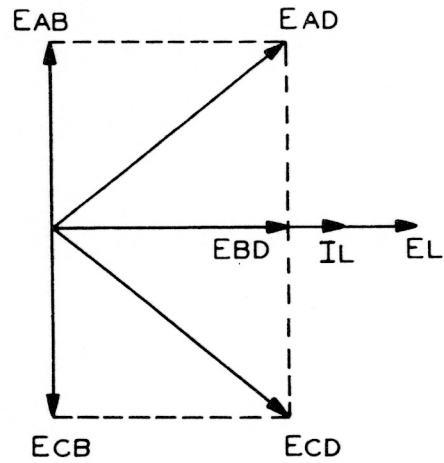


Figure 4-3. Balanced Condition, Phasing Discriminator, Vector Diagram

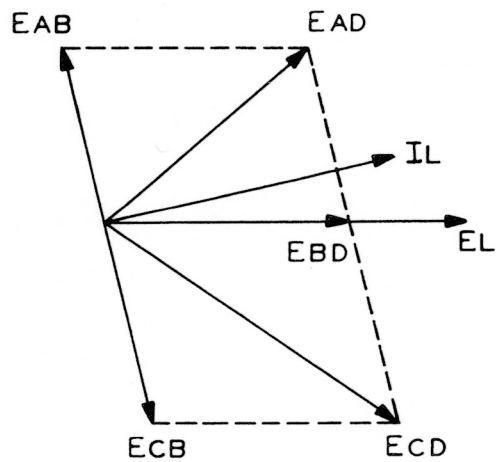


Figure 4-4. Unbalanced Condition, Phasing Discriminator, Vector Diagram

analyzing the antenna impedance and making network corrections to match it to the transmitter impedance of 52 ohms resistive. The loading discriminator determines whether the antenna load is more or less than 52 ohms. The phasing discriminator determines whether the reactance is inductive or capacitive. Both discriminators produce polarized outputs proportional to the phasing and loading errors. These outputs are fed through the servo amplifiers, to the phasing and loading system motors, to tune the antenna.

4-9. PHASING DISCRIMINATOR. The phasing discriminator is transformer-connected to the antenna transmission line (see figure 4-2) and its output is connected through the phasing servo amplifier to the series elements of the Antenna Tuner. The primary of the input transformer is a straight section of silver-plated brass rod. A six-turn secondary is closely coupled in the primary field by a high frequency iron core placed around the primary rod. The circuit is wired symmetrically around the center of the secondary, and sub-components are chosen so that the transformer is essentially without load.

4-10. BALANCED CONDITION, PHASING DISCRIMINATOR. Vector diagrams (see figures 4-3 and 4-4) show the balanced and unbalanced condition of the phasing discriminator. When the voltage and current of the transmission line are in phase (see figure 4-3), as shown by vectors  $E_L$  and  $I_L$  in the diagram, then  $E_{AB}$  leads  $E_L$  by exactly 90 degrees, while  $E_{CB}$  lags  $E_L$  by 90 degrees, since the transformer is essentially without load. The voltage across  $HD$  is in phase with  $E_L$  since  $C-201$  and  $C-202$  constitute a voltage divider. The germanium diodes  $CR-201$  and  $CR-202$ , with their load resistors  $R-202$  and  $R-203$ , are connected between points  $AD$  and  $CD$ , respectively. Voltage  $E_{AD}$  is the vector sum of  $E_{AB}$  and  $E_{BD}$  while the voltage  $E_{CD}$  is the vector sum of  $E_{CB}$  and

$E_{BD}$ . These are the voltages which actually are measured by the diodes and their loads. Both load resistors are by-passed for r-f by C-203. The diodes and loads are connected into the circuit with opposite polarities. The diodes and loads thus produce a d-c voltage almost proportional to the r-f voltage which appears across them. With the transmitter keyed, and due to the detecting action of CR-201, a positive voltage drop appears across R-202. Also due to CR-202, a negative voltage drop appears across R-203. The phasing discriminator error voltage appears at point E. Since the voltage at R-202 is positive and the voltage at R-203 is negative, the voltage at E represents the sum of the two. If the voltage drops are equal in magnitude, the error voltage is zero. This is the balanced condition, when the detecting action of CR-201 and CR-202 is the same.

4-11. UNBALANCED CONDITION, PHASING DISCRIMINATOR. Assume that the current leads the voltage slightly, as shown in the second vector diagram (see figure 4-4).  $E_{BD}$  is still in phase with  $E_L$ . The voltage across AB still leads the current in the primary by 90 degrees. Vector sums of  $E_{AB}$  and  $E_{BD}$  still produce detected voltages  $E_{AD}$  and  $E_{CD}$ , but they are no longer equal. The d-c voltage developed across R-203 is greater than the voltage developed across R-202. In effect, the sum of voltages at both diode load resistors becomes negative, and the negative error voltage appears at E. With current leading voltage, the error is capacitive; that is, the antenna reactance is capacitive. The negative error voltage at E is used through means of the servo amplifier and control circuits to drive the series elements until less capacitive reactance or more inductive reactance is obtained. If the current lags the voltage,  $E_{AD}$  becomes greater in magnitude than  $E_{CD}$  and a positive error voltage appears

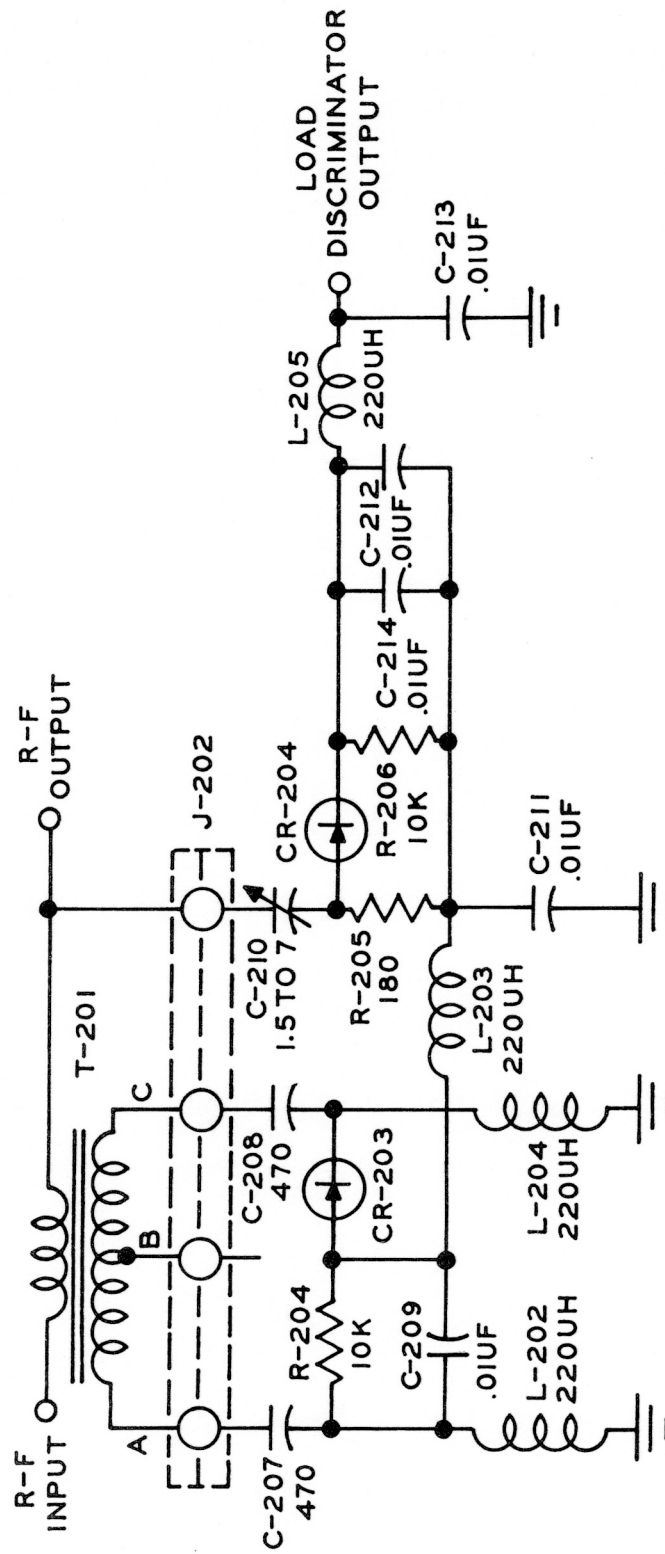


Figure 4-5. Loading Discriminator, Simplified Schematic Diagram

at E; the antenna reactance is inductive. The positive error voltage is used to drive the series elements until less inductive reactance or more capacitive reactance is obtained. When current and voltage are in phase, no error voltage appears at E, and driving of the series phasing elements stops.

NOTE

During retune operation of the Antenna Tuner, it is desirable to unbalance the phasing discriminator capacitively to obtain certain results which are noted in later text. When the control circuit grounds point F (see figure 4-2), CR-201 is short-circuited through a low resistance (R-207) and very little voltage appears across R-202. Therefore, the error voltage at point E is produced principally from the voltage drop across R-203, and is negative.

4-12. LOADING DISCRIMINATOR. The loading discriminator (see figure 4-5) must be able to determine whether the antenna impedance, looking from the network input, is exactly 52 ohms, more than 52 ohms, or less than 52 ohms. The loading discriminator is composed of CR-203 and CR-204, their associated loads and circuits. The d-c voltage developed across R-204 due to the detection of r-f voltage by CR-203 is proportional to the r-f voltage across the input transformer secondary, at points AC. The d-c voltage developed across R-206, due to the detection by CR-204, is proportional to the r-f voltage across R-205. C-210 and R-502 form an RC voltage divider, so that the voltage developed across R-205 is proportional to the r-f voltage in the transformer primary. The r-f voltage across the secondary at points AC is linear with respect to frequency. The voltage developed across R-204 is proportional to frequency. The reactance of C-210 is always high with respect to R-205, and C-211 is a very low impedance to ground. Since the impedance through the branch is inversely proportional to frequency, the current in the circuit is proportional to frequency and the voltage appearing across R-205 is also



proportional to frequency. Capacitors C-207 and C-208 isolate the d-c voltages rectified in the two discriminator circuits, and keep them from affecting each other. R-f chokes L-202 and L-204 provide a d-c ground return for CR-203.

4-13. If the antenna impedance is determined by the discriminator to be 52 ohms, the discriminator output is zero, since the output consists of the sum of the d-c voltage drops across R-204 and R-206. If the impedance is less than 52 ohms, excessive current is drawn and the voltage across the transmission line is low. The voltage drop across R-204 exceeds the drop across R-206 and a positive error voltage results. This error voltage, through means of the servo amplifier, will drive the r-f autotransformer toward minimum. If the impedance is more than 52 ohms, the transmission line voltage is high and the current low. The drop across R-206 exceeds the drop across R-204 and a negative error voltage results. This error voltage, through means of the servo amplifier, will drive the r-f autotransformer toward maximum.

4-14. SERVO AMPLIFIERS. The servo amplifiers receive information from the discriminator circuits and convert this information into a form that will drive the various elements of the Antenna Tuner as directed by the discriminators. The servo amplifier includes two complete amplifier systems, one for the loading system and one for the phasing system, using halves of tubes common to both circuits. Each amplifier consists of an input circuit, a chopper, two amplifier stages and a power output stage. The loading amplifier power output tube has one winding of the two phase motor it drives as its load. The phasing amplifier power output tube has a step-down transformer as its load. The transformer is connected to a two phase motor which drives a switch. Circuits of the two amplifiers are much alike.

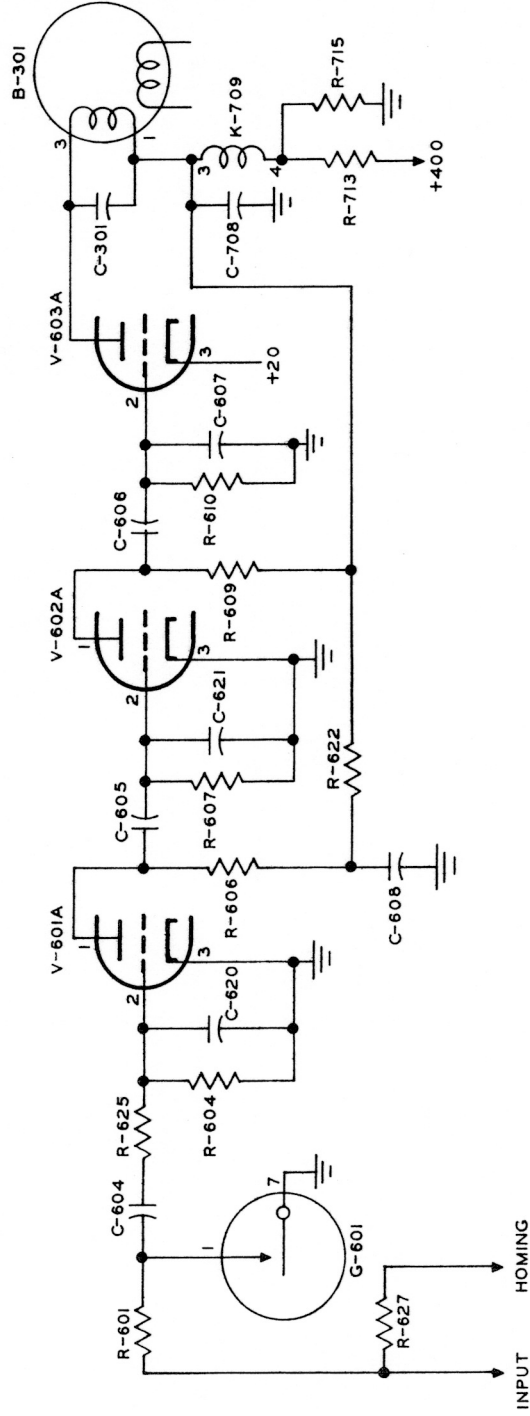


Figure 4-6. Loading Servo Amplifier, Simplified Schematic Diagram

4-15. LOADING SERVO AMPLIFIER CIRCUIT. (See figure 4-6). The d-c error voltage from the loading discriminator is applied to the loading servo amplifier circuit through an attenuating resistor (R-601) and converted into a 400 cps square wave signal by Chopper G-601. The chopper square wave output will lead or lag the 400 cps reference voltage by 90 degrees, depending on the polarity of the discriminator output. Tubes V-601A and V-601B are simple amplifiers. The load the power output tube V-603A is the r-f autotransformer drive motor, B-301. The motor winding is resonated by C-301 to reduce harmonics and increase the load impedance for the power output tube. Motor B-301 is a 400 cps, two phase motor. One phase input is the 400 cps supply voltage; the other is the servo amplifier output. Direction of rotation of the motor depends on whether the servo amplifier output leads or lags the supply voltage by 90 degrees, as determined by the polarity of the discriminator output. A positive discriminator output voltage will cause B-301 to drive the r-f autotransformer toward maximum; a negative output will cause it to drive toward minimum. R-622 and C-608 provide for decoupling between the plate supplies of the amplifier. R-713 and C-708, located on the control circuit relay panel, provide decoupling between the servo amplifier and the plate voltage supply. C-621 and C-607 are used to correct unbalance in the square wave which comes from G-601, due to transit time of the copper reed. The cathode of power output tube V-603A is connected to approximately +20 volts, and the tube is thus biased to near cutoff when no signal is applied from the discriminator. The coil of Relay K-709, located in the control circuit, is in series with the loading servo amplifier plate supply. Plate current demand of about 2 milliamperes from V-601A and V-601B is not sufficient to energize

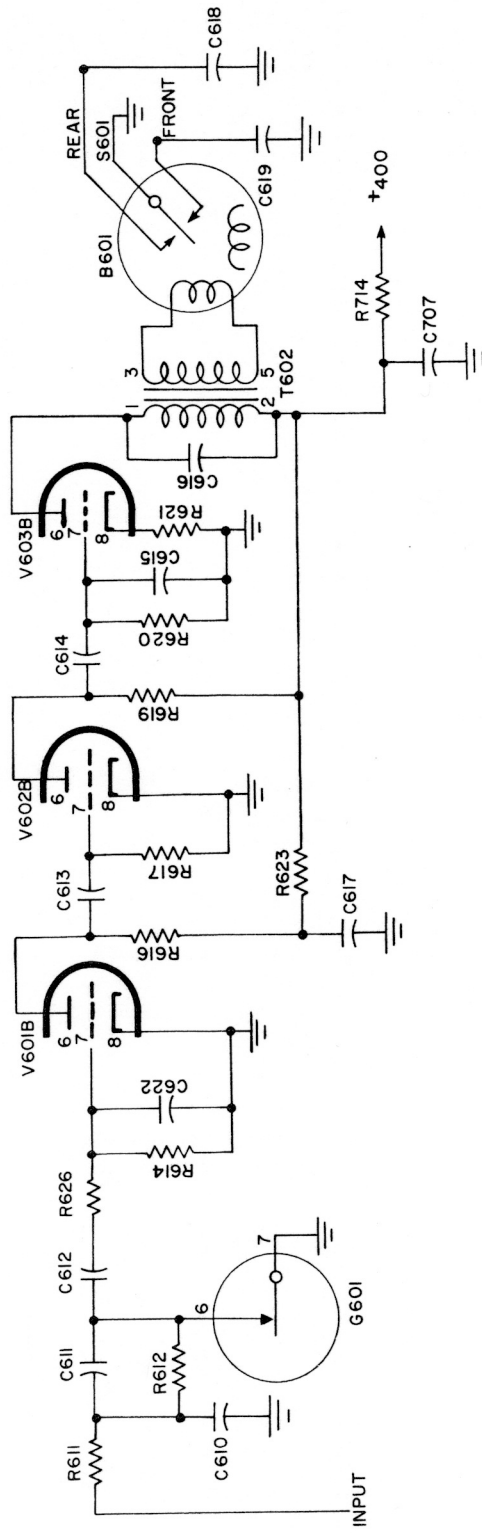


Figure 4-7. Phasing Servo Amplifier, Simplified Schematic Diagram.

the relay. When a discriminator signal is applied, the bias on V-603A is overcome and the power output tube draws about 10 milliamperes plate current, which is sufficient to energize K-709. Thus, K-709 will be energized only when a loading error exists and discriminator information is applied to the control circuit. R-715 is a bleeder resistor which helps to stabilize the plate voltage between signal and no-signal conditions. R-625 and C-620 form an r-f filter. R-627 is a portion of a voltage divider, in conjunction with R-204, which places approximately +12 volts d-c on the chopper when the control circuit calls for automatic homing of the tuning elements (refer to paragraph 4-27). If the Antenna Tuner is operated on 250 volts plate supply (refer to paragraph 3-18) instead of 400 volts, R-713 will not be in the circuit, but the decoupling function will not be necessary.

4-16. PHASING SERVO AMPLIFIER CIRCUIT. (See figure 4-7). The d-c error voltage from the phasing discriminator is applied to the phasing servo amplifier circuit through an audio filter composed of R-611 and C-610 and a lead network, and converted into a 400 cps square wave signal by Chopper G-601. The amplifier circuit functions in the same manner as the loading servo amplifier, except for the use of separate sub-components, the designations of which are apparent by comparison of the simplified schematic diagrams (see figures 4-6 and 4-7).

4-17. LEAD NETWORK. Function of the lead network, which is incorporated in the phasing servo amplifier only, is to counteract any hunting tendency in the phasing servo system. The network operates to obtain as much phase lead as possible without destroying sensitivity of the circuit. It consists of C-611 shunted by R-612 and the effective resistance to ground of Chopper G-601.



4-18. OUTPUT CIRCUIT. The plate load of power output tube V-603B is the primary of Transformer T-602. The secondary of the step-down transformer provides one phase input of Motor B-601, which is mounted on the servo amplifier chassis and does not drive the series tuning elements directly. The motor operates S-601, providing proper information to the control circuit. If an inductive error is present, B-601 attempts to run counter-clockwise, grounding lead (11) of J-601, and indicating to the control circuit that the error is inductive. If a capacitive error exists, the motor attempts to run clockwise, grounding lead (3) of J-601 and indicating to the control circuit that the error is capacitive. The phasing amplifier can now be described, from the preceding discussion, as an on-off device, control of which is determined by the error voltage level in the input circuit. C-618 and C-619 are included in the amplifier as spark suppressors for S-601.

4-19. ELECTRICAL-MECHANICAL THEORY, CONTROL CIRCUITS.

4-20. GENERAL. Operation of the control circuits is considered, in the text that follows, as a sequence with seven broad subdivisions:

- a. Selection of channel or operating frequency.
- b. Automatic keying of the associated transmitter, either as a function of channel selection or after a manual start.
- c. Homing of the r-f autotransformer to center tap.
- d. Starting of the phasing system in a home direction, toward minimum values of inductance and capacitance.
- e. Further operation of the phasing system in a mechanical cycle, which is interrupted as the phasing discriminator analyzes the specific reactance

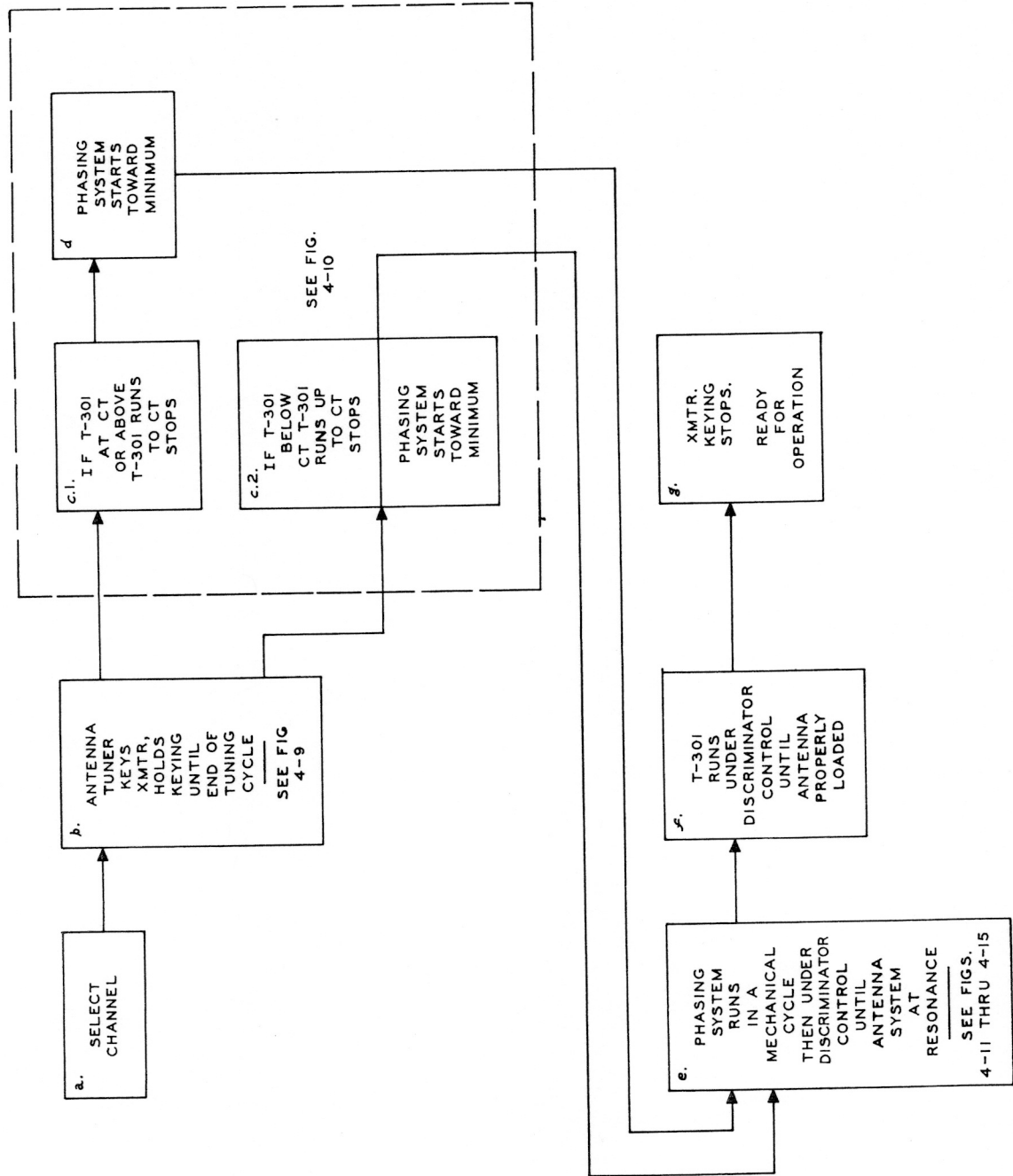


Figure 4-8. Master Block Diagram, Control Circuits

problem presented by the antenna, and takes control of the phasing system, providing sense information which will bring the antenna to resonance and stop the excursion of series phasing elements; this taking place either at the time when it is possible for series elements alone to phase, or resonate, the antenna, or after the necessity for shunt antenna capacitance has been proved.

f. Further operation of the r-f autotransformer until antenna loading is correct and the antenna system is fully tuned.

g. Interruption of the automatic keying function, leaving the complete radio set ready for operation on a selected channel.

4-21. Explanations of control circuit operation which follow are keyed to a master block diagram, figure 4-8. Other diagrams, texts and tables are used to expand upon the broad subdivisions of the master block diagram. Following this series of explanations, circuits are reviewed by detailed tracing, to assist maintenance personnel toward complete understanding of the Antenna Tuner's operation.

4-22. DEFINITIONS. In the following text, repeated reference will be made to several terms, which are defined as follows:

a. R-F ERROR. The condition in which antenna and series tuning elements are not in phase, or not at a point of resonance, and the phasing discriminator is therefore unbalanced. This condition may be a specific problem of phasing error which is to be solved by the discriminator, or may be a forced condition, introduced to achieve a certain operating result.

b. PHASING ERROR. A condition of r-f error which is further defined as either inductive or capacitive. That is, a condition in which the discriminator is

unbalanced by excess inductance or excess capacitance, respectively, appearing in the antenna circuit.

c. **LOADING ERROR.** The condition in which antenna and series tuning elements present a load of more or less than 52 ohms to the transmitter, and the loading discriminator is therefore unbalanced.

d. **CONTROL CIRCUIT ERROR LINE.** A control circuit which is grounded at any time r-f error exists. The line allows operation of a maximum reversing relay (refer to paragraph 4-23, below), energizes a time delay relay, holds a keying relay until the r-f error has been reduced to zero, and holds two reversing relays until r-f current is no longer present in the antenna system.

4-23. **RELAY FUNCTIONS.** Since control circuit operation involves action of 11 relays, it is most convenient to identify each and describe its function briefly, as a preliminary step. Thereafter in this discussion, reference will be made to the relay concerned by its component number, in the same manner as identification on schematic diagrams.

a. **K-701 (COIL-CAPACITOR SWITCHING RELAY).**

1. When not operated, allows Phasing System Motor B-401 (driving Inductor L-401) to run.

2. When operated, allows Phasing System Motor B-501 (driving Capacitor C-501) to run.

b. **K-702 (HOMING RELAY).**

1. When operated, runs the r-f autotransformer (T-301, Motor B-301) toward minimum, which is the grounded end of the transformer coil, nearest the assembly's gear train.

2. Disables Motors B-401 and B-501 so they cannot run during the period of operation of K-702.

3. Unbalances the phasing discriminator (refer to paragraph 4-11).
  4. Operates K-706 (refer to sub-paragraph f., below) when r-f is present in the antenna circuit.
- c. K-703 (CAPACITIVE ERROR RELAY).
1. Operates at any time capacitive phasing error is apparent to the phasing discriminator.
  2. Runs the phasing system motor selected by K-701 toward maximum.
- d. K-704 (INDUCTIVE ERROR RELAY).
1. Operates at any time inductive phasing error is apparent to the phasing discriminator.
  2. Runs the phasing system motor selected by K-701 toward minimum.
- e. K-705 (MINIMUM REVERSE RELAY). When operated, runs the phasing system motor selected by K-701 toward maximum.
- f. K-706 (MAXIMUM REVERSE RELAY). When operated, runs the phasing system motor selected by K-701 toward minimum.
- g. K-707 (RETUNE RELAY).
1. Operates at any time transmitter channel selection takes place.
  2. When operates, operates K-708, K-702 and drops out K-710.
- h. K-708 (AUTO KEYING RELAY). When operated, keys transmitter.
- i. K-709 (LOADING ERROR RELAY). Operates at any time loading error is apparent to the loading discriminator.
- j. K-710 (SHUNT CAPACITOR RELAY). When operates, shunts antenna with C-101.
- k. K-711 (TIME DELAY RELAY). Allows tuning cycle to proceed for maximum of 30 seconds from the time r-f is present. If tuning is not completed within 30 seconds, operates thermally to unkey transmitter, stop motors and drop out reversing relays.



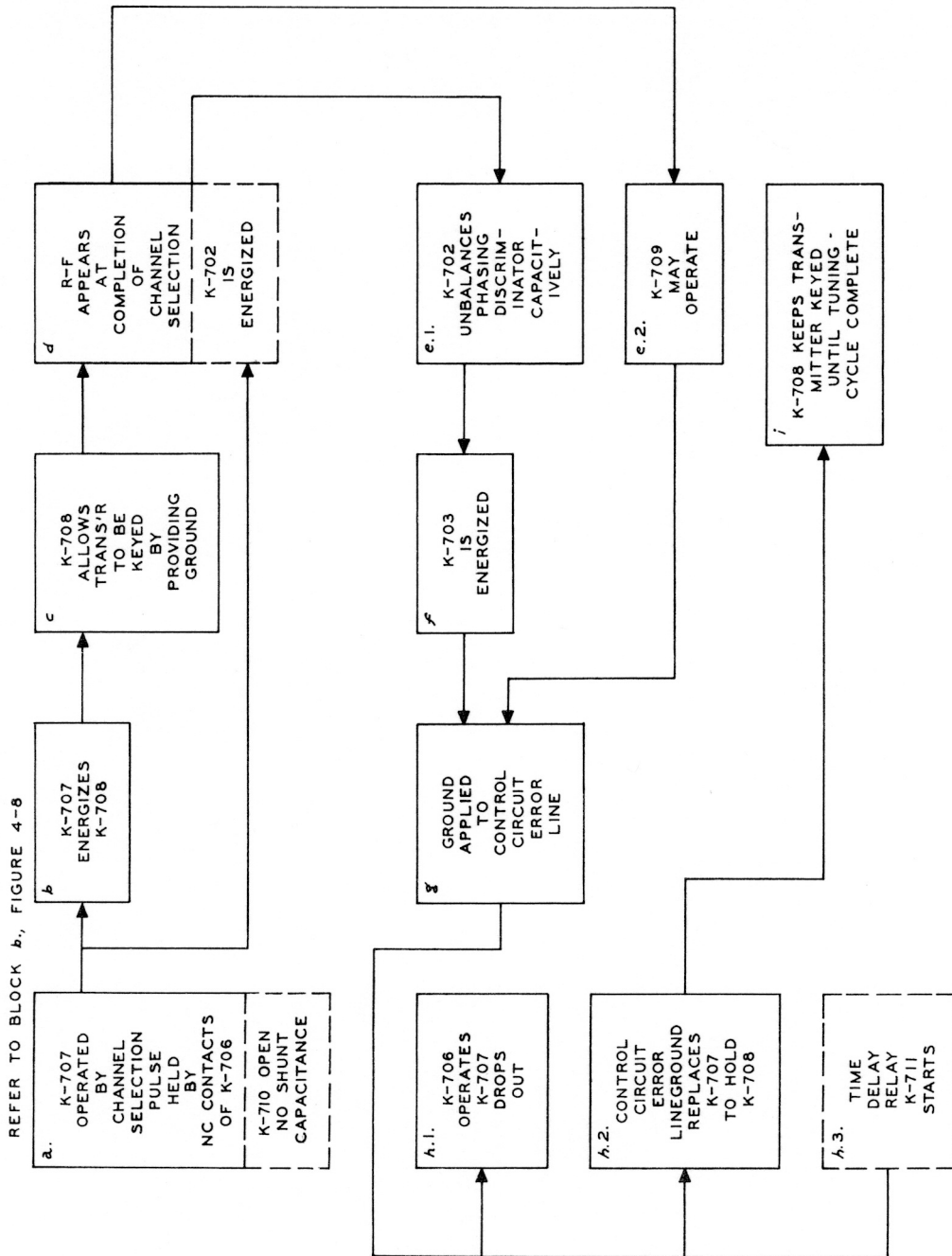


Figure 4-9. Automatic Keying, Holding Function, Block Diagram

4-24. Functions of relays and switches, in addition to the above listing, are reviewed and summarized in Table 4-1.

4-25. CONTROL CIRCUIT OPERATION. (See figure 4-8). Channel selection is the first step in the sequence of control circuit operation. It is accomplished by operation of the radio set control's channel selector.

4-26. AUTOMATIC KEYING, HOLDING FUNCTION. (See figure 4-8, block b., and figure 4-9). The general function of the automatic keying and hold circuit is noted in the basic block diagram, figure 4-8. Figure 4-9 illustrates a more detailed step summary of the circuit's operation, which follows:

a. Relay K-707 is operated by a pulse received from the channel selection circuit, and is held by normally-closed contacts of K-706. (K-710 is open, therefore no shunt capacitance is in the antenna circuit).

b. K-707 energizes K-708 and K-702 (See figure 4-9, block d.) if the Antenna Tuner is connected for fully automatic keying as a function of channel selection. If manual-start keying is used, K-708 will not be energized until the key is pressed.

c. K-708 allows the transmitter to be keyed by providing a keying circuit ground.

d. R-f appears in the antenna system at completion of channel selection. (K-702 is energized).

e. The phasing discriminator is unbalanced (refer to paragraph 4-11) capacitively, as a result of the presence of r-f while K-702 is energized (See figure 4-9, block e.1.) K-709 may operate, as a result of r-f being present (See figure 4-9, block e.2.).

f. K-703 is energized because the phasing discriminator is unbalanced capacitively.

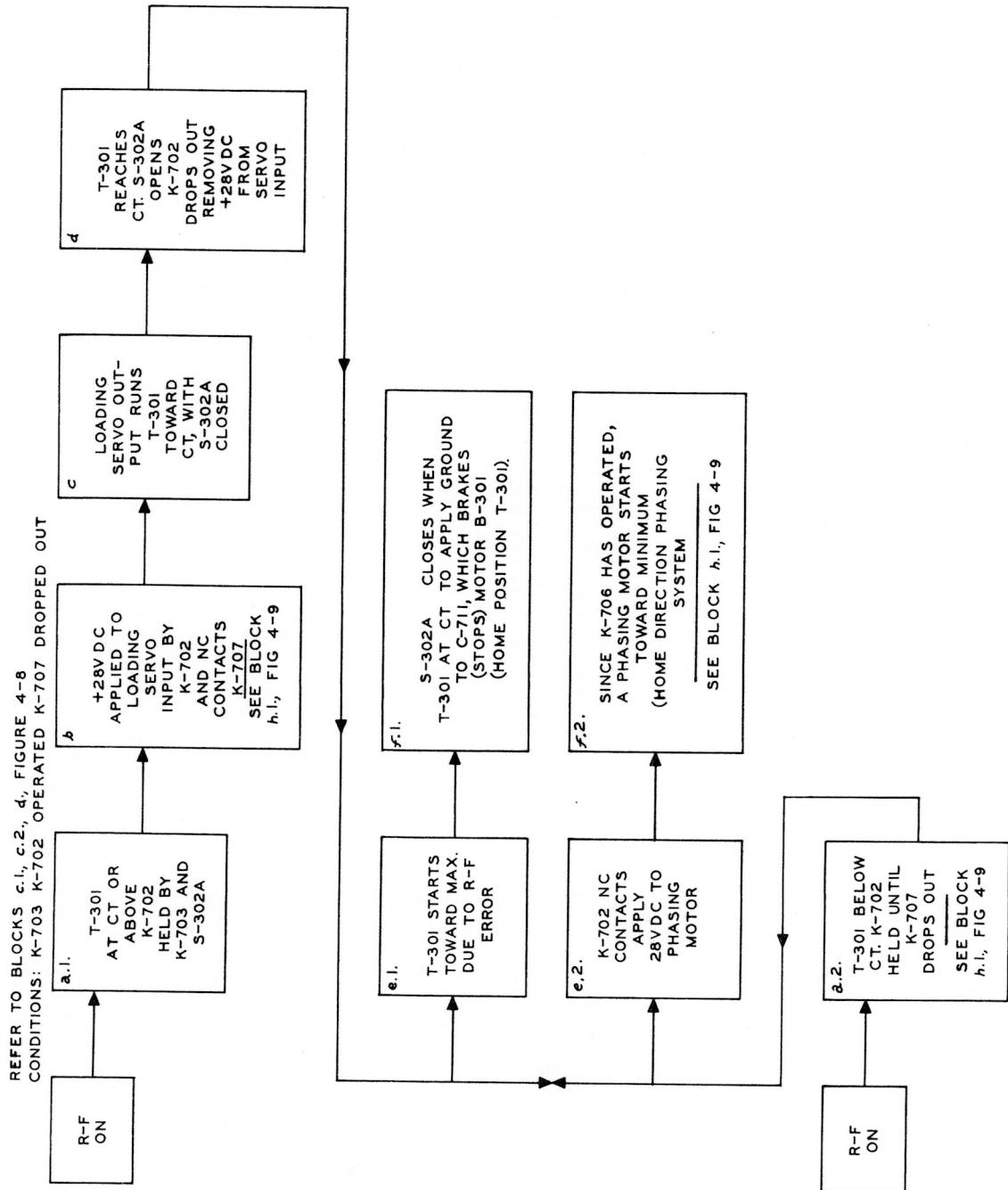


Figure 4-10. Automatic Homing Function, Block Diagram

g. As a result of K-703 being energized, or the operation of K-709, a ground is placed on the control circuit error line.

h. K-706 operates and K-707 drops out (See figure 4-9, block h.1.). In parallel action, the control circuit error line ground replaces K-707 to hold K-708 (See figure 4-9, block h.2.) and as a secondary function, allows K-711 to operate after 30 seconds of delay. A delay capacitor (C-710) holds K-708 until the ground is established.

i. K-708 keeps the transmitter keyed until tuning is complete.

4-27. AUTOMATIC HOMING FUNCTION. (See figure 4-8, blocks c.1., c.2. and d., and figure 4-10). The general function of automatic homing is noted in the basic block diagram, figure 4-8. Figure 4-10 illustrates a more detailed step summary of the circuit's operation, which follows. It is apparent, referring to figure 4-10, that two possible starting points exist (see blocks a.1. and a.2.). A longer sequence results when the homing operation begins with the r-f autotransformer (T-301) at or above center tap, its home position.

#### NOTE

The automatic homing function achieves two things. It brings T-301 to center tap and stops its driving motor (B-301) at that position, then starts the phasing system (B-401, B-501) toward minimum inductance and capacitance, its home direction.

Later explanation will clarify reasons for the initial operation of the phasing system toward minimum. Basically, the phasing system is always started toward minimum in order to decrease the average tuning time.

a. With r-f present and T-301 at center tap or above (see figure 4-10, block a.1.), K-702 is held by K-703 and S-302A. It is assumed that K-703

and K-702 have operated and K-707 has dropped out (see figure 4-9, blocks d., f. and h.1.).

b. Plus 28 volts d-c is applied to the loading servo circuit by K-702 and normally-closed contacts of K-707.

c. Loading servo circuit output runs T-301 (B-301) toward center tap, with S-302A closed.

d. T-301 reaches center tap. S-302A opens and K-702 drops out, removing the 28 volt d-c circuit from the servo input.

e. T-301 starts briefly toward maximum, due to r-f error (see figure 4-10, block e.1.) and K-702 normally-closed contacts apply 28 volts d-c to a phasing system motor (see figure 4-10, block e.2.) selected by K-701.

f. T-301 returns to center tap. S-302A agains closes, applying a ground to C-711, which brakes and stops B-301 and thus holds T-301 at its home position (see figure 4-10, block f.1.). Since K-706 has operated, as noted in figure 4-9, block h.1., a phasing motor selected by K-701 starts toward minimum (see figure 4-10, block f.2.).

g. In the shorter sequence of the automatic homing operation, starting at figure 4-10, block a.2., with T-301 below center tap, the operation begins as r-f is present and K-702 is held until K-707 drops out. A delay capacitor, C-709, delays the drop-out of K-707. The sequence then proceeds as noted in blocks e.1. and e.2., and is completed as noted in blocks f.1. and f.2.

4-28. MECHANICAL CYCLE. Series tuning elements of the phasing system are set in motion toward minimum inductance and capacitance at the completion of the automatic homing function (refer to paragraph 4-27.f., above). The phasing discriminator will, within a few seconds at most, analyze a specific case of phasing error and provide sense information, take control of the series



elements, bring the antenna system to resonance, then stop the elements. However, the phasing discriminator may not be able to see a problem, or a standard phasing error case, at the time the series elements are started toward minimum. Most specifically, the reactance of the antenna may be too high to resonate with the series elements alone. Shunt capacitance will then be required across the antenna before the discriminator can see a phasing error case which can be solved by adjustment of the series elements. It thus becomes apparent that a system of interim operating control must be provided which will conduct the series elements through a specified excursion from any starting point, bring in shunt capacitance as the elements reach their maximums, and in general continue the action initiated by the automatic homing function until such time as the discriminator provides correct sense information. The interim system must then give way to control of the series elements by the discriminator, with actual movement of the elements continuing until a resonant condition halts them. The interim system is referred to as the mechanical cycle.

4-29. Since the starting point of the mechanical cycle may fall near the position of maximum inductance and capacitance, depending on the last previous point of resonance reached by the series elements; its direction of operation is dictated by the automatic homing function as toward minimum, and the introduction of shunt capacitance may be necessary before the discriminator can act, it is apparent that the cycle must be capable of operating the series elements from near maximums through minimums, through maximums (at which point it will switch in shunt capacitance), and at least a short distance toward minimums, at which time the discriminator will take control. For the purpose of the discussion immediately following, it is assumed that no r-f current is present, but that a ground has been placed on the control circuit error line.

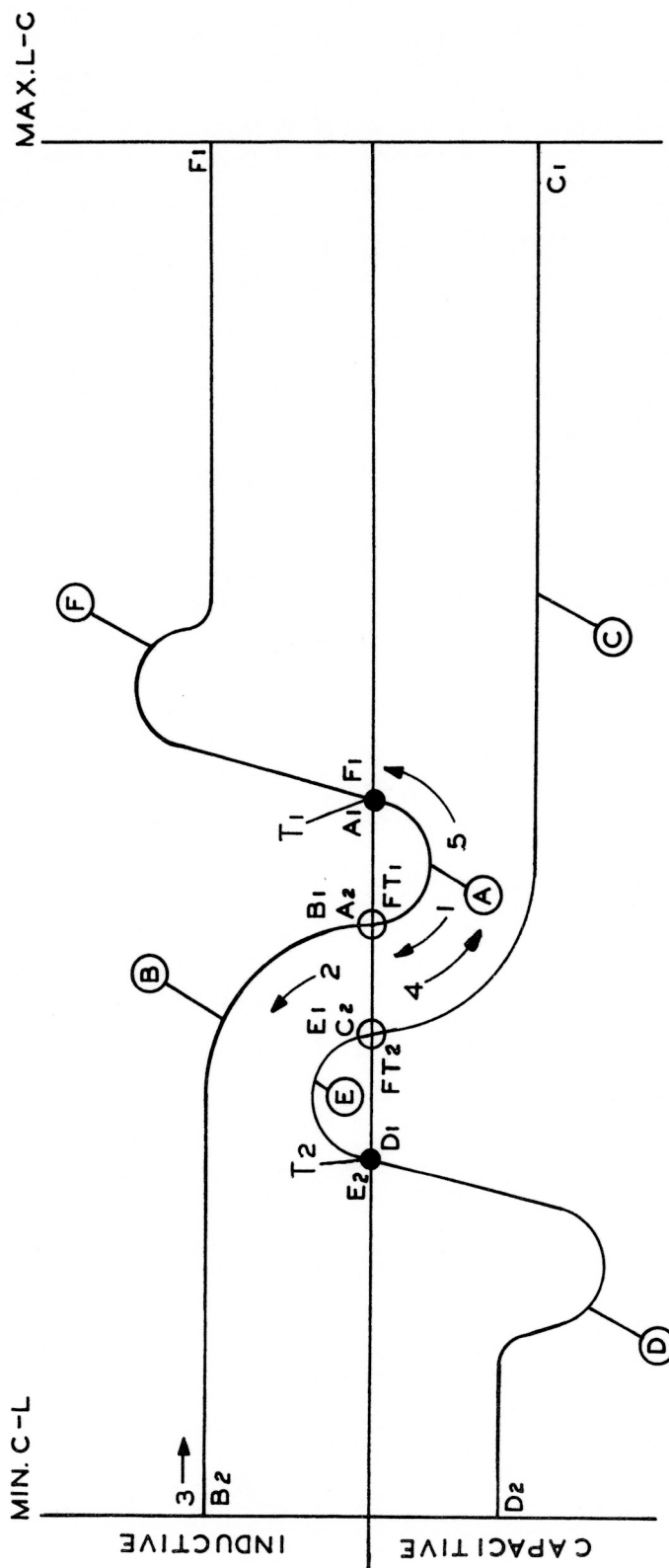


Figure 4-12. Phasing Errors (Typical) Seen by Discriminator as Reactance Varies

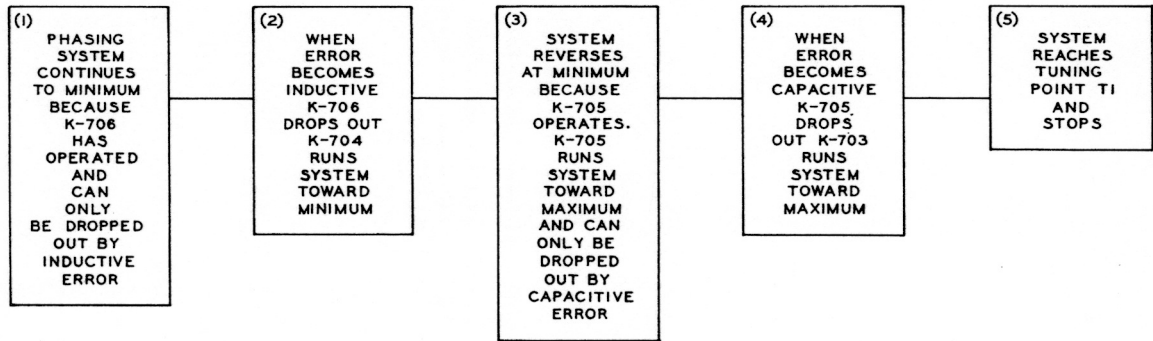


Figure 4-13. Case A, Capacitive Phasing Error, Block Diagram

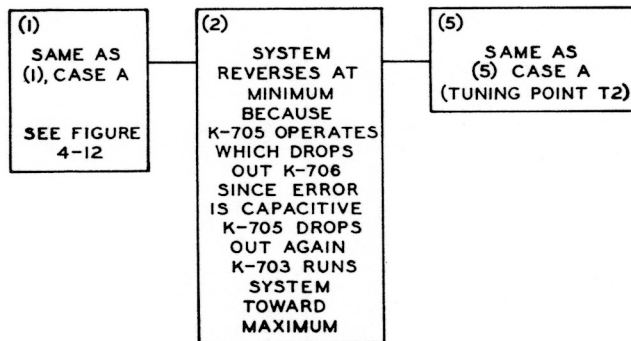


Figure 4-14. Case D, Capacitive Phasing Error, Block Diagram

a. POSITION (a.1.), OPERATION A. (See figure 4-11). Starting at a point just below maximum inductance, L-401 runs toward minimum as the full mechanical cycle begins, because Relay K-706 (MAXIMUM REVERSE) has operated and K-701 (COIL-CAPACITOR SWITCHING) is not operated.

b. POSITION (b), OPERATION B. When L-401 reaches minimum, K-701 operates. C-501 starts toward minimum because K-706 is still operated.

c. POSITION (c), OPERATION C. When C-501 reaches minimum, K-705 (MINIMUM REVERSE) operates. K-706 and K-701 drop out. L-401 runs toward six turns from minimum.

d. POSITION (d), OPERATION D. When L-401 reaches six turns from minimum, K-701 operates. C-501 runs toward maximum because K-705 is still operated.

e. POSITION (e), OPERATION E. When C-501 reaches maximum, K-701 drops out. L-401 runs toward maximum because K-705 is still operated.

f. POSITION (a.2.) When L-401 reaches maximum, K-710 (SHUNT CAPACITOR) operates, placing C-101 across the antenna. K-706 operates and L-401 again starts toward minimum, as in OPERATION A. The discriminator will take control and the phasing system will reach a tuning point, then stop.

4-30. PHASING ERROR ANALYSIS. (See figure 4-8, block e., and figures 4-12 through 4-15). One of six general cases of phasing error (two of the cases are essentially identical) must be analyzed by the discriminator before it can take control of the series elements' excursion and bring the antenna system into resonance. Referring to figure 4-12, capital letters (A through F) are used to refer to areas of the phasing error curve, rather than to any specific point within the areas. Boundaries of each error area are indicated by capital letters and numerals. A1 and A2 are the terminal points of area A, for example. Numerals and directional arrows refer to the excursion of the

phasing system toward minimums, then toward maximums, in the most complicated case that will be placed before the discriminator. T1 and T2 are tuning points, at which the antenna system and series elements are in phase, or resonant. FT1 and FT2 are false tuning points, or error nulls that do not satisfy the requirements of resonance. The phasing system is forced through these false nulls when necessary, to reach T1 or T2, a function which will be explained in later text.

4-31. The specific case of phasing error analyzed by the discriminator depends upon frequency of operation and the starting point on the phasing error curves, or the position of series elements in the mechanical cycle. Shunt antenna capacitance and false tuning points are not brought into this discussion (refer to paragraph 4-32). It is assumed that the antenna reactance can be resonated by series elements alone.

a. CASE A, CAPACITIVE PHASING ERROR. (See figures 4-12 and 4-13). The phasing system has started toward minimums and the discriminator sees a capacitive phasing error within area (A). The system continues (1) toward minimums because K-706 (MAXIMUM REVERSE) has operated. It has been established that K-706 is operated during OPERATIONS A and B of the mechanical cycle (refer to paragraph 4-29). At points A2 and B1, the phasing error becomes inductive. Relay K-704 (INDUCTIVE ERROR) operates, and K-706 drops out. It has also been established that K-704 will operate at any time inductive error is apparent to the phasing discriminator (refer to paragraph 4-23.d.) and will run a phasing system motor selected by K-701 (COIL-CAPACITOR SWITCHING) toward minimum. The system continues toward minimums (2), but the inductive phasing error persists. At minimums, the system reverses because K-705 (MINIMUM REVERSE) operates. The system runs (3) toward maximums. It has been

established that K-705 is operated during OPERATIONS C, D and E of the mechanical cycle. At points B1 and A2, the phasing error again becomes capacitive. Relay K-703 (CAPACITIVE ERROR) operates, and K-705 drops out. It has also been established that K-703 will operate at any time capacitive error is apparent to the phasing discriminator and run a selected phasing system motor toward maximum. This the actual point at which the discriminator takes final control of the excursion of the phasing elements. The system continues toward maximums (4), but the phasing error reduces to zero, K-703 drops out and the system stops at (5), the tuning point T1.

b. CASE B, INDUCTIVE PHASING ERROR. The system has started toward minimum and the discriminator sees an inductive phasing error within area (B). Progress of the system to tuning point T1 is identical with that of Case A, except that it begins with operation (2) and continues through operations (3), (4) and (5).

c. CASE C, CAPACITIVE PHASING ERROR. The system has started toward minimum and the discriminator sees a capacitive error within area (C). Progress of the system to tuning point T2 parallels that of operations (1) and (2) in Case A, but the system does not reach minimums before arrival at T2.

d. CASE D, CAPACITIVE PHASING ERROR. (See figure 4-14). The system has started toward minimums and the discriminator sees a capacitive phasing error within area (D). Progress of the system to tuning point T2 parallels operation (1) of Case A until the system reaches minimums. Then K-705 (MINIMUM REVERSE) operates, dropping out K-706 (MAXIMUM REVERSE), and the system starts toward maximums. The capacitive error persists, and K-705 drops out after performing its function, but K-703 (CAPACITIVE ERROR) runs the system toward maximum, under control of the discriminator, until T2 is reached.



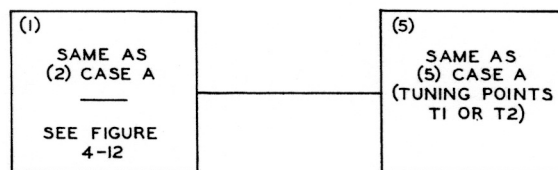


Figure 4-15. Cases E-F, Inductive Phasing Error, Block Diagram

e. CASES E-F, INDUCTIVE PHASING ERROR. (See figure 4-15). The system has started toward minimums and the discriminator sees an inductive error within areas (E) or (F). K-706 drops out, but K-704 (INDUCTIVE ERROR) runs the system toward minimums, under control of the discriminator, as in operation (2), Case A. Tuning points T1 or T2 are reached before the system arrives at minimums.

4-32. ANTENNA SHUNT CAPACITANCE. If antenna reactance is too great to be resonated by series tuning elements alone, it has been established, the mechanical cycle will switch shunt capacitance into the circuit when inductance and series capacitance are at maximums. (Refer to paragraph 4-29.f.) A new reason for the forcing of series elements to start toward minimums by the automatic homing function thus becomes apparent. Shunt capacitance is kept out of the circuit until the need for it has been proved, by failure of the discriminator to interrupt the mechanical cycle and take control of the series elements' excursion. If the series elements arrive at maximum, K-710 operates to put C-101 across the antenna. It will be apparent that the effect of shunt capacitance is to move the phasing error curves (see figure 4-12) into a typical useful area, or an area which includes resonant points, so that the discriminator can see and analyze a standard phasing error case, rather than a persisting error.

NOTE

Shunt capacitance cannot be in the circuit when the phasing system starts to seek resonance. At each new channel selection operation, K-707 operates to drop out K-710 and disconnect C-101.

Shunt capacitance may also be brought into the circuit by the presence of antenna resistance of considerably more than 52 ohms, through action of the r-f autotransformer and its switching system. When the series phasing elements are in their cycle, the r-f autotransformer is held at center tap. The antenna may be brought to resonance by the series elements, and their excursion will then stop. With a high resistance presented by the antenna, the r-f autotransformer will run toward maximum, under control of the loading discriminator. If the resistance is too high to bring about correct loading at maximum of the r-f autotransformer, S-302B operates to provide a ground for the coil of K-710, which in turn operates to put C-101 across the antenna. At the same time, the homing function is re-started, and K-706 (MAXIMUM REVERSE) is operated, with series elements starting toward minimum, and the r-f autotransformer returning to center tap. After phasing is re-adjusted, the r-f autotransformer again runs to achieve correct loading, operating toward minimum if the loading discriminator determines that a low impedance is present, and toward maximum if a high impedance is present.

4-33. INTERRUPTION OF MECHANICAL CYCLE. It has now been established that the phasing discriminator will interrupt the mechanical cycle and take control of the excursion of series tuning elements at one of several times. The points at which the discriminator takes control, and the methods, can be discussed further in two general cases.

a. If the mechanical cycle (see figure 4-11) is within OPERATIONS A or B, the phasing system will continue operation under control of the mechanical cycle until inductive phasing error appears. K-704 (INDUCTIVE ERROR) operates, and drops out K-706 (MAXIMUM REVERSE), then continues to run the system toward minimums under discriminator control.

NOTE

The phasing system will continue to operate under control of the mechanical cycle UNTIL K-704 (OR K-703) OPERATES. This forces the series elements through false tuning points, where the discriminator sees no r-f error and would stop their excursion if it had control.

b. If the mechanical cycle is within OPERATIONS C, D or E, the phasing system will continue to run under control of the mechanical cycle until capacitive phasing error appears. K-703 (CAPACITIVE ERROR) operates, and drops out K-705 (MINIMUM REVERSE), then continues to run the system toward maximums under discriminator control. The system will continue to operate under control of the mechanical cycle until K-703 operates again forcing the series elements through false tuning points.

4-34. LOADING ERROR ANALYSIS. (See figure 4-8, block f.). The general function of the loading system is noted in figure 4-8. Refer also to description of the loading servo amplifier circuit, paragraph 4-15. In

operation, when the loading discriminator sees a load of more than 52 ohms presented to the transmitter, it will produce a positive servo amplifier output voltage and drive B-301 (T-301) toward maximum. When the loading discriminator sees exactly 52 ohms presented to the transmitter, its output drops to zero and B-301 stops. If the loading discriminator sees a load of less than 52 ohms, B-301 and T-301 run toward minimum, since a negative output voltage is produced. When a load of exactly 52 ohms is presented to the transmitter, the antenna system is tuned, since phasing has been previously accomplished.

4-35. UNKEYING OF TRANSMITTER. (See figure 4-8, block f.). When the antenna system is tuned, or phased and loaded, all r-f error has been reduced to zero. Thus, all grounds are removed from the control circuit error line (refer to paragraph 4-22.d.) and K-708 (AUTO KEYING) drops out, resulting in removal of the transmitter keying ground. The complete radio set is then ready for operation on a selected frequency.

4-36. TOUCH-UP TUNING. When the transmitter is in actual operation, additional fine tuning of the antenna system is constantly provided under control of the discriminator. The automatic circuits are not involved in this touch-up tuning. At any time r-f appears in the antenna system and tuning is not completely correct, S-601, in the output circuit of the phasing servo amplifier, operates either K-704 (CAPACITIVE ERROR) or K-703 (INDUCTIVE ERROR), to correct L-401 for small phasing errors. T-301 is adjusted by the loading servo amplifier output to correct for small errors in antenna resistance.

4-37. DETAILED TRACING, CONTROL CIRCUITS.

4-38. Detailed tracing of control circuits which follows reviews the various functions of which have been described in the preceding text. Motor control circuits, including damping and protection provisions, are traced first in the

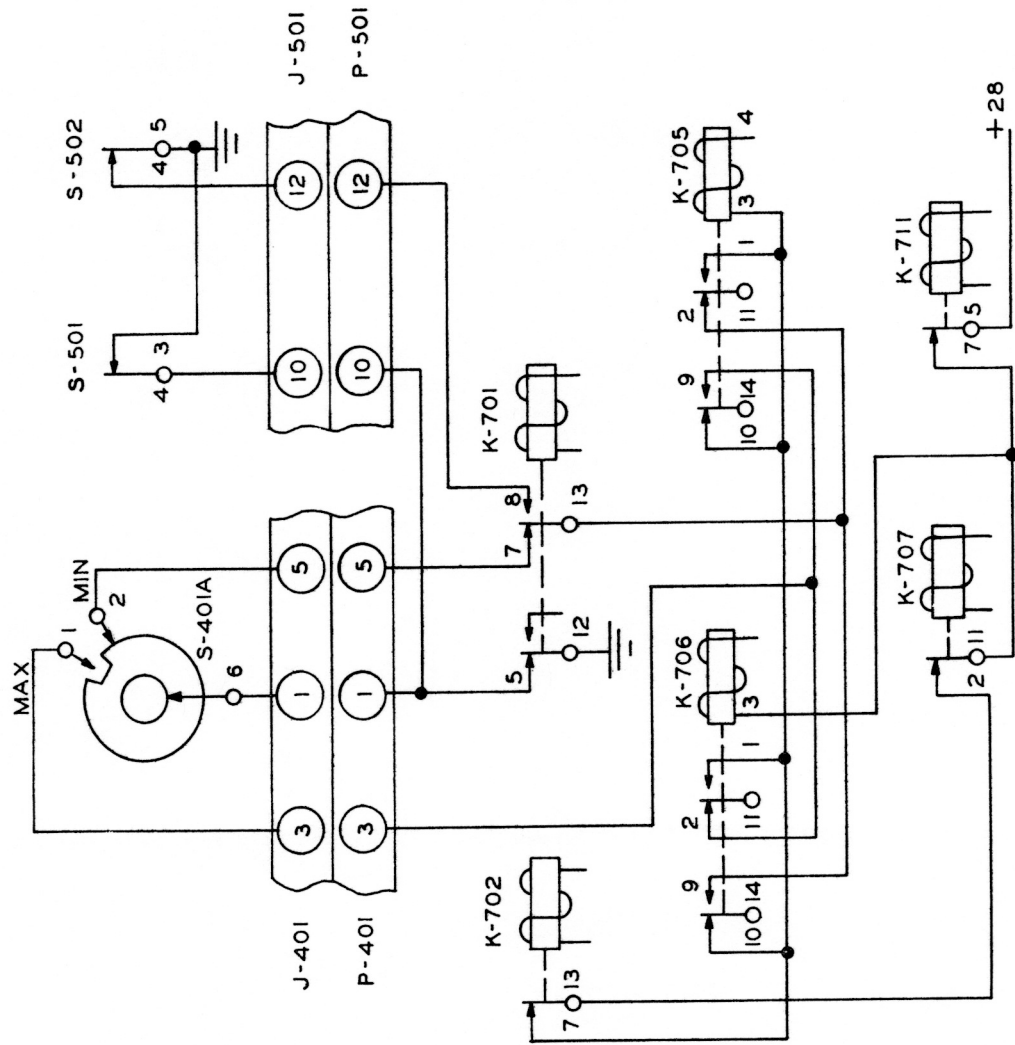


Figure 4-16. Motor Control Circuits (Preliminary), Simplified Schematic Diagram





following discussion. Thereafter, the circuits are traced in the sequence used to discuss their theory, including automatic keying, automatic homing, the mechanical cycle, shunt capacitance, interruption of the mechanical cycle and unkeying of the transmitter.

4-39. MOTOR CONTROL CIRCUITS. Motor control circuits cause phasing system motors to operate in one of two directions of rotation. For purposes of simplification, the circuits are considered as though only one relay was operated at a time, and it is assumed that only the inductor motor (B-401) is being controlled. In the preliminary circuit tracing (see figure 4-16), K-705.2 and K-705.9 are grounded through limit switches S-401A, S-501 and S-502. K-706.2 and K-706.9 are grounded by the same means. K-705.1, K-705.10 and K-705.3 are at +28 volts d-c through K-702, K-707 and K-711. K-706.1 and K-706.10 are at the same potential by the same means, and K-706.3 is at the same potential through K-711 directly. The operation of the motor control circuit can now be discussed under four cases:

a. K-704 (INDUCTIVE ERROR). If K-704 is operated (see figure 4-17), B-401 will run toward minimum because the red motor lead is at +28 volts d-c through P-401.11, K-701.14 and K-701.10, K-704.13 and K-704.8, K-705.14 and K-705.10. The black motor lead is grounded through P-401.4, K-703.13 and K-703.7, 705.11 and K-705.2

b. K-706 (MAXIMUM REVERSE). If K-706 is operated, B-401 will run toward minimum because the black motor lead is grounded through the circuit described under K-704, above. The red motor lead is at +28 volts d-c through P-401.11, K-701.14 and K-701.10, K-704.13 and K-704.7, K-706.11 and K-706.1.

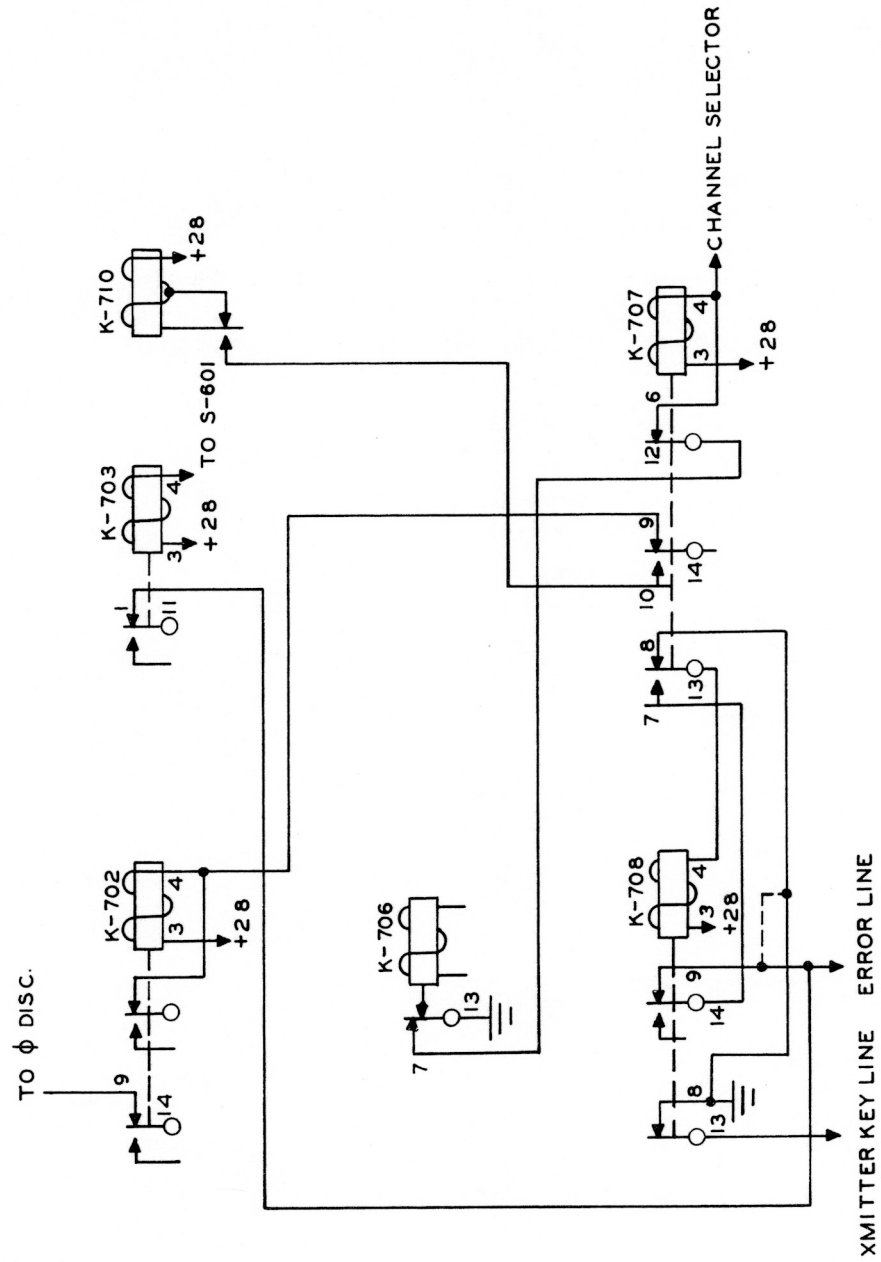


Figure 4-18. Automatic Keying, Holding Circuits, Keying Function

c. K-703 (CAPACITIVE ERROR). If K-703 is operated, B-401 will run toward maximum. The red motor lead will be grounded through P-401.11, K-701.14 and K-701.10, K-704.13 and K-704.7, K-706.11 and K-706.2. The black motor lead will be at +28 volts d-c through P-401.4, K-703.13 and K-703.8, K-706.14 and K-706.10.

d. K-705 (MINIMUM REVERSE). If K-705 is operated, B-401 will run toward maximum. The red motor lead will be grounded through the circuit described under K-703, above. The black motor lead will be at +28 volts d-c through P-401.4, K-703.13 and K-703.7, K-705.11 and K-705.1.

#### 4-40. MOTOR PROTECTION CIRCUITS.

a. Phasing system motors B-401 and B-501 are protected by limit switches should the normal reversing circuit fail to operate when L-401 or C-501 reach their limits. B-401 is protected by S-401A. This switch operates slightly after S-401B, S-402A and S-402B, and opens the ground circuit to the motor at minimum or maximum limits in case of failure to reverse or switch to control of B-501. B-501 is protected by S-502.4 and S-502.5 at minimum and S-502.3 and S-502.4 at maximum. At minimum, S-502 opens after S-501.1 and S-501.3 close, breaking the ground circuit to the motor in case of failure to switch to control of B-401. At maximum, S-501.4 and S-501.3 break the ground circuit to the motor in case of failure to switch to control of B-401. R-501 and R-501 are 10-ohm resistors which reduce the torque of the phasing system motors so that they will start and stop smoothly. The resistors also offer overload protection.

b. DYNAMIC BRAKING. When control is switched from B-401 to B-501, the leads of B-401 are short-circuited at K-701.14 and K-701.9, dynamically braking the motor and preventing it from coasting. When control is switched from

B-501 to B-401, the leads of B-501 are short circuited at K-701.11 and K-701.2, with the same effect. When either motor is stopped by the de-energizing of Relays K-703, K-704, K-705 or K-706, leading to the motor then in operation grounded, to brake the motor.

4-41. AUTOMATIC KEYING, HOLDING CIRCUITS. The following discussion reviews the automatic keying and holding circuits (refer to paragraph 4-26) and provides detailed circuit tracing.

a. When the transmitter is channeled to a new frequency, a ground pulse from the channel selector circuit appears on K-707.4 through J-102.10. (See figure 4-18). K-707 (RETUNE) operates because of the ground on K-707.4, and the presence of +28 volts d-c at K-707.3. K-707 is held by the ground on K-707.4, through K-707.6 and K-707.12, K-706.7 and K-706.13. K-710 (SHUNT CAPACITOR) drops out, because its holding ground is opened at K-707.10 and K-707.14. K-702 (HOMING) operates. K-702.3 is at +28 volts d-c. K-702.4 is grounded by K-707.9 and K-707.14. K-708 (AUTO KEYING) is energized. K-708.3 is at +28 volts d-c. K-708.4 is grounded by K-707.13 and K-707.8. K-708.13 and K-708.8 provide a ground for the transmitter keying line.

NOTE

The ground for K-708.4 is established as stated above when fully automatic keying is being used. If the radio set has been installed with modification of connections to K-708, for "radio silence" during channel selection, K-708 gets its ground from the control circuit error line when the transmitter key is operated and r-f appears in the antenna system.

b. When r-f appears, either in the case of fully automatic keying or manual-start keying, K-702.14 and K-702.9 put a ground on the phasing discriminator to unbalance it capacitively. (Refer to paragraph 4-11).

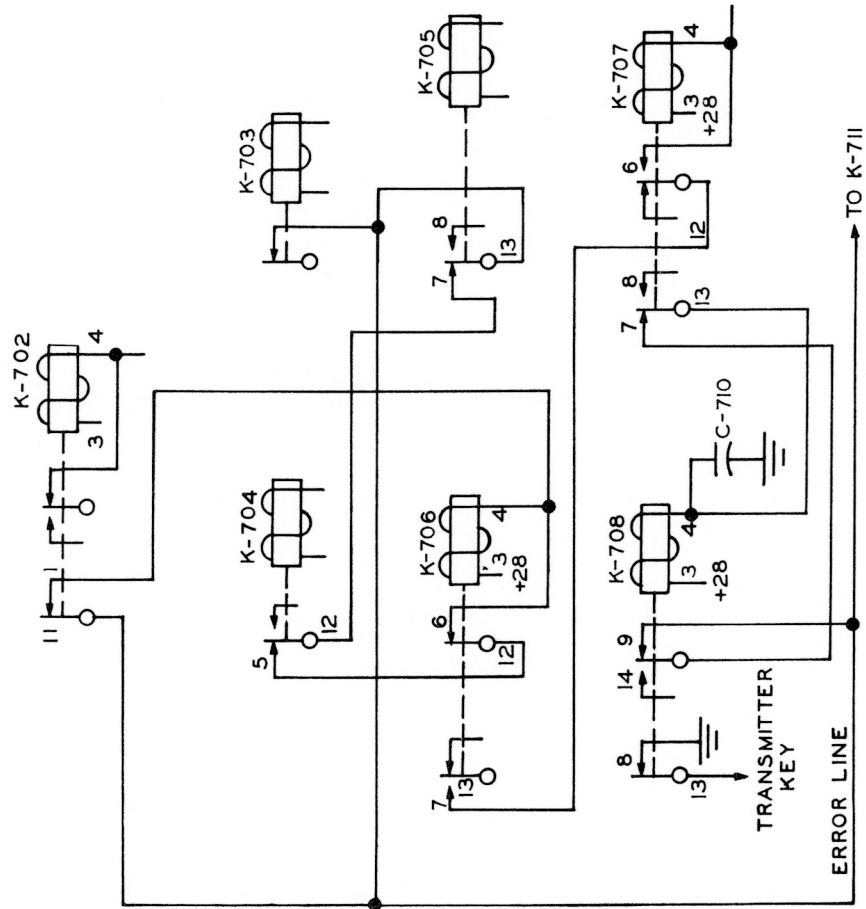


Figure 4-19. Automatic Keying, Holding Circuits, Holding Function



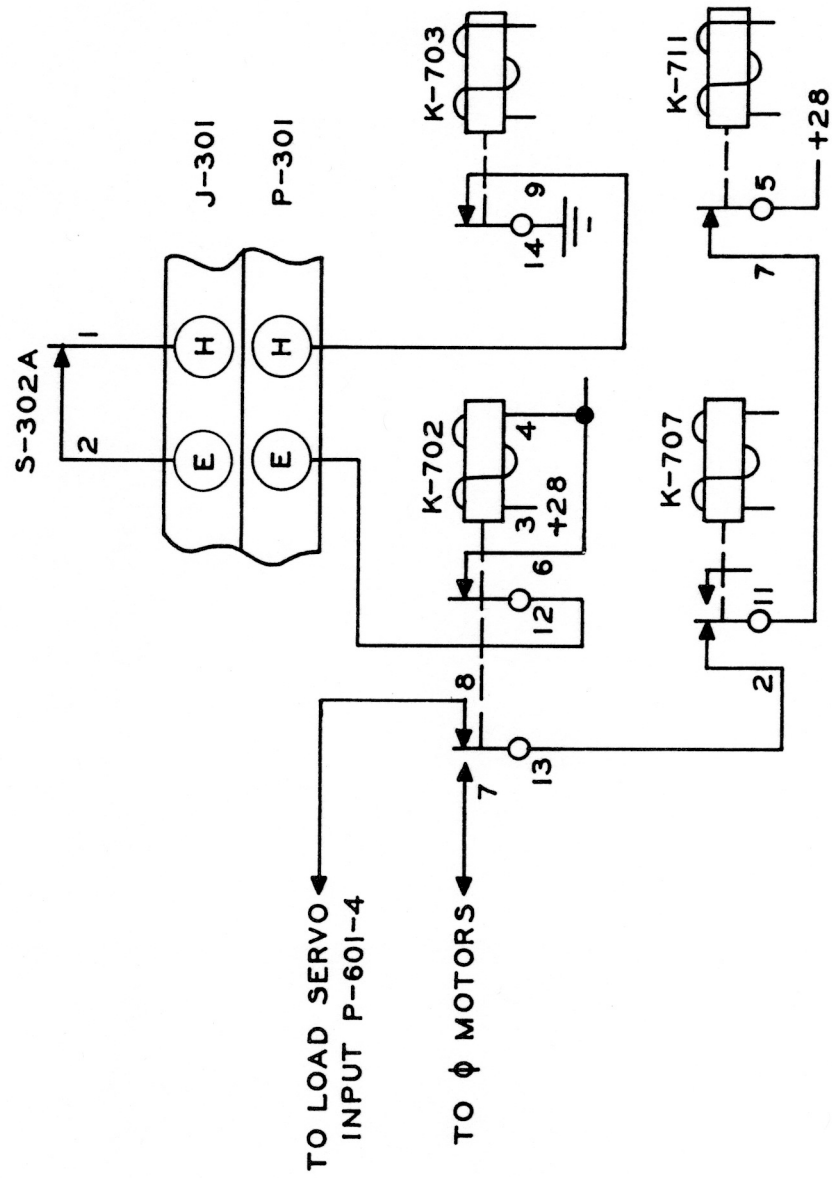


Figure 4-20. Automatic Homing Circuits, R-F Autotransformer to Center Tap

c. When the phasing discriminator is unbalanced, capacitive error operates S-601 in the phasing servo amplifier and causes K-703 to operate.

d. K-703 (CAPACITIVE ERROR) places a ground on the control circuit error line through K-703.1 and K-703.11.

e. If K-709 (LOADING ERROR) operates, K-709.8 and K-709.9 also ground the control circuit error line.

f. K-706 (MAXIMUM REVERSE) operates. (See figure 4-19). K-706.3 is at +28 volts d-c. K-706.4 is grounded by K-702.1 and K-702.11, the latter point being on the error line. K-706 is held because K-706.4 is grounded by K-706.12, K-704.5 and K-704.12, K-705.7 and K-705.13, the latter point being on the error line.

g. K-707 drops out. The holding ground on K-707.4 is now open at K-706.7 and K-706.13.

h. K-708 is held because K-708.4 is grounded through K-707.13 and K-707.7, K-708.14 and K-708.9, the latter point being on the error line. C-710 is a delay capacitor, which delays the drop-out of K-708, holding it while K-707 makes its transfer of grounds. K-708 holds, and the transmitter is keyed, as long as a ground exists on the control circuit error line.

4-42. AUTOMATIC HOMING CIRCUITS. The following discussion reviews the automatic homing function (see paragraph 4-27) and provides detailed circuit tracing.

a. K-702 (HOMING) is held (see figure 4-20) because K-702.4 is grounded through K-702.6 and K-702.12, S-302A, K-703.9 and K-703.14. Plus 28 volts d-c is applied to the loading servo amplifier input through K-702.8 and K-702.13, K-707.2 and K-707.11, K-711.7 and K-711.5. T-301 runs toward center tap (refer to paragraphs 4-17, 4-27).

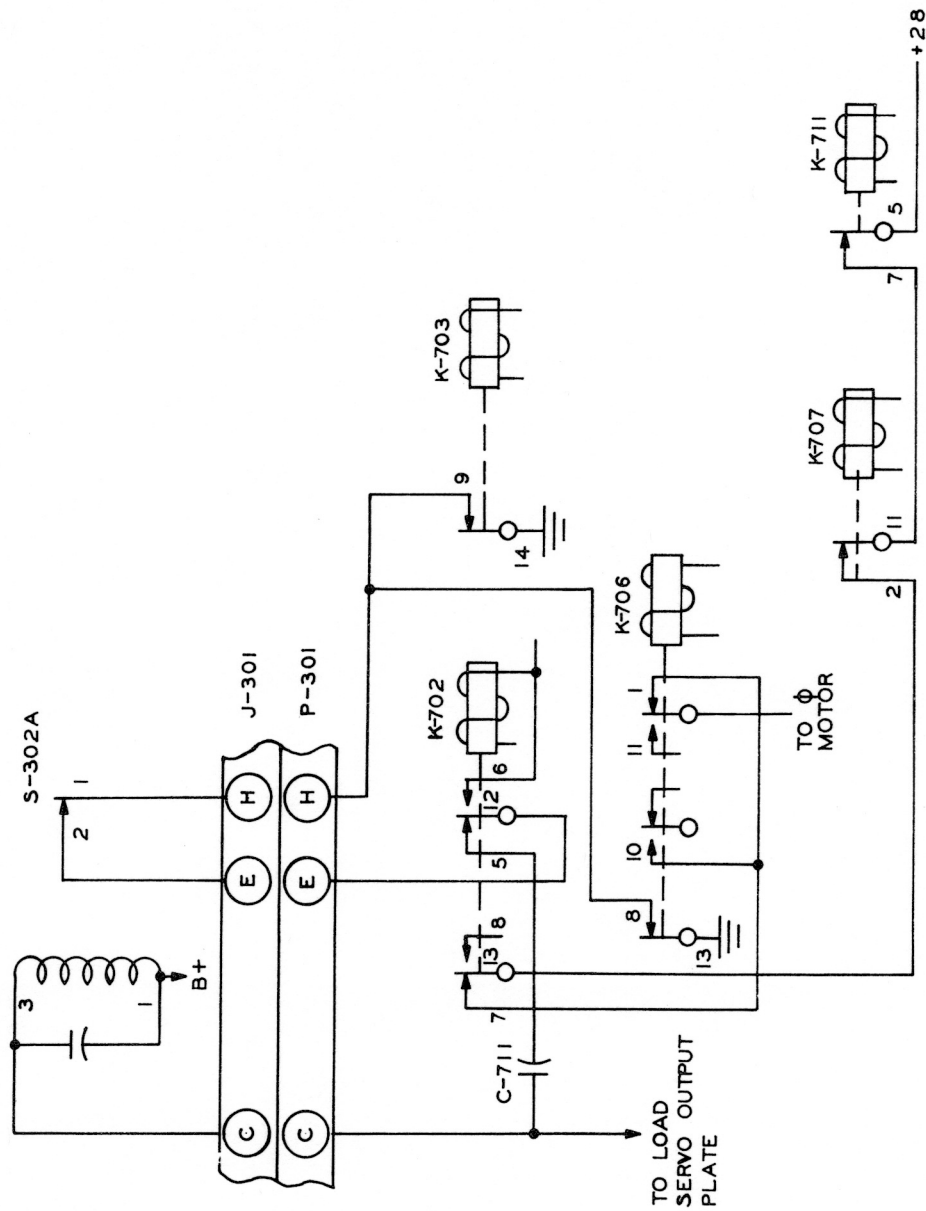


Figure 4-21. Automatic Homing Circuits, Braking Operation

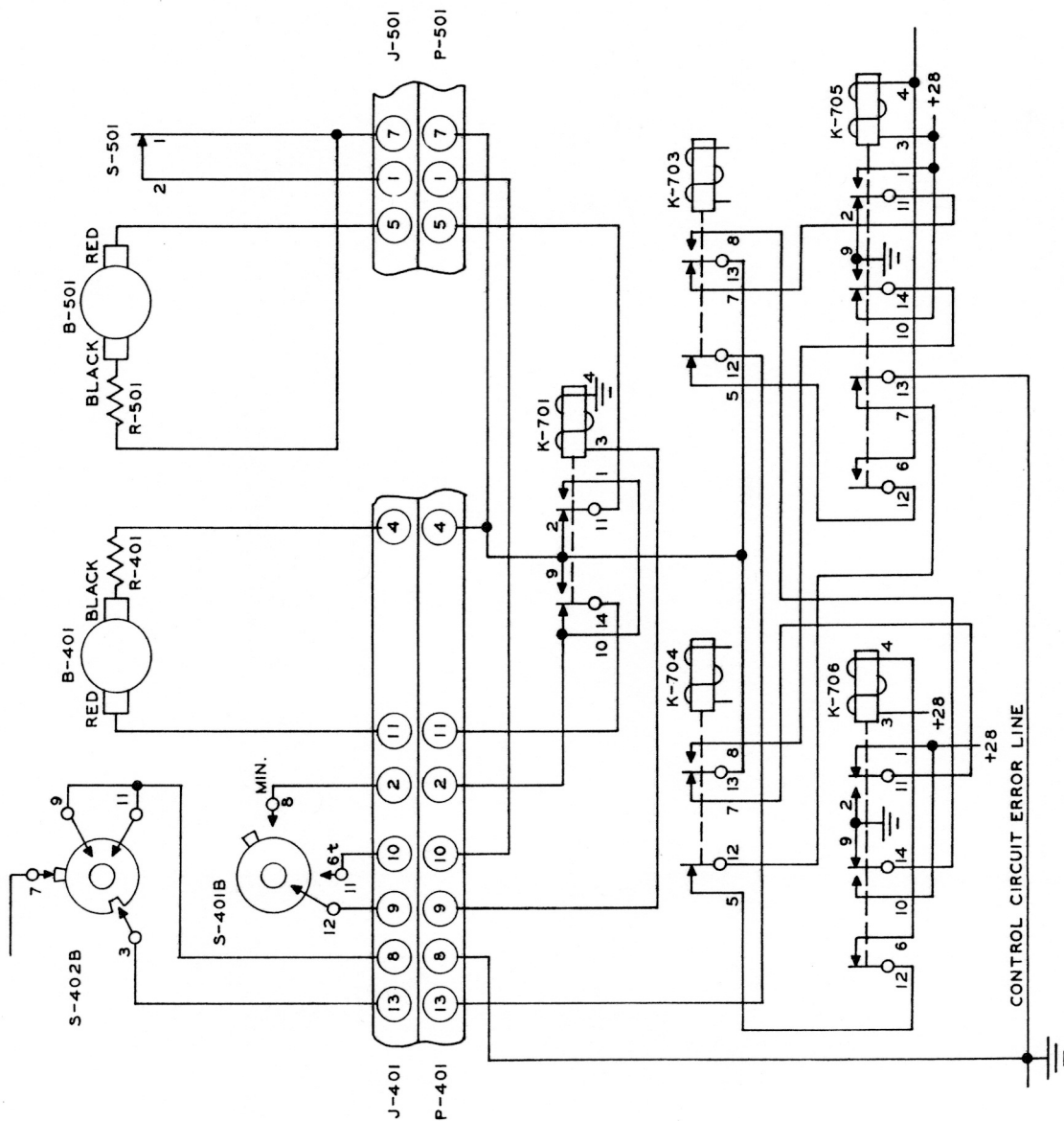


Figure 4-22. Mechanical Cycle, Operations A-B, Simplified Schematic Diagram

b. When S-302 opens as T-301 reaches center tap, the holding ground is removed on K-702. K-702 drops out, removing the +28 volts d-c from the loading servo input. Since the antenna still presents a high impedance to the discriminator, loading error runs T-301 briefly toward maximum.

c. Plus 28 volts d-c (see figure 4-21) is placed on a phasing motor by K-711.7, K-707.11 and K-707.2, K-702.13 and K-702.7, K-706.1 and K-706.11. (Refer to paragraph 4-38).

d. S-302 closes. C-711 is grounded through K-702.5 and K-702.12, S-302A, and either K-703.9 and K-703.14 or K-706.8 and K-706.13. The other terminal of C-711 is connected to the loading servo amplifier output. The capacitance to ground across the servo amplifier output causes B-301 to stop.

4-43. MECHANICAL CYCLE (CIRCUITS). The following discussion reviews the mechanical cycle and provides detailed circuit tracing. It is assumed, for the purpose of this discussion, that r-f is not present, but that a ground has been applied to the control circuit error line.

a. POSITION (a.1.), OPERATION A. (See figures 4-11, 4-22). L-401 (B-401) runs toward minimum. K-706 (MAXIMUM REVERSE) has operated, and is held because K-706.4 is grounded through K-706.6 and K-706.12, K-704.5 and K-704.12, K-705.7 and K-705.13, the latter point being on the error line. K-701 (COIL-CAPACITOR SWITCHING) does not operate because K-701.3 is open. Therefore B-401 runs toward minimum.

b. POSITION (b), OPERATION B. When L-401 (B-401) gets to minimum, K-701 operates. K-701.4 is grounded, K-701.3 is at +28 volts d-c through P-401.9, S-401B.8 and S-401B.12, P-401.9, S-401B.12 and S-401B.8, P-401.2, K-410.10, K-704.13 and K-704.7, K-706.11 and K-706.1, which causes C-501 (B-501) to run toward minimum.

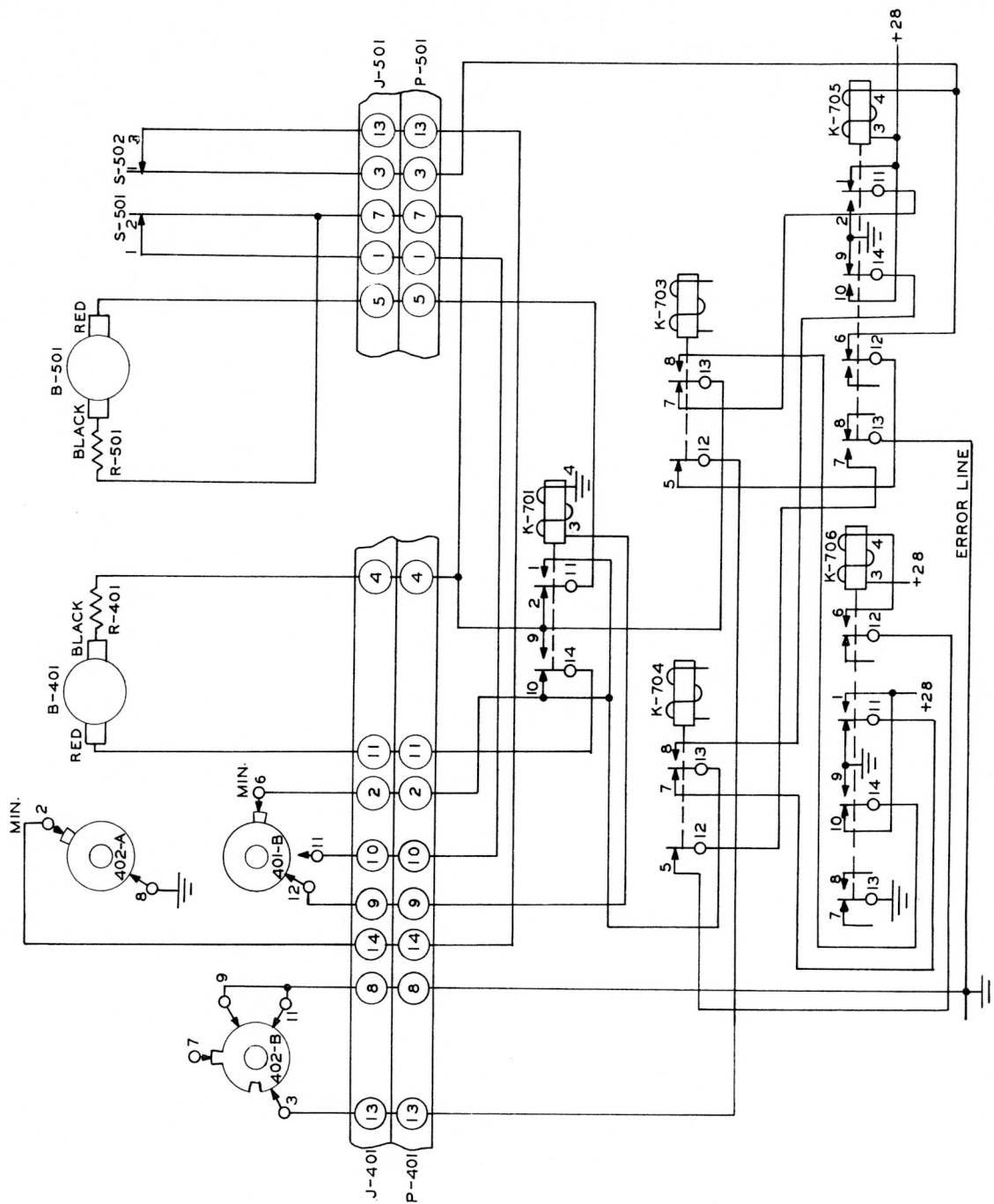


Figure 4-23. Mechanical Cycle, Operations C-D-E, Simplified Schematic Diagram



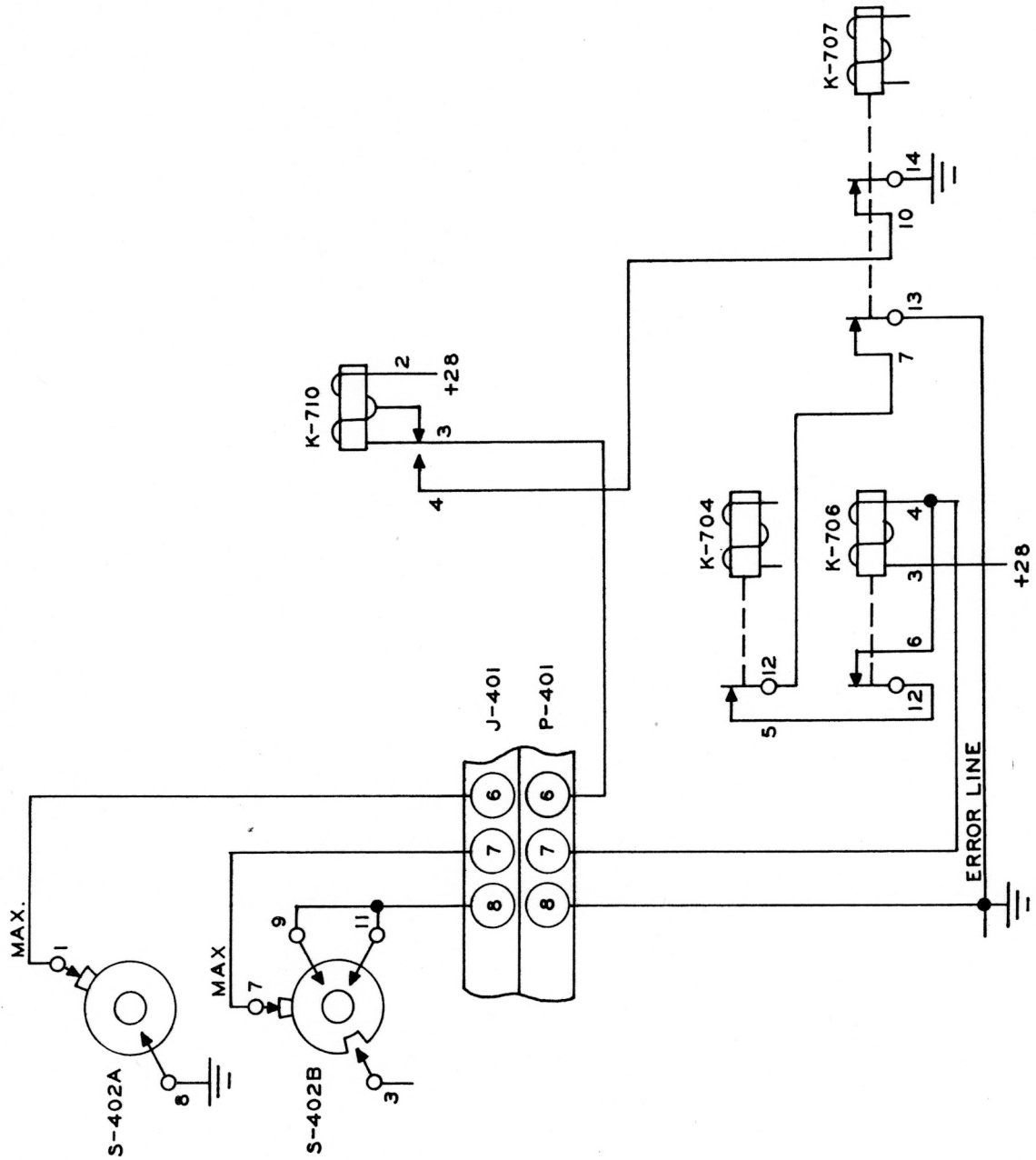


Figure 4-24. Shunt Capacitance Switching Circuit, Simplified Schematic Diagram

c. POSITION (c), OPERATION C. (See figure 4-23). With both L-401 and C-501 at minimum, K-705 (MINIMUM REVERSE) operates. K-705.3 is at +28 volts d-c. K-705.4 is grounded through P-501.3, S-502.1 and S-502.3, P-501.13, P-401.14, S-402A.3 and S-402A.9. K-705 is held because K-705.4 is grounded through K-705.6 and K-705.12, K-703.5 and K-703.12, P-401.13, S-402B.3, P-401.8 and K-709.8, the latter point being on the error line. K-701 drops out because K-701.3, through S-401B.12 and S-401B.8, K-701.10, K-704.13 and K-704.7, K-706.11 and K-706.2, is now grounded. K-706 also drops out because its holding circuit is broken at K-705.7 and K-705.13. L-401 (B-401) now runs to a position six turns from minimum (toward maximum).

d. POSITION (d), OPERATION D. When L-401 reaches six turns from minimum, K-701 operates. K-701.3 is at +28 volts d-c through P-401.9, S-401B.12 and S-401B.11, P-401.10, P-501.1, S-501.2 and S-501.1, P-501.7, K-701.2, K-703.7 and K-703.13, K-705.11 and K-705.12. Therefore, C-501 (B-501) runs toward maximum.

e. POSITION (e), OPERATION E. When C-501 reaches maximum, K-701 drops out because the +28 volt d-c circuit opens at S-501.2 and S-501.1. Therefore, L-401 (B-401) runs to maximum, and shunt capacitance is switched in at POSITION (a.2.).

4-44. ANTENNA SHUNT CAPACITANCE (CIRCUITS). (See figure 4-24). With L-401 at maximum, K-710 (SHUNT CAPACITANCE) operates to place C-101 across the antenna because K-710.2 is at +28 volts d-c and K-710.3 is grounded by S-402A.2 and S-402A.9. K-710 is held because K-710.4 is grounded through K-707.10 and K-707.14. K-706 (MAXIMUM REVERSE) operates. K-706.3 is at +28 volts d-c. K-706.4 is grounded by S-402B.7 and S 402B.9, the latter point being on the error line.

With T-301 at maximum, K-710 operates to place C-101 across the antenna because K-710.2 is at +28 volts d-c and K-710.3 is grounded through P-301.A, S-302B.3 and S-302B.4. K-710 is held in the same fashion as described above, when shunt capacitance is brought into the circuit by L-401 reaching maximum.

4-45. INTERRUPTION OF MECHANICAL CYCLE (CIRCUITS). It has been established that the mechanical cycle, if it is within OPERATIONS A and B, will continue until inductive error is apparent to the phasing discriminator and K-704 (INDUCTIVE ERROR) operates (Refer to paragraph 4-33). When K-704 operates, K-706 (MAXIMUM REVERSE) drops out because its holding circuit is broken at K-704.5 and K-704.12. If the mechanical cycle is in operations C, D or E, it will continue until K-703 (CAPACITIVE ERROR) operates. When K-703 operates, K-705 (MINIMUM REVERSE) drops out because its holding circuit is broken at K-703.5 and K-703.12.

4-46. UNKEYING TRANSMITTER (CIRCUITS). (See figure 4-25). When r-f error has been reduced to zero, all grounds are removed from the control circuit error line, including K-704.1 and K-704.11, K-703.1 and K-703.11, and K-709. Thus, the holding circuit of K-708 (AUTO KEYING), through K-708.9 and K-708.14, K-708.7 and K-708.13 is broken, and transmitter keying stops.

4-47. TIME DELAY CIRCUIT. Time Delay Relay K-711 (see figure 7-2) is operated from a ground on the control circuit error line. It is grounded only when K-708 (AUTO KEYING) has operated and is held. If the phasing system fails to reach a tuning point within 30 seconds after the start of the tuning cycle, K-711 operates thermally to open K-711.7 and K-711.5 and remove the +28 volt d-c connection from B-401 and B-501, from the reversing relays, K-705 and K-706, and from the transmitter keying control circuit at J-102.12. K-711 receives +28 volt d-c supply from J-102.11 at K-711.3. In some cases, depending upon the type of associated transmitter, it may be necessary to interconnect J-102.11 and J-102.13. Terminal J-102.11 should have +28 volts when the transmitter keying circuit requires that input, and J-102.13 should have +28 volts when transmitter filaments are turned on.

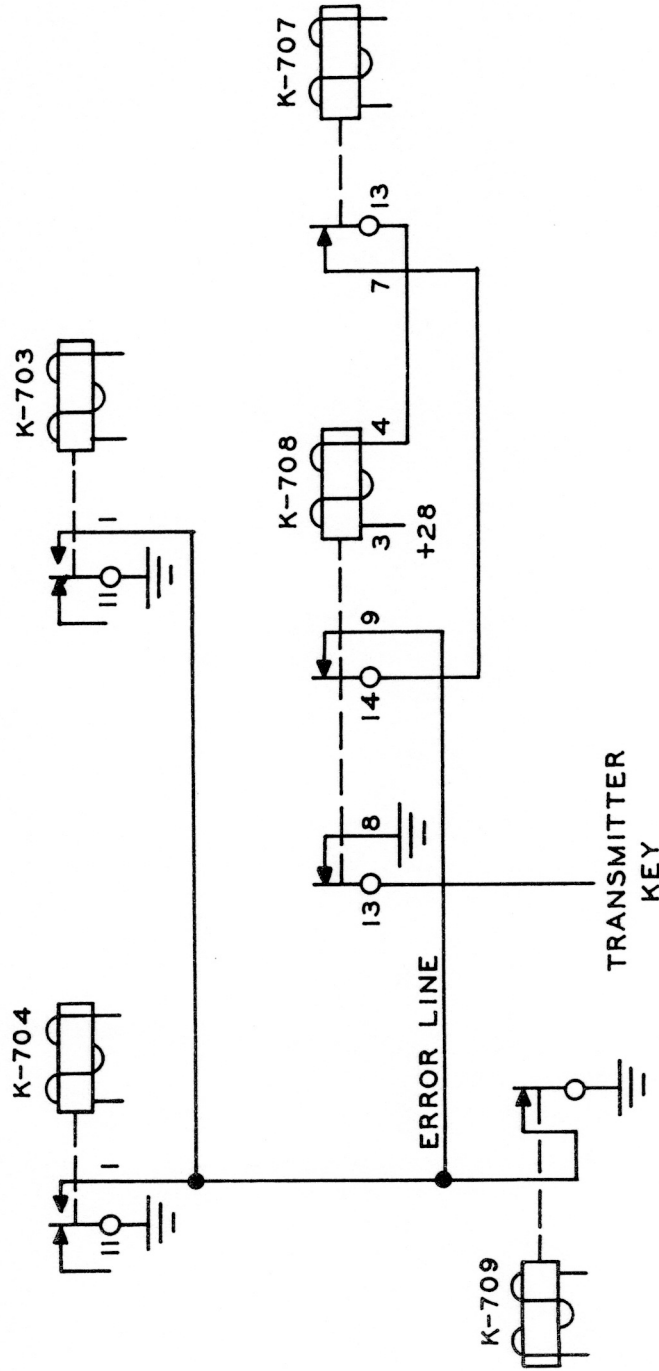


Figure 4-25. Unkeying Transmitter, Simplified Schematic Diagram

TABLE 4-1

## RELAY AND SWITCH FUNCTIONS

Terminal	COIL - CAPACITOR - MOTORS RELAY K-701	Terminal	HOMING RELAY K-702
1	Ground, motors going to maximum or not running; +28, motors going to minimum	1	Operates K-705 with error ground when homing
2	Ground, motors going to minimum or not running; +28, motors going to maximum	2	Not used
3	K-701 operation	3	K-702, +28 line
4	K-701 ground	4	K-702 operation
5	B-401 limit switch (S-401A) ground	5	T-301 (B-301)
6	Not used	6	K-702 holding
7	B-401 minimum limit switch	7	+28 to motors and K-705 except when homing or retuning
8	B-501 minimum limit switch	8	+28 to servo for homing transformer
9	Same as 2	9	Phasing unbalance for unkeying
10	Same as 1	10	Not used
11	B-501, +28 to minimum, ground to maximum	11	Error line
12	Normal ground for 5	12	K-702 holding or B-301 braking when S-302A is closed
13	B-401 or B-501 minimum limit	13	+28 except when retuning
14	B-401, +28 to minimum, ground to maximum	14	Ground for 9



Terminal	CAPACITIVE ERROR (To Maximum) K-703	Terminal	INDUCTIVE ERROR (To Minimum) K-704
1	Error line	1	Error line
2	Not used	2	Not used
3	+28 line	3	+28 except when retune operates
4	Operated by servo switch S-601	4	Operated by servo switch S-601
5	K-705 holding circuit	5	K-706 holding circuit
6	Not used	6	Gets ground from error line through K-705 for T-301 brake or K-702 holding
7	Motor lead normally ground +28 when K-705 operates	7	Motor lead normally ground; +28 when K-706 operates
8	Motor lead normally +28, ground when K-706 operates	8	Motor lead normally +28; ground when K-705 operates
9	Ground for T-301 brake or K-702 holding circuit	9	Not used
10	Not used	10	Not used
11	Ground for error line	11	Ground for error line
12	K-705 holding circuit	12	K-706 holding circuit and ground for pin 6
13	B-401 and B-501 common lead, +28 to maximum, ground to minimum	13	B-401 or B-501 motor lead, +28 to minimum, ground to maximum
14	Ground for 9	14	See K-704.9

Terminal	MINIMUM REVERSE K-705	Terminal	MAXIMUM REVERSE K-706
1	+28 except when homing or retuning	1	+28 except when homing or retuning
2	Ground through B-401 or B-501 minimum limit switches	2	Ground through B-401 and B-501 maximum limit switches
3	Same as 1	3	+28 from time delay relay K-711
4	K-705 operation	4	K-706 operation
5	Not used	5	Not used
6	K-705 holding circuit	6	K-706 holding circuit
7	K-706 holding circuit	7	K-707 holding circuit
8	Ground from error line for T-301 brake or K-702 hold	8	Ground for T-301 brake or K-702 hold
9	Ground through B-401 and B-501 maximum limit switches	9	Ground through B-401 or B-501 minimum limit switch
10	Same as 1	10	Same as 1
11	Same as K-703.7	11	Same as K-704.7
12	K-705 holding circuit	12	K-706 holding
13	Error line	13	Ground for 7 or 8
14	Same as K-704.8	14	Same as K-703.8

Terminal	RETUNE K-707	Terminal	AUTO KEYING K-708
1	Not used	1	External tuning indication
2	Supplies +28 to K-704.3 and K-702.13 (goes to motors)	2	External tuning indication
3	+28 line	3	+28 line
4	K-707 operation	4	Operate and hold
5	Not used	5	See K-704.9
6	K-707 hold	6	Not used
7	K-708 hold with error	7	Not used
8	K-708 operation with ground or error as desired, but only if K-707 has operated and held	8	Ground for 13 and K-707.8 if used
9	K-702 operation	9	Error line
10	K-710 hold	10	Not used
11	+28 from K-711 time delay relay	11	External tuning indication
12	K-707 hold	12	See K-704.9
13	K-708 operation and hold	13	Transmitter keying line
14	Ground for 9 and 10	14	K-708 holding circuit

Terminal	LOADING ERROR K-709	Terminal	TIME DELAY K-711
3	Servo, V-603A plate	2	Operation from error line
4	To B+	3	+28 line
8	Error line	5	+28 line
9	Ground for error line	7	Supplies +28 to J-102.12, K-707.11, and K-706.3
	SHUNT CAPACITANCE K-710		
1	Not used		
2	+28 line		
3	Operate		
4	Hold		
5	Not used		

Terminal		Terminal	
	S-301		S-402A
	Grounded past maximum on T-301, operates K-702	2	Operates K-710 at maximum inductance
	S-302A	3	Operates K-705 at minimum inductance and minimum capacitance
	Closes at T-301 center tap, stays closed to maximum. Closes circuit for braking T-301 or holding K-702	9	Ground
	S-302B		S-402B
	Grounded at maximum T-301 to operate K-710	4	Holding circuit for K-705
	S-401A	8	Operates K-706 at maximum inductance
1	B-401 maximum limit	10-12	Error line
2	B-401 minimum limit		S-501
6	Ground for limit switches	1-3	Operates K-705 at minimum capacitance and minimum inductance
	S-401B	4-5	B-501 minimum limit
8	+28 when motors to minimum, ground when motors to maximum		S-502
11	+28 when motors to maximum, ground when motors to minimum	1-2	B-501 maximum limit
12	+28 to K-701.3 to operate	3-4	Opens K-701 when capacitance at maximum

SECTION V

ORGANIZATIONAL AND SQUADRON MAINTENANCE

5-1. GENERAL.

5-2. Operation of Automatic Antenna Tuner 180L-2 is entirely automatic. There are no controls that require adjustment. Information on operation of the associated transmitter should be obtained from the instruction book or handbook of operating instructions supplied with that equipment. Pre-flight and post-flight tests of radio sets including the Antenna Tuner as a component, described in following text, will normally be carried out by operational personnel.

5-3. TUNING CYCLE.

5-4. When a new channel or operating frequency is selected by the operator, using the radio set control component, and the transmitter is keyed, emitting either a continuous wave or voice carrier signal, the Antenna Tuner will begin its tuning cycle. Keying of the transmitter may be either fully automatic, as a function of channel selection, or manually-started (refer to paragraph 3-16). The phasing and loading operations which are included in the tuning cycle will be completed in 15 seconds or less after the transmitter is keyed.

NOTE

If operating conditions or tactical restrictions make radio silence desirable or necessary prior to actual communications, when using Antenna Tuner 180L-2 as modified for "radio silence" operation, do not close the microphone push-to-talk button immediately after selecting a new channel. When communication is desired or permissible, close the push-to-talk button for a brief interval to start the tuning cycle.



CAUTION

Under the above operating conditions, do not speak into the microphone until the tuning cycle is complete, when making the first transmission after a channel change. If a remote tuneup indicator is in use, wait until completion of the tuning cycle is indicated. If such an indicator is not in use, operate the microphone push-to-talk button briefly as described above; wait approximately 15 seconds, then close the push-to-talk button and speak. Subsequent transmissions on the same channel may be made without waiting.

5-5. INDICATIONS, MINIMUM PERFORMANCE STANDARDS.

5-6. TRANSMITTER. Power amplifier plate current indications should be normal for the transmitter in use at all appropriate frequencies. Obtain information on transmitter indications from the instruction book or handbooks of operation and service instructions for the equipment concerned. Current indications for Receiver-Transmitters 18S-4 and 618S-1 are provided by similar multiple-use panel meters; correct indications are those within a red-marked area of the meter scale for both equipments.

5-7. ANTENNA TUNER. The SWR (Standing Wave Ratio) Indicator on the panel of Antenna Tuner 180L-2 will give varying indications during the tuning cycle, but should come to rest at an indication of 2 units or less on its arbitrary scale. Should any tuning cycle continue for 30 seconds, without correct tuning conditions being obtained, Relay K-711 (TIME DELAY) will operate thermally, preventing further operation of the Antenna Tuner. Wait for at least 30 seconds before attempting to start a new tuning cycle by re-channeling or keying the transmitter. Check the antenna system for faults.

5-8. PRE-FLIGHT INSPECTION.

5-9. Make a thorough visual inspection of Antenna Tuner 180L-2 prior to use

in air operations. Careful observance of these procedures will reduce the chance of equipment failure in service, since any abnormal condition may be quickly reported to maintenance personnel if correction of the fault is beyond the scope of the operator.

a. Antenna terminal connections must be securely in place. The antenna and feed-through insulator or mast must be clear of obstructions.

b. Mounting 350D-3 must be securely fastened and grounded to the airframe. Clamps and safety wiring must be secure.

c. Cable connectors must be securely in place. Tighten locking rings by hand if necessary. Inspect cables for broken wires or loose connections at terminals.

#### 5-10. PRE-FLIGHT TEST.

5-11. The pre-flight test will make certain that the equipment is operating properly. The aircraft should be located outside the hangar, and tests should be conducted with engines running or auxiliary power connected. The procedure does not require use of test equipment other than the plate current indicators of associated transmitters and the panel meter of the Antenna Tuner.

a. Turn primary power and 115 volt, 400 cps circuit breakers "ON". Allow time for equipment to warm up.

b. Set the function selector switch of the radio set control for voice or continuous wave transmission. Operate the channel selector to appropriate frequencies. If necessary, key the transmitter to produce r-f current in the antenna circuit. Make certain that the tuning cycle is complete after each channel change.

c. Observe power amplifier plate current indications for each appropriate frequency. Make certain that indications are normal for the transmitter in use.

d. Observe SWR indications on the panel meter of the Antenna Tuner for each appropriate frequency. The indication should be 2 units or less for all cases.

e. If the Antenna Tuner apparently fails to function properly, remove it from Mounting 350D-3 by cutting safety wires and freeing the knurled fasteners on the clamps below the front panel. Tag the unit for transfer to maintenance or overhaul personnel and replace it with one known to be fully operative.

5-12. POST-FLIGHT INSPECTION, TEST.

5-13. It is recommended that procedures of the pre-flight inspection and test be repeated after air operations are complete.

5-14. LUBRICATION.

5-15. Lubrication of Antenna Tuner 180L-2 will normally be accomplished at major inspection periods, and performed by maintenance personnel.

5-16. INSPECTION SCHEDULE.

TABLE 5-1

INSPECTION SCHEDULE

Antenna Tuner Element, Function	Inspection Performed	Time	Paragraph
Installed Equipment (External)	Antenna, terminal connections; Mounting 350D-3, clamps, safety wiring, cables and connectors securely in place, unbroken.	Before and after each flight.	5-8, 5-12
Tuning Cycle	Operate equipment; observe power amplifier plate current and SWR indications for each appropriate frequency, obtaining normal indications.	Before and after each flight.	5-10
Servo Amplifier	Connections, resistors, switch contacts, operation of Chopper G-601.	50 hours	6-8

Antenna Tuner Element, Function	Inspection Performed	Time	Paragraph
Variable Inductor	Rotation of coil, switch contacts, r-f contacts, connections and hardware.	50 hours	6-9
	Lubrication.	100-150 hours	6-9g.
Series Capacitor	Switch contacts, connections and hardware.	50 hours	6-10
	Lubrication	100-150 hours	6-10e.
R-F Autotransformer	Switch contacts, connections and hardware.	50 hours	6-11
	Lubrication	100-150 hours	6-11e.
Discriminators	Connections, resistors.	50 hours	5-12
	Forward, reverse resistance of germanium diodes.	100-150 hours Annual Overhaul	6-12d.
Control Circuit	Functional.	100-150 hours	6-20
Operation Test	Functional.	100-150 hours	6-23
Mechanical Adjustment, Alignment	Functional.	Annual Overhaul	--

SECTION VI

FIELD (ARMAMENT ELECTRONICS SQUADRON) AND FASRON MAINTENANCE

6-1. GENERAL.

6-2. Periodic (50 hour) and major (100-150 hour) inspections of Automatic Antenna Tuner 180L-2 require removal of the equipment from the aircraft to a test bench, for internal visual inspection and operational checks by maintenance personnel.

6-3. TEST EQUIPMENT REQUIRED.

6-4. Test equipment described in Section II and Table 3-1 should be provided as needed for periodic and major inspections. Major inspection procedure is an extension of the periodic inspection plan, following the same basic outline. Indication of additional steps that will normally be completed at major inspection is given at appropriate points in the following text.

6-5. PROCEDURE.

6-6. EQUIPMENT REMOVAL. Remove Antenna Tuner 180L-2 from Mounting 350D-3 by cutting safety wires and freeing the knurled fasteners on the clamps below the front panel. Remove the case by taking out six machine screws, located along the lower edges of the sides. Remove the front panel by taking out five machine screws and loosening the set screw which holds the r-f output bus in the rear of the ANT terminal (E-102). Note that one of the panel attaching screws is short, so that it will not damage the SWR Indicator case.

6-7. Connect the Antenna Tuner to a 115 volt, 400 cps power source, the high side input at J-102.8 and the low side at J-102.12. The Antenna Tuner



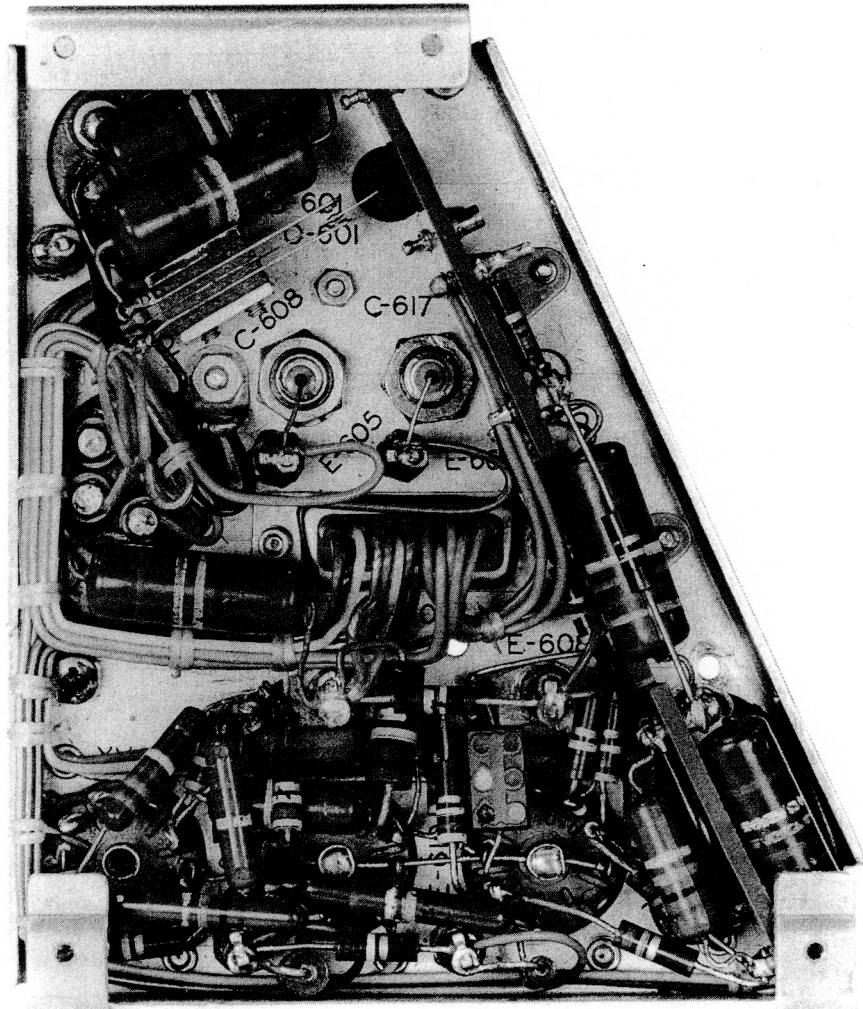


Figure 6-1. Servo Amplifier, Top View, Cover Removed



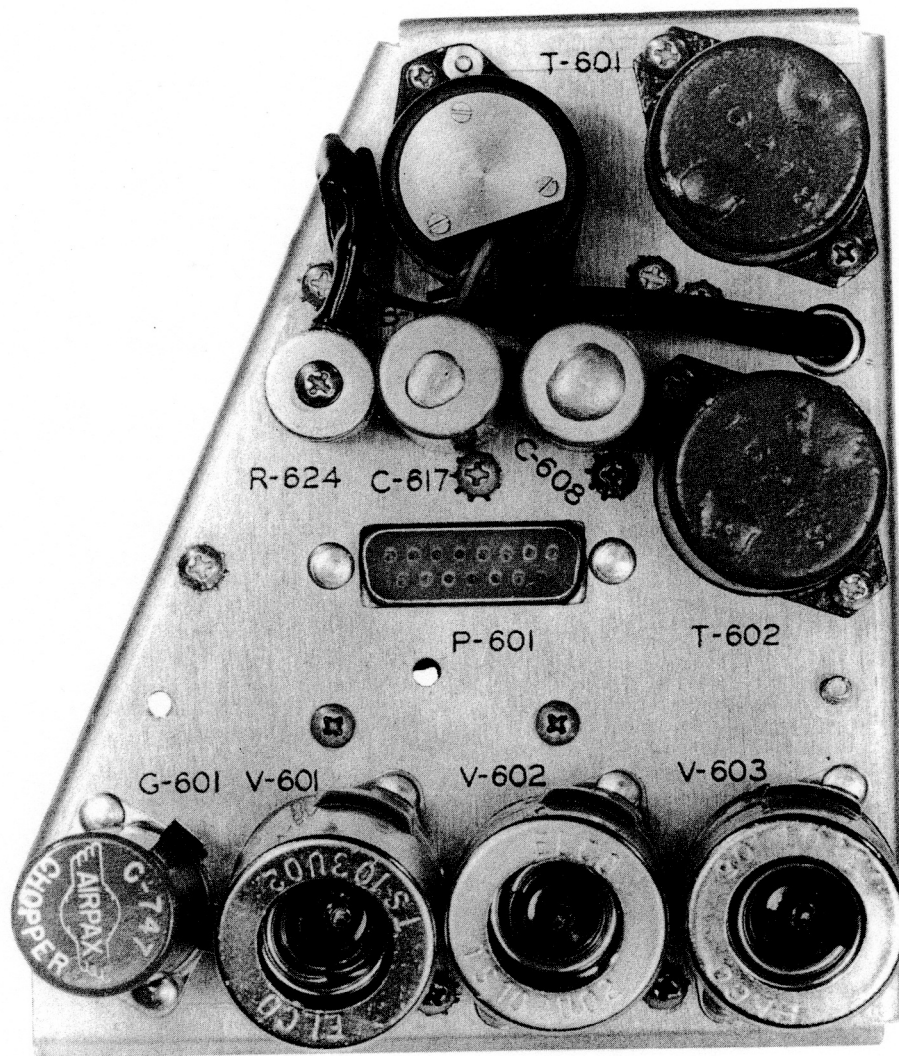


Figure 6-2. Servo Amplifier, Bottom View

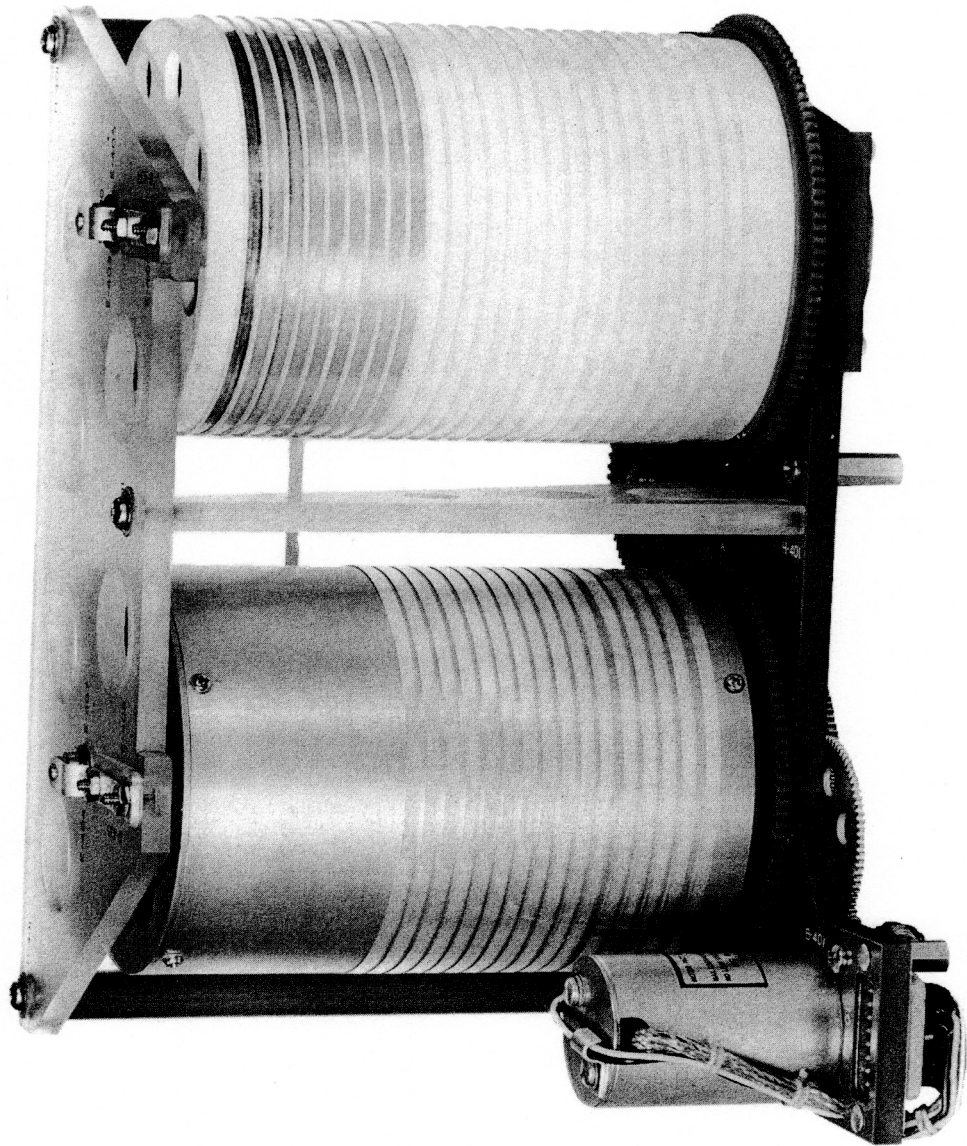


Figure 6-3. Variable Inductor, Front View

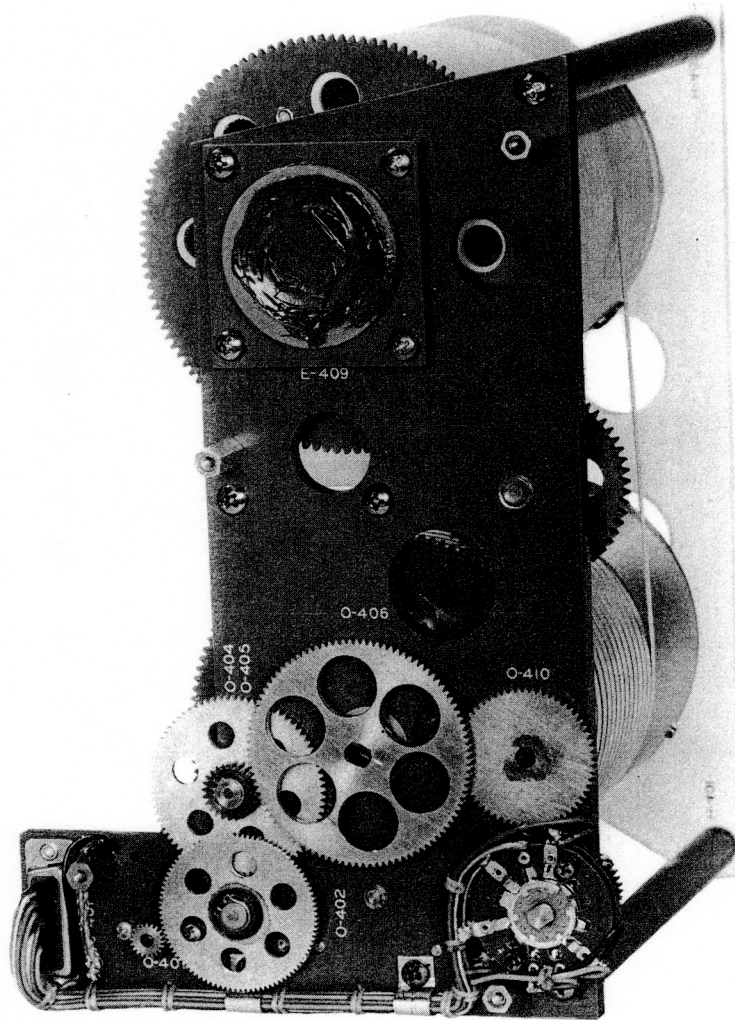


Figure 6-4. Variable Inductor, Bottom View

need not be connected to primary power, an antenna load or a transmitter during the initial steps of periodic inspection procedure.

6-8. SERVO AMPLIFIER. a. Loosen two captive screws through holes in the cover plate (see figures 6-1 and 6-2) and remove two flat head screws from the front panel mounting frame.

b. Lift rear of servo amplifier chassis to disconnect P-601 and J-601. Slide chassis to rear and lift to remove from mounting frame. Take out four screws and remove cover.

c. Inspect connections. Inspect resistors for any evidence of undue heating.

d. Inspect S-601 contacts for deterioration. Replace switch assembly if necessary.

e. Connect patch cord between P-601 and J-601 (or replace the servo amplifier assembly in the mounting frame). Turn 115 volt, 400 cps power supply "ON". Test operation of Chopper G-601 by measuring resistance between points G-601.1 and .7, and between G-601.6 and .7. The values obtained should match within 10 per cent. Replace chopper if such indication is not obtained. Turn power supply "OFF".

f. (MAJOR) Remove, test tubes. Replace defective tubes.

6-9. VARIABLE INDUCTOR. a. Free P-401 from J-401, which is located just ahead of Motor B-401 on the inductor assembly frame.

b. Remove screws holding r-f line at E-406 and E-408 (see figures 6-3 and 6-4). Remove four screws holding the variable inductor assembly to the bottom of the mounting frame, as indicated by the outline marking on the bottom. Remove the assembly from the frame.



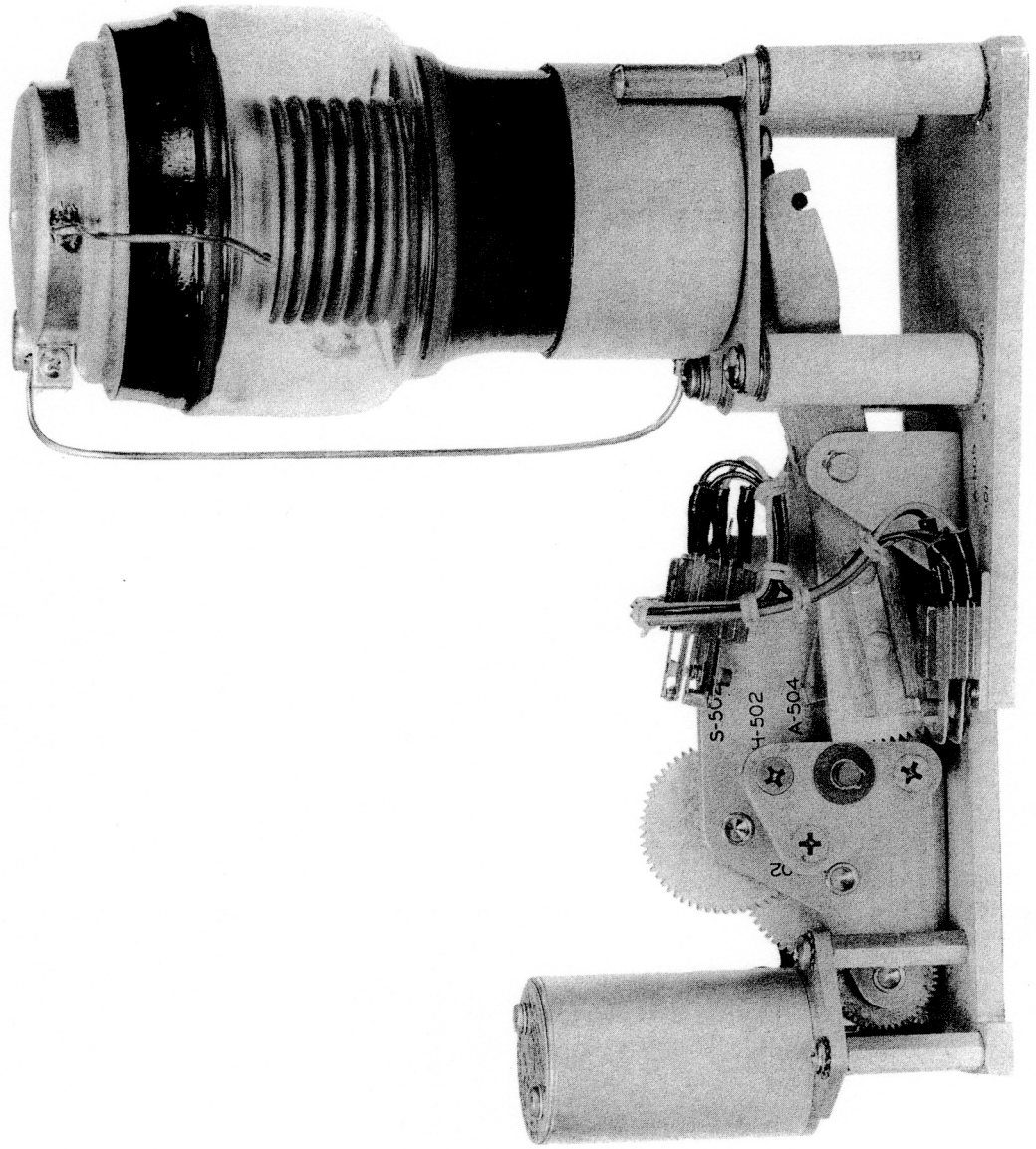


Figure 6-5. Variable Capacitor, Side (Front) View

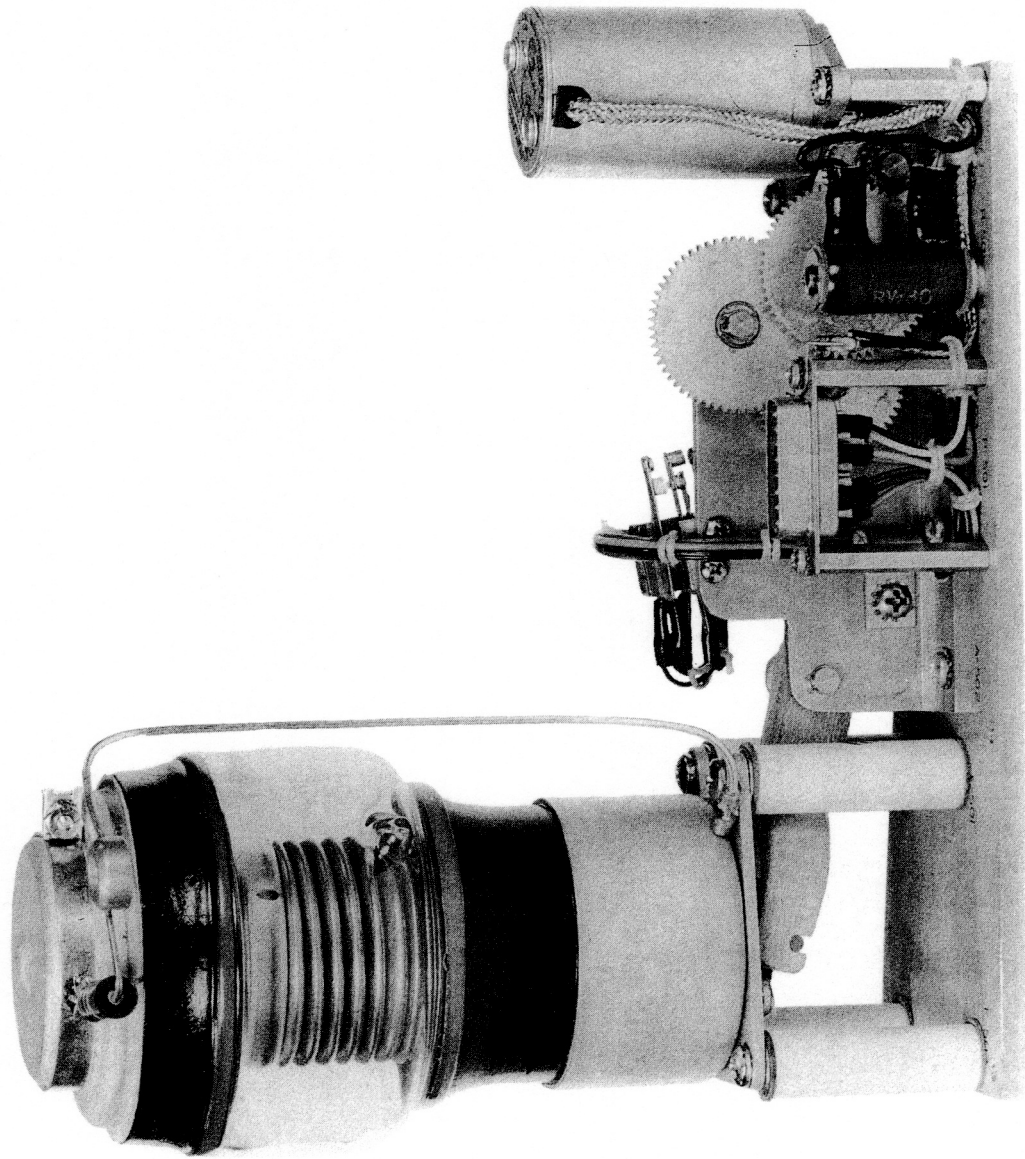


Figure 6-6. Variable Capacitor, Side (Rear) View



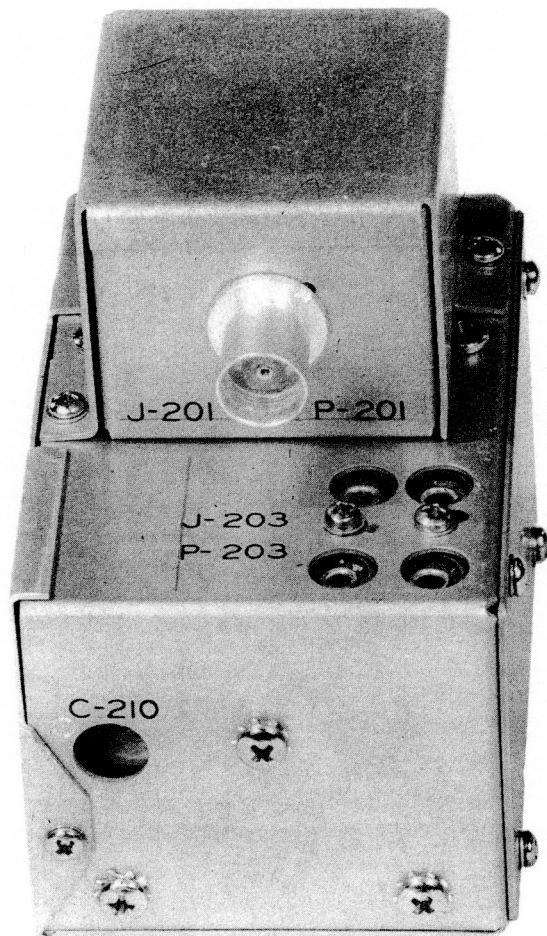


Figure 6-7. Discriminator, Top View

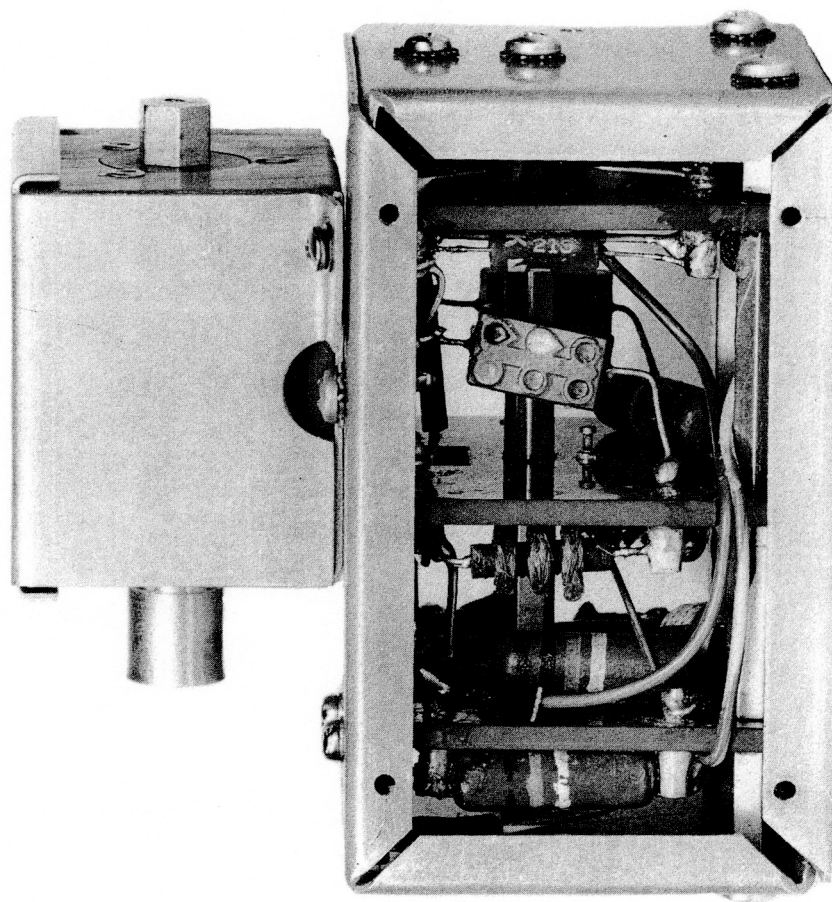


Figure 6-8. Discriminator, Side View, Covers Removed

c. Rotate coil drums by hand to see that the silver ribbon rolls easily from one drum to another, without binding.

d. Inspect wafer switches (S-401 and S-402) for deterioration of blades or contacts. Replace if necessary.

e. Inspect r-f contacts for deterioration. Burnish if necessary.

f. Inspect for loose connections and hardware.

g. (MAJOR) Lubricate gears, shafts and bearings according to the lubrication chart (Table 6-4).

6-10. SERIES VARIABLE CAPACITOR. a. Disconnect P-501 from J-501 and remove the r-f line from the top of the capacitor assembly, by loosening the machine screw in the connector clamp (see figures 6-5 and 6-6).

b. Remove six screws holding the assembly to the bottom of the mounting frame, as indicated by the outline marking.

c. Inspect switch contacts (S-501 and S-502) for deterioration. Replace if necessary.

d. Inspect for loose connections and hardware.

e. (MAJOR) Lubricate gears, shafts and bearings according to the lubrication chart.

6-11. DISCRIMINATOR. a. Disconnect P-201 from J-201 and P-203 from J-203. (See figure 6-7). Detach r-f line at the rear of T-201 by loosening the set screw which holds it.

b. Remove four screws holding the discriminator to the mounting frame and remove the assembly from the frame. Remove six screws and take off two side covers (see figure 6-8).

c. Inspect resistors for any evidence of undue heating. Inspect connections.

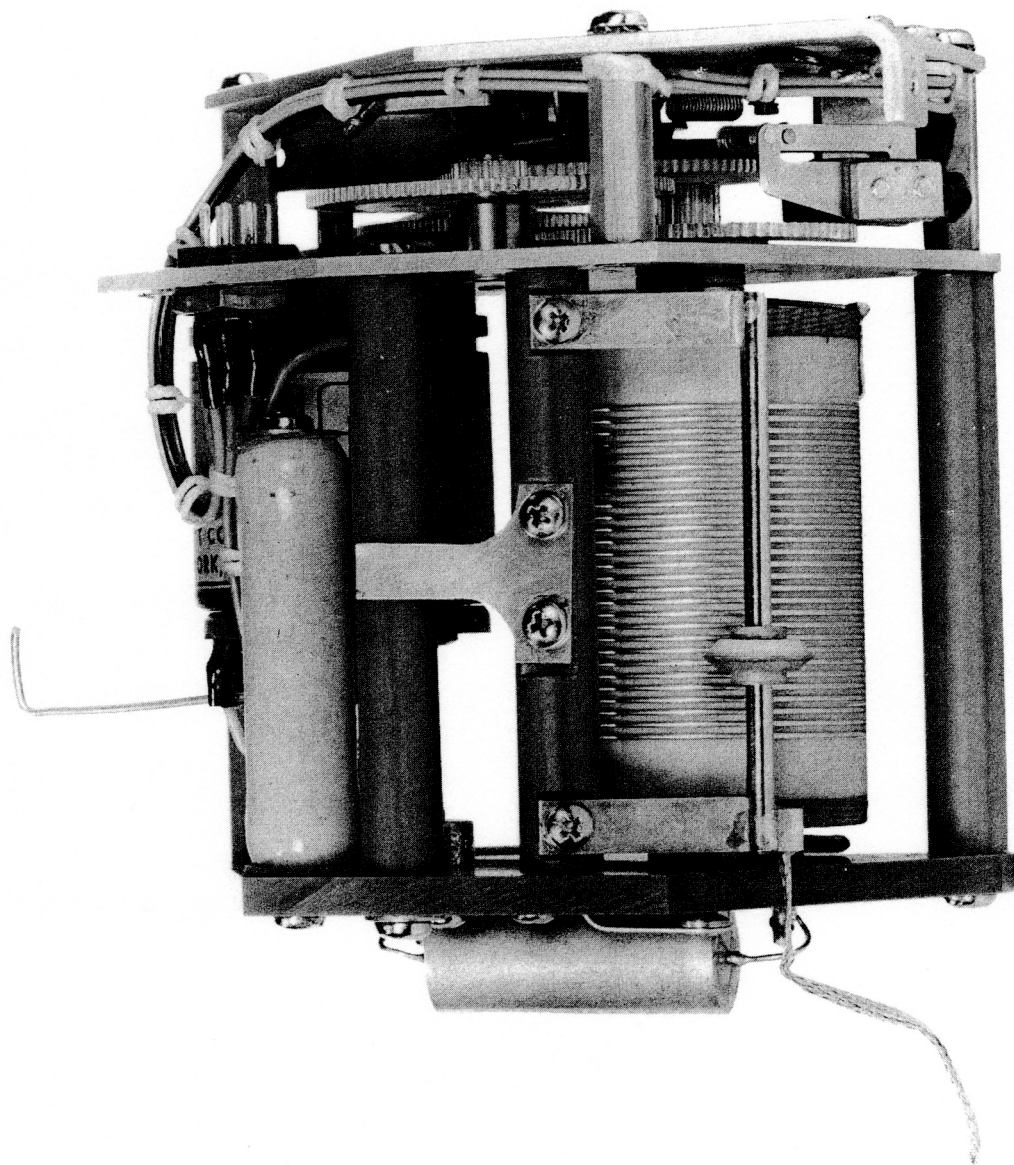


Figure 6-9. R-F Autotransformer, Side View

NOTE

The following test procedure need be carried out ONLY when evidence exists that there is a fault in the discriminator. If the antenna should apparently be tuned, with the equipment installed in an aircraft, but a high indication is noted on the SWR Indicator (above 2 units on the meter scale), perform the following check.

d. (MAJOR, OVERHAUL). Measure forward and reverse resistance of germanium diodes, CR-201, CR-202, CR-203 and CR-204. Unsolder one lead of each crystal, holding the leads with pliers between staked solder lugs and crystals, and measure resistance with a vacuum tube volt-ohmmeter, or remove crystals and test with a crystal rectifier test set. Forward resistance of the crystal diodes should be less than 500 ohms. Reverse resistance should be 1 megohm or higher. Replace crystal diodes if such indications are not obtained.

6-12. R-F AUTOTRANSFORMER. a. Disconnect P-301 from J-301.

b. Remove six screws holding the r-f autotransformer assembly to the mounting frame and remove the assembly from the frame (see figure 6-9).

c. Inspect switch contacts (S-301 and S-302) for deterioration. Replace if necessary.

d. Inspect for loose connections and hardware.

e. (MAJOR) Lubricate gears, shafts and bearings according to the lubrication chart.

6-13. REPLACEMENT OF SUB-ASSEMBLIES.

6-14. The sub-assemblies removed during the foregoing inspection procedure should be replaced by reversing the removal steps.



- 6-15. DISCRIMINATOR. Replace covers, returning six screws. Return discriminator to mounting frame, replacing four screws. Re-connect P-201 and P-203 in respective jacks, and re-connect the r-f line at rear of T-601, tightening the set screw.
- 6-16. R-F AUTOTRANSFORMER. Return the r-f autotransformer to the mounting frame, replacing three screws at side and one at top. Re-connect P-301 and J-301.
- 6-17. SERIES VARIABLE CAPACITOR. Return capacitor assembly to mounting frame, replacing six screws. Return r-f line to top of capacitor, tightening machine screw in connector clamp. Re-connect P-501 and J-501.
- 6-18. VARIABLE INDUCTOR. Return variable inductor assembly to mounting frame. Replace four screws. Replace screws holding r-f line at E-408 and E-406. Re-connect P-401 and J-401.
- 6-19. SERVO AMPLIFIER. Replace cover, returning four screws. Insert amplifier chassis from rear, under top strip of panel mounting frame and press downward to re-connect P-601 and J-601. Replace two flat head screws in panel mounting frame and tighten two captive screws through holes in amplifier cover.
- 6-20. CONTROL CIRCUIT TEST (MAJOR, OVERHAUL).
- 6-21. With all sub-assemblies replaced, connect Antenna Tuner 180L-2 to a fully-operative transmitter of appropriate type, to primary power and 115 volt, 400 cps sources. Do not connect the r-f transmission line from the transmitter to J-101. Provide a 52-ohm antenna load directly to the transmitter output. Short-circuit P-102.11 and P-102.12 of the Antenna Tuner, so that Relay K-711(TIME DELAY), will not operate during the control circuit test.



6-22. PROCEDURE. a. Apply primary power, 400 volt plate supply, and 115 volt, 400 cps supply to the Antenna Tuner. Allow time for equipment to warm up.

b. To position the series elements to the correct starting point, connect a 1.5 volt battery from P-203.2 to ground, positive to ground, and key the transmitter. The variable inductor should run until about half the silver ribbon is wound on each drum. Remove the battery connection and unkey the transmitter. The variable inductor should stop. The variable capacitor should be at maximum with the movable internal element near the top plate.

c. Key the transmitter manually, and hold it keyed during each of the following steps, sub-paragraphs d. through h.

d. Connect the 1.5 volt battery from P-203.2 to ground, negative to ground. Variable Inductor L-401 (Motor B-401) should run toward minimum. That is, the larger portion of the silver ribbon should wind off the ceramic coil drum, onto the aluminum short-circuiting drum.

e. When the variable inductor reaches a point less than one turn from minimum, it should stop. Series Variable Capacitor C-501 (Motor B-501) should start toward minimum. That is, the movable internal element should be drawn away from the top plate of the capacitor by the motor-driven yoke.

f. When the capacitor reaches minimum, it should stop. The variable inductor should start toward maximum; the silver ribbon should re-wind on the ceramic coil drum. At about six turns of re-wind, the inductor should stop and the series capacitor should start toward maximum, the internal element moving toward the top plate.

g. When the series capacitor reaches maximum, it should stop. The variable inductor should resume its progress toward maximum.

h. When the variable inductor reaches maximum, Relay K-710 (SHUNT CAPACITOR SWITCHING) should switch in Antenna Shunt Capacitor C-101. The variable inductor should reverse and start toward minimum. When the inductor has run about halfway toward minimum, remove the battery connection and unkey the transmitter. L-401 should stop.

i. Manually position R-F Autotransformer T-301 until its pickup roller is about four turns from the "top" of its coil. That is, about four turns from the end of the coil farthest from the front panel.

j. Operate the channel selector of the radio set control. Relay K-710 should drop out, switching C-101 out of the antenna circuit.

k. Connect the 1.5 volt battery to P-203.2, positive to ground. T-301 (Motor B-301) should run toward center tap and stop.

l. When T-301 has arrived at center tap, the variable inductor should again start toward minimum, and repeat the cycle of operation described in sub-paragraphs d. through g., above. Remove the battery connection when the inductor has passed the six-turn point and is moving toward maximum. L-401 should stop.

m. Connect the 1.5 volt battery between P-203.1 and ground, negative to ground. Key and hold transmitter keying manually. R-F Autotransformer T-301 should run toward minimum and stop.

n. Reverse the battery connection; key and hold transmitter keying manually. T-301 should run toward maximum. At maximum, K-710 should operate to switch in C-101; at almost the same time, T-301 should reverse and run toward minimum.

o. When T-301 has returned to center tap, L-401 should start toward minimum. T-301 should stop at center tap. Remove the battery connection and unkey the transmitter. L-401 should stop.

6-23. TROUBLE ANALYSIS.

6-24. Failure of Antenna Tuner 180L-2 to function properly, either when installed in an aircraft or when undergoing a bench test, should be checked against the list of general cases and symptoms which follows. Repair or replace the possible faulty component indicated, as a primary step in restoring the Antenna Tuner to fully operative condition.

TABLE 6-1

TROUBLE-SHOOTING CHART

A. GENERAL FAULT: COMPLETE OPERATING FAILURE. MOVING ELEMENTS NEVER START		
Secondary Symptom	Possible Fault Area	Possible Faulty Component
SWR Indicator remains at zero	1. Power Supply Circuit	<ul style="list-style-type: none"> <li>a. Power sources</li> <li>b. Transmitter power unit</li> <li>c. Power, control cable</li> <li>d. P-102, J-102</li> <li>e. K-711</li> <li>f. Keying line to Transmitter (from J-102.12)</li> </ul>
	2. R-f Circuit	<ul style="list-style-type: none"> <li>a. R-f cable, Transmitter connector</li> <li>b. P-101, J-101</li> </ul>
	3. Keying Circuit	<ul style="list-style-type: none"> <li>a. Power, control cable</li> <li>b. P-102.12, J-102.12 (open)</li> <li>c. K-707</li> <li>d. K-708</li> <li>e. Keying line to Transmitter (from J-102.12)</li> </ul>

Secondary Symptom	Possible Fault Area	Possible Faulty Component
SWR Indication	4. Power Supply Circuit	Refer to l.a. through l.f.
	a. Plate Voltage supply	a. Refer to l.a. through l.d.
	b. 115 V, 400 cps supply	b. Refer to l.a. through l.d.
	c. Filament supply	c. Refer to l.a. through l.d.; P-102.13, J-102.13 (open)
	5. R-f Circuit	a. P-201, r-f line (open)
	6. Discriminator	a. P-203, J-203 (open)
	7. Servo Amplifier	
	a. 115 V, 400 cps supply	a. Fixed phase, B-601 or B-301, T-601 (open)
	b. Vacuum Tube Filaments	b. V-601A-B, V-602A-B, V-603A-B
	c. Chopper	c. G-601
	d. Plate Voltage supply	d. R-713 and R-714 (open)

B. GENERAL FAULT: MOVING ELEMENT OR ELEMENTS OPERATE, BUT TUNING NEVER ACCOMPLISHED (SWR INDICATOR NEVER SETTLES TO INDICATE TUNING POINT)

Secondary Symptom	Possible Fault Area	Possible Faulty Component
Series Phasing Elements L-401, C-501 continue excursion for 30 seconds, until stopped by Time Delay relay and R-F Autotransformer T-301 stops at center tap	1. R-f Circuit	a. E-302, r-f line from T-201 b. T-301 (open at center tap or pickup roller) c. E-303, E-408, r-f line d. L-401 (open or E-408, E-406 contact buttons corroded) e. E-406, r-f line to C-501 f. C-501

Secondary Symptom	Possible Fault Area	Possible Faulty Component
Series Phasing Elements	1. R-f Circuit	g. E-102 h. Antenna and leadin (open) i. C-101
	2. Discriminator a. No phasing output b. Negative phasing output only c. Positive phasing output only	a. CR-201 and CR-202 (faulty), P-203.2 (grounded) b. CR-201 (faulty or reversed), P-203.3 (grounded) c. CR-202 (faulty or reversed)
	3. Phasing Servo Amp. a. Plate Voltage supply b. Chopper contacts c. Output Transformer d. Phase-Sensitive Motor e. Phasing Switch f. Vacuum Tubes	a. R-714 (open) b. G-601.6 and G-601.7 c. T-602 d. B-601 e. S-601 f. V-601B, V-602B, V-603B
	4. Control Circuit	a. K-702.9 and K-702.14 (fail to open)
L-401, C-501 continue excursion for 30 seconds, until stopped by Time Delay Relay and T-301 runs to minimum, stops	5. Discriminator a. Positive loading output only	a. CR-204 (faulty or reversed)
	6. Control Circuit	a. S-302A (fails to open) b. K-702.8 and K-702.13 (fail to open)



Secondary Symptom	Possible Fault Area	Possible Faulty Component
L-401, C-501 continue excursion for 30 seconds, until stopped by Time Delay Relay and T-301 does not run	7. Discriminator a. No loading output	a. CR-203 and CR-204 (faulty) P-203.1 (grounded)
	8. Loading Servo Amplifier a. Plate Voltage supply b. Chopper contacts c. Vacuum Tubes	a. K-709, R-713; variable phase, B-301 (open) b. G-601.1 and G-601.7 c. V-601A, V-602A, V-603A
T-301 runs toward maximum, but stops at center tap. After L-401, C-501 finds a tuning point and stops, T-301 runs to maximum and stops, or oscillates between maximum and center tap until stopped by Time Delay Relay	9. Discriminator a. Negative loading output only 10. Control Circuit	a. CR-203 (faulty or reversed) a. K-710 b. S-302B (fails to close) c. C-711 (grounded)
T-301 runs to maximum, stops but L-401, C-501 never start	11. Control Circuit	a. K-706 (fails to operate)
C. GENERAL FAULT: MOVING ELEMENTS OPERATE, SWR INDICATOR SETTLES, ANTENNA APPARENTLY TUNED, TRANSMITTER KEYING STOPS: BUT NO SIGNAL RADIATION.		
Secondary Symptom	Possible Fault Area	Possible Faulty Component
No signal heard by receiving station	12. R-F Circuit	a. Refer to Bl.e. through Bl.h.



D. GENERAL FAULT: MOVING ELEMENTS OPERATE, BUT STOP BEFORE 30 SECONDS WITH ANTENNA UNTUNED AND/OR EQUIPMENT BROUGHT TO TEST BENCH FOR CONTROL CIRCUIT CHECK, BUT FAILS TO GIVE CORRECT RESULT AT SOME POINT DURING CONTROL CIRCUIT TEST PROCEDURE (Refer to paragraph 6-22).		
Secondary Symptom	Conditions	Possible Faulty Component or Circuit Section
1. L-401 does not start toward minimum	+1.5 V d-c on P-302.2, Transmitter keyed	<p>a. K-704 (coil, fails to operate)</p> <p>b. K-701 (fails to drop out)</p> <p>c. Motor circuit: Plus lead, B-401, P-401.11, K-701.14, K-701.10, K-704.13, K-704.8, K-705.14, K-705.10, K-702.7, K-702.13, K-707.2, K-707.11; ground lead, B-401, R-401, P-401.4, K-703.7, K-703.13, K-705.11, K-705.2, K-701.7, K-701.13, P-401.5, S-401A.2, S-401A.6, P-401.1, K-701.5, K-701.12</p>
2. C-501 does not start toward minimum	+1.5 V d-c on P-203.2, Transmitter keyed	<p>a. K-701 (coil, fails to operate)</p> <p>b. S-401B.12, P-401.9, P-401.2, S-401B.8</p> <p>c. S-401A.6, S-401A.2 (open before S-401B.12 and S-401B.8 close)</p> <p>d. Motor circuit: Plus lead, B-501, P-501.5, K-701.11, 701.1; rest of circuit same as for L-401 (B-401) in D1.c. above, starting with K-704.13, K-704.8; ground lead, B-501, R-501, P-501.7, same as D1.c. above through K-705.11, K-705.2; K-701.8, K-701.13; P-501.2, S-502.4, S-502.5</p>

Symptom	Conditions	Possible Faulty Component or Circuit Section
3. L-401 does not run toward 6 turns, stops at minimum; C-501 also stops at minimum	+1.5 V d-c on P-203.2, Transmitter keyed	<ul style="list-style-type: none"> <li>a. K-705 (fails to operate)</li> <li>b. S-502.4, S-502.5 (open before S-502.1 and S-502.3 close)</li> <li>c. Motor circuit (B-401): K-705.1, K-705.11, K-705.14, K-705.9, P-401.3, S-401A.1, S-401A.6.</li> </ul>
4. C-501 does not start toward maximum; L-401 stops at 6 turns	+1.5 V d-c on P-203.2, Transmitter keyed	<ul style="list-style-type: none"> <li>a. Motor circuit (B-401) K-701.1, K-701.11, P-501.10, S-501.4, S-501.3</li> </ul>
5. C-501 does not start toward maximum; L-401 does not stop at 6 turns		<ul style="list-style-type: none"> <li>b. K-701 (fails to operate)</li> <li>c. S-401B.12, S-401B.11, P-401.10, P-501.1, S-501.1, S-501.2</li> </ul>
6. L-401 does not start toward maximum after stopping at 6 turns; C-501 has run to maximum	+1.5 V d-c on P-203.2, Transmitter keyed	<ul style="list-style-type: none"> <li>a. S-501.3, S-501.4, (open before S-501.1 and S-501.2 open)</li> </ul>
7. L-401 runs to maximum, fails to throw in shunt capacitance	+1.5 V d-c on P-203.2, Transmitter keyed	<ul style="list-style-type: none"> <li>a. K-710 (fails to operate)</li> </ul>
8. L-401 throws in shunt capacitance, but fails to hold in		<ul style="list-style-type: none"> <li>b. P-401.6, S-402A.2, S-402A.9</li> <li>c. K-710</li> <li>d. K-707.10, K-707.14</li> <li>e. K-705 (fails to drop out)</li> </ul>
9. K-401 runs to maximum, fails to reverse toward minimum		<ul style="list-style-type: none"> <li>f. S-401A.1 (opens before S-402B.4 opens)</li> </ul>

Symptom	Conditions	Possible Faulty Component or Circuit Section
10. L-401 does not stop when battery connection re-removed	No signal on P-203.2, Transmitter unkeyed	a. K-704.5, K-704.12 (fail to open)
11. Shunt capacitance holds in	Channel selector operated	a. K-707 (fails to operate) b. K-710.3, K-710.4 (fail to open)
12. T-301 does not start toward center tap from 4 turns from maximum	-1.5 V d-c on P-203.2	a. K-703, K-702 (fail to operate) b. K-707 (fails to drop out) K-706 (fails to operate) c. K-702 (fails to hold), P-301.E, S-302A, P-301.H, K-703.9, K-703.14
13. T-301 stops at center tap; L-401 does not start toward minimum	-1.5 V d-c on P-203.2	d. K-702, K-706 (fail to operate)
14. L-301 does not stop when battery connection removed	No signal on P-203.2	e. K-703.5, K-703.12 (fail to open)
15. T-301 does not start toward minimum	+1.5 V d-c on P-203.1, Transmitter keyed	a. C-711 grounded
16. T-301 does not start toward maximum, or runs to maximum, does not switch in shunt capacitance	-1.5 V d-c on P-203.1, Transmitter keyed	a. C-711 grounded b. K-710 (fails to operate) P-301.A, S-302.B c. K-710 (fails to hold), K-707.10, K-707.14
17. T-301 does not reverse, run toward minimum		d. K-702 (fails to operate), P-301J, S-301 e. K-706 (fails to operate)
18. T-301 does not stop at center tap, runs toward maximum or minimum	T-301 runs toward maximum  T-301 runs toward minimum	f. C-711 not grounded  g. K-702 (fails to operate) h. S-302 (fails to open)

6-25. RESISTANCE AND VOLTAGE MEASUREMENTS.

6-26. The following resistance and voltage tables are furnished to assist maintenance personnel in servicing the equipment.

TABLE 6-2

RESISTANCE MEASUREMENTS (TYPICAL)

Pin	V-601	V-602	V-603	G-601
1	430K (D)	270K (D)	50K (D)	110K (D) or 0 (A)
2	500K (D)	500K (D)	200K (D)	∞ (D)
3	0 (A)	0 (A)	13 (A)	1 (A)
4	11 (A)	11 (A)	0 (A)	1 (A)
5	18 (A)	18 (A)	11 (A)	0 (A)
6	330K (D)	250K (D)	62K (D)	0 (A) or 580K (D)
7	500K (D)	500K (D)	500K (D)	0 (A)
8	0 (A)	0 (A)	1000 (B)	
9	NC	NC	NC	

CONDITIONS OF MEASUREMENT: Multimeter TS-352/U, measurements from pin to ground with P-102 removed. Scale code: (A) x1, (B) x10, (C) x1000, (D) x100K.

TABLE 6-3

VOLTAGE MEASUREMENTS

Pin	V-601		V-602		V-603		G-601	
	Meter 1	Meter 2	Meter 1	Meter 2	Meter 1	Meter 2	Meter 1	Meter 2
1	57 (D)	58 (D)	75 (D)	78 (D)	305 (E)	305 (F)	0	0
2	-.52 (A)	-.73 (A)	-.58 (A)	-.78 (A)	0 (A)	0 (A)	0	0
3	0 (A)	0 (A)	0 (A)	0 (A)	19.8 (C)	20 (C)	3.1 (B) (AC)	3.1 (B) (AC)
4	12.9 (C)	13.2 (C)	12.9 (C)	13.2 (C)	0 (A)	0 (A)	3.1 (B) (AC)	3.1 (B) (AC)
5	27.0 (C)	27.5 (C)	27.0 (C)	27.5 (C)	12.9 (C)	13.2 (C)	0	0
6	57 (D)	57 (D)	67 (D)	68 (D)	238 (D)	245 (E)	0	0
7	-.63 (A)	-.85 (A)	-.50 (A)	-.85 (A)	0 (A)	0 (A)	0	0
8	0 (A)	0 (A)	0 (A)	0 (A)	8.2(B)	8.3 (B)	-	-
9	NC	NC	NC	NC	NC	NC	-	-

CONDITIONS OF MEASUREMENT: Meter 1, Multimeter TS-352/U; Meter 2, ME-25A/U. Measurements from pin to ground. Scale codes: Meter 1, (A) 3V, (B) 12V, (C) 60V, (D) 300V, (E) 1,200V. Meter 2, (A) 3V, (B) 10V, (C) 30V, (D) 100V, (E) 300V, (F) 1,000V.

6-27. LUBRICATION.

6-28. Inspect components requiring lubrication at each major inspection period. If parts appear to be clean, sufficiently lubricated and free-running, lubrication may be omitted until the following period. When lubricating parts, use a minimum amount of lubricant.

TABLE 6-4  
LUBRICATION CHART

Sub-Assembly	Parts	Lubricant
R-F Autotransformer	Bronze bearings, gear hubs, gear teeth	MIL-L-7870
Variable Inductor	Gear post oil wicks, gear teeth, bearings	MIL-L-7870
Variable Capacitor	(a) Capacitor bearing surfaces	MIL-L-7870
	(b) Other gear posts, gear teeth, bearings	MIL-L-7870
	(c) Worm gears	MIL-G-7421

6-29. MOTOR LUBRICATION. All motor bearings are factory lubricated for the life of the motor. No further lubrication is necessary.

6-30. OPERATIONAL TEST.

6-31. With Antenna Tuner 180L-2 connected to all power sources and a fully-operative transmitter of appropriate type, plus an antenna load, perform an operational test which will cover all appropriate frequencies. Attach the r-f transmission line from the transmitter to J-601, and connect the antenna load to the ANT terminal (E-102) of the Antenna Tuner. Procedure of the test should be equal to that of the Pre- and Post-Flight tests, and should result



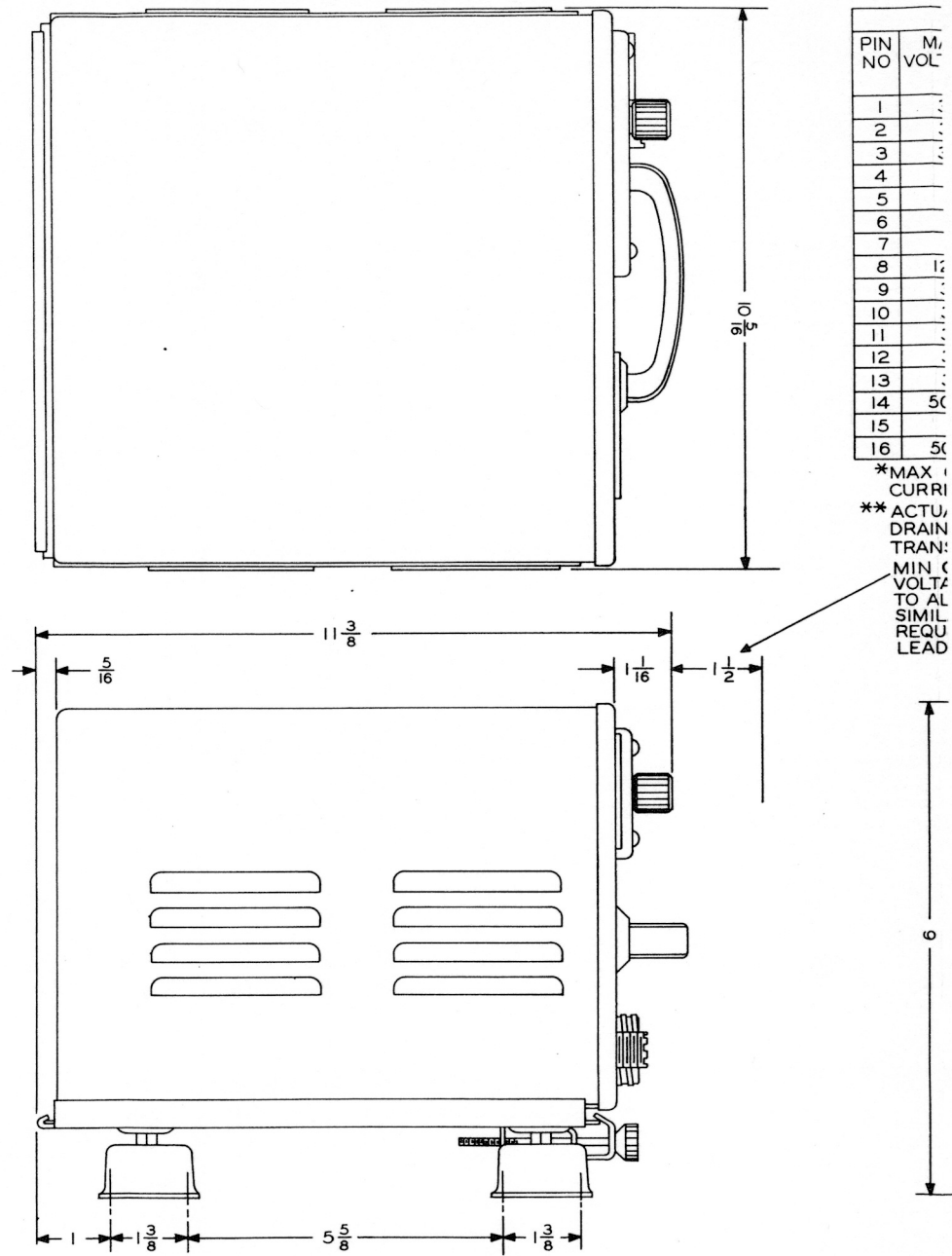
in normal indications of power amplifier plate current and standing wave ratio.  
(Refer to paragraphs 5-5 through 5-7, and 5-11a. through 5-11d).

6-32. EQUIPMENT RE-INSTALLATION.

6-33. Replace the Antenna Tuner panel and case. Replace six screws at the lower edges of the case, and five panel screws. Return the equipment to Mounting 350D-3 in the aircraft and re-connect cabling. (Refer to paragraph 3-6).

## SECTION VII

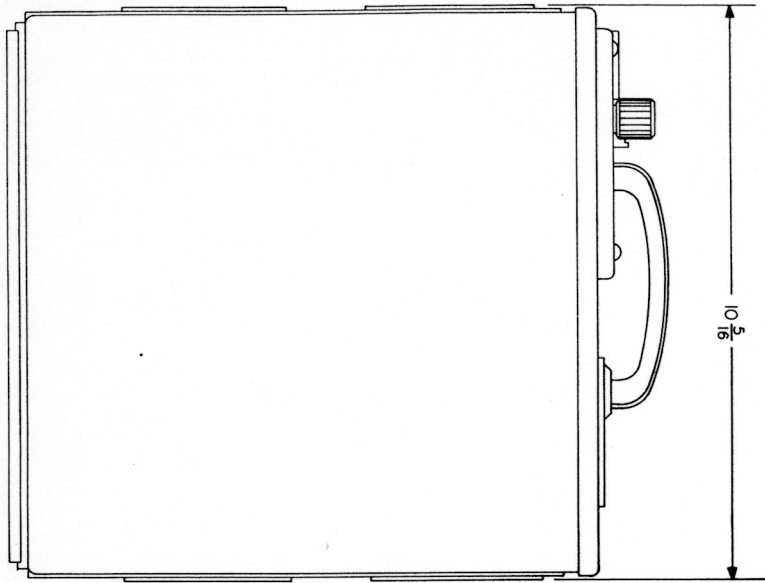
### DIAGRAMS



\*MAX CURRI  
 \*\*ACTU, DRAIN  
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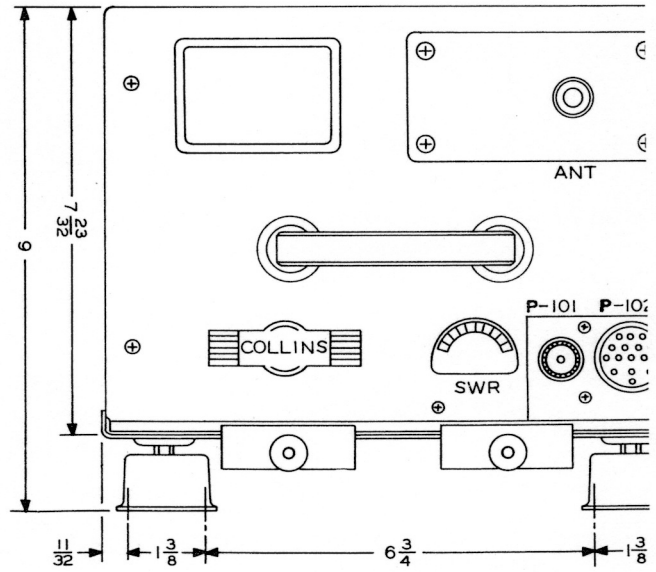
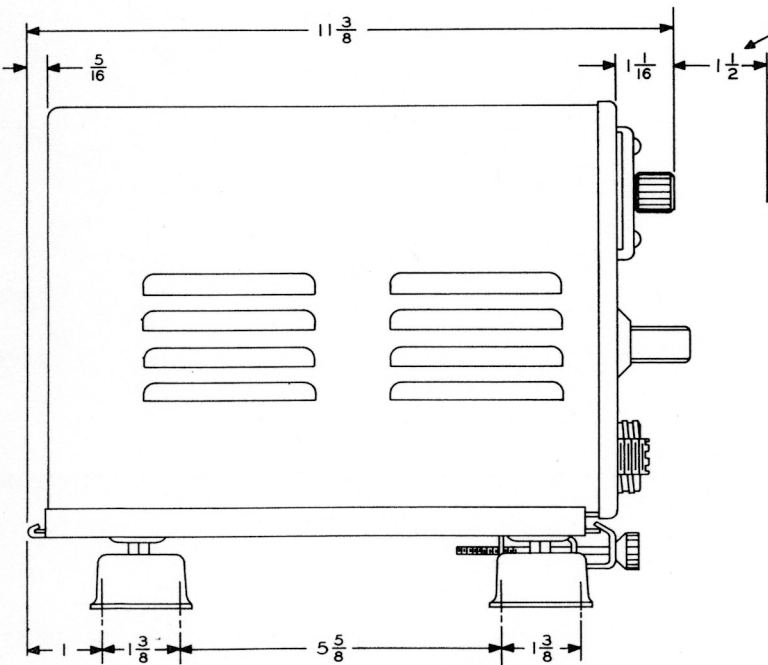
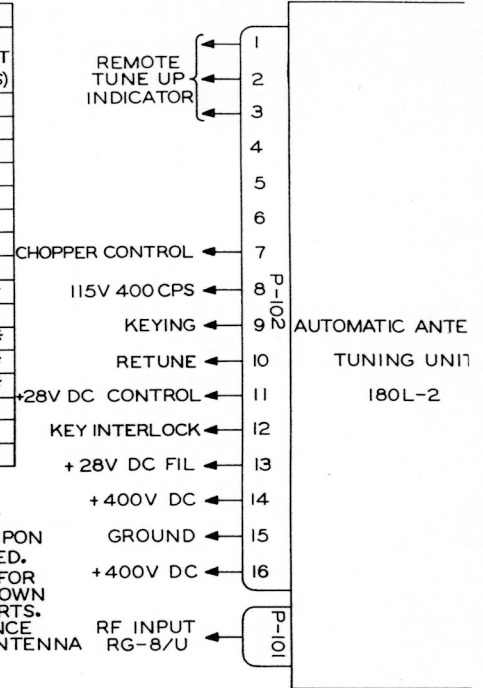
- NOTES:
1. APPROXIMATE WEIGHT 17.4 LBS.
  2. 16 MTG HOLES  $\frac{9}{64}$  DIA. - #6 SCREWS.
  3. ALL DIMENSIONS ARE IN INCHES.
  4. CLEARANCE OF  $\frac{1}{2}$  REQUIRED ON ALL SIDES AND TOP, FOR FREE MOVEMENT OF UNIT ON SHOCKMOUNT.
  5. SPOT FACE 4 OF 16 MOUNTING HOLES FOR CONTACT WITH GROUNDING STRIPS.
  6. 6 INCH CLEARANCE REQUIRED AT FRONT FOR REMOVAL OF CONNECTOR AND FRONT PANE

Figure 7-1. Antenna Tuner 180



P-102		
PIN NO	MAX VOLTAGE	MAX CURRENT (AMPERES)
1	30	3.0*
2	30	3.0*
3	30	3.0*
4		
5		
6		
7		
8	120	0.15
9	30	2.0**
10	30	0.15
11	30	6.0**
12	30	4.0**
13	30	1.5**
14	500	0.025
15	0	6.0
16	500	0.025

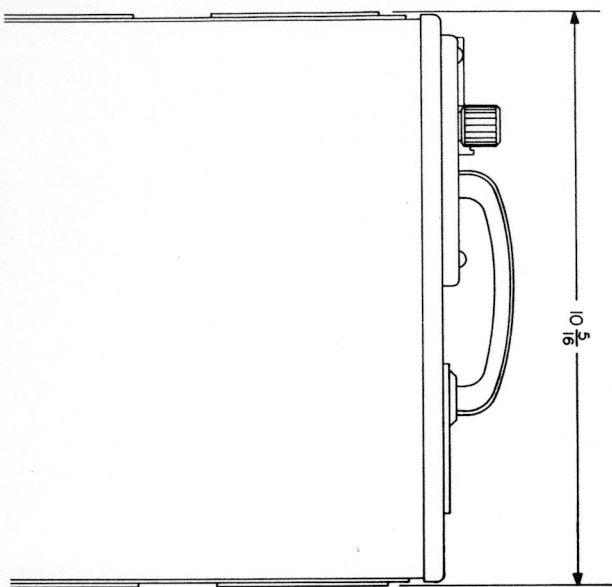
\*MAX CONTACT CURRENT RATING.  
 \*\*ACTUAL CURRENT DRAINS DEPEND UPON TRANSMITTER USED.  
 MIN CLEARANCE FOR VOLTAGE BREAKDOWN TO ALL METAL PARTS. SIMILAR CLEARANCE REQUIRED FOR ANTENNA LEAD-IN WIRE.



NOTES:

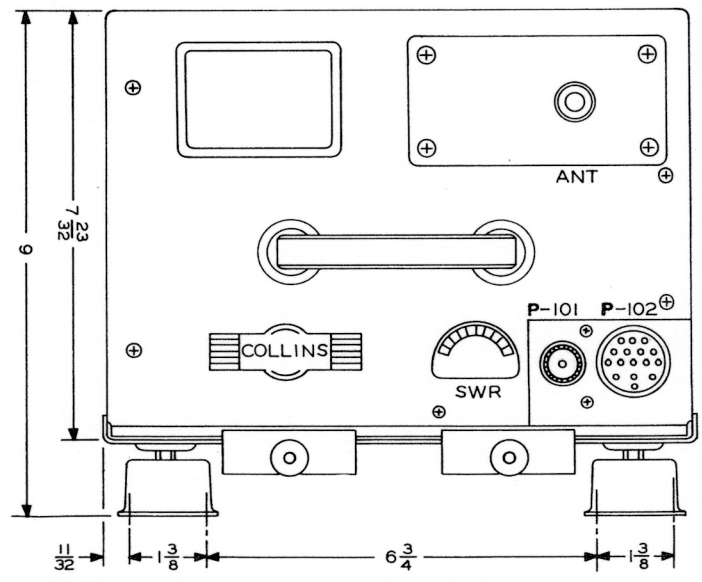
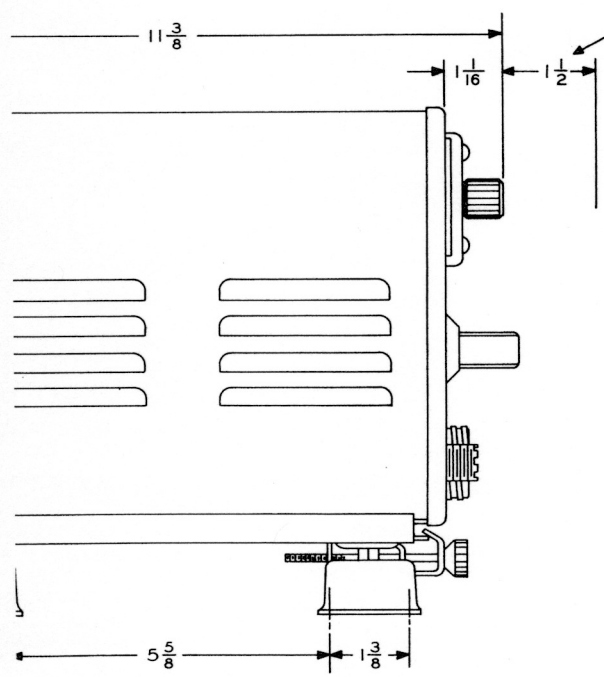
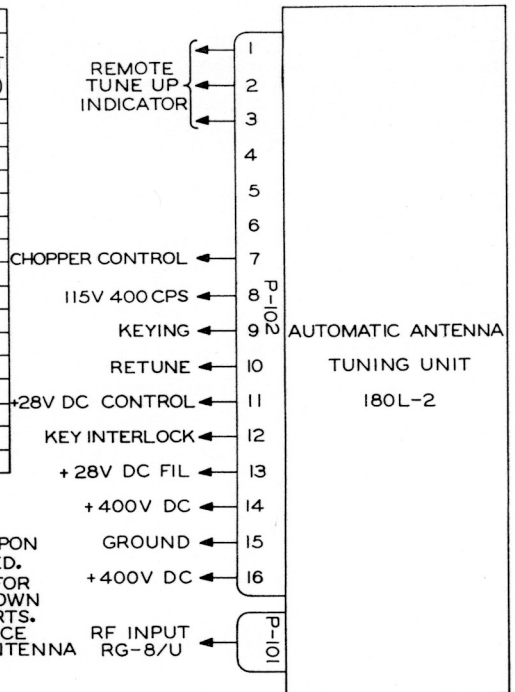
1. APPROXIMATE WEIGHT 17.4 LBS.
2. 16 MTG HOLES 9/64 DIA. - #6 SCREWS.
3. ALL DIMENSIONS ARE IN INCHES.
4. CLEARANCE OF 1/2 REQUIRED ON ALL SIDES AND TOP. FOR FREE MOVEMENT OF UNIT ON SHOCKMOUNT.
5. SPOT FACE 4 OF 16 MOUNTING HOLES FOR CONTACT WITH GROUNDING STRIPS.
6. 6 INCH CLEARANCE REQUIRED AT FRONT FOR REMOVAL OF CONNECTOR AND FRONT PANEL.

Figure 7-1. Antenna Tuner 180L-2, Installation and Mounting Dimens



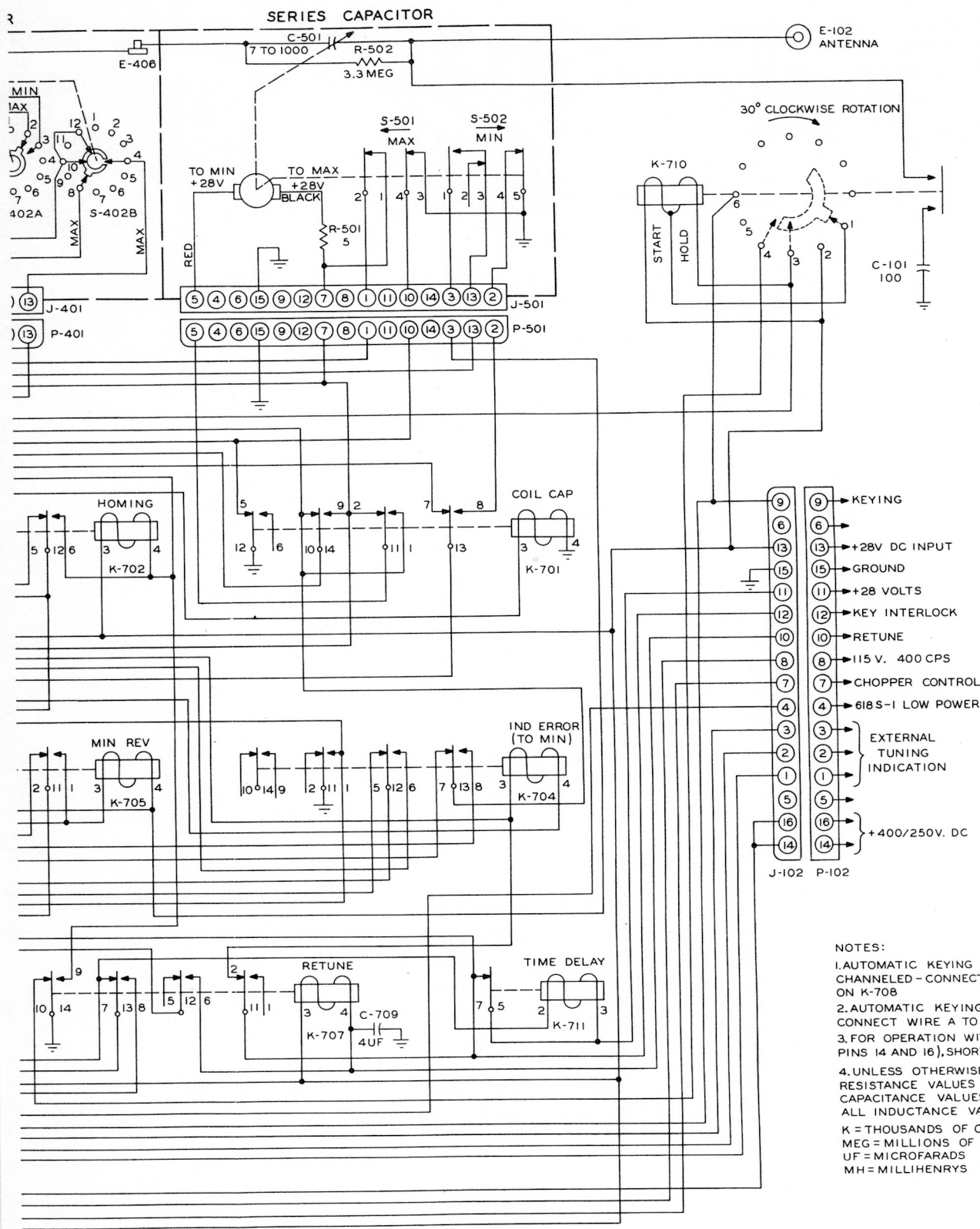
P-102		
PIN NO	MAX VOLTAGE	MAX CURRENT (AMPERES)
1	30	3.0*
2	30	3.0*
3	30	3.0*
4		
5		
6		
7		
8	120	0.15
9	30	2.0**
10	30	0.15
11	30	6.0**
12	30	4.0**
13	30	1.5**
14	500	0.025
15	0	6.0
16	500	0.025

\*MAX CONTACT CURRENT RATING.  
 \*\* ACTUAL CURRENT DRAINS DEPEND UPON TRANSMITTER USED.  
 MIN CLEARANCE FOR VOLTAGE BREAKDOWN TO ALL METAL PARTS. SIMILAR CLEARANCE REQUIRED FOR ANTENNA LEAD-IN WIRE.



- NOTES:
1. APPROXIMATE WEIGHT 17.4 LBS.
  2. 16 MTG HOLES  $\frac{9}{64}$  DIA. - #6 SCREWS.
  3. ALL DIMENSIONS ARE IN INCHES.
  4. CLEARANCE OF  $\frac{1}{2}$  REQUIRED ON ALL SIDES AND TOP FOR FREE MOVEMENT OF UNIT ON SHOCKMOUNT.
  5. SPOT FACE 4 OF 16 MOUNTING HOLES FOR CONTACT WITH GROUNDING STRIPS.
  6. 6 INCH CLEARANCE REQUIRED AT FRONT FOR REMOVAL OF CONNECTOR AND FRONT PANEL.

Figure 7-1. Antenna Tuner 180L-2, Installation and Mounting Dimensions



- NOTES:
1. AUTOMATIC KEYING WHEN TRANSMITTER CHANNCELED - CONNECT WIRE A TO PIN 8 ON K-708
  2. AUTOMATIC KEYING WHEN KEY PRESSED - CONNECT WIRE A TO PIN 9 ON K-708
  3. FOR OPERATION WITH 250 VOLTS (J-102, PINS 14 AND 16), SHORT R-713 AND R-714
  4. UNLESS OTHERWISE INDICATED, ALL RESISTANCE VALUES ARE IN OHMS, ALL CAPACITANCE VALUES ARE IN MICROMICROFARADS, ALL INDUCTANCE VALUES ARE IN MICROHENRYS.
- K = THOUSANDS OF OHMS  
 MEG = MILLIONS OF OHMS  
 UF = MICROFARADS  
 MH = MILLIHENRYS

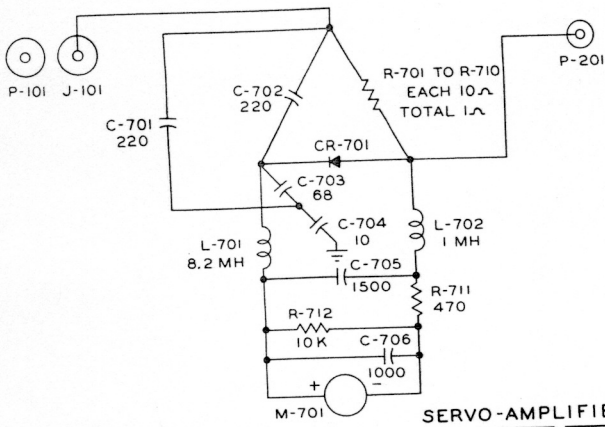
Figure 7-2. Antenna Tuner 180L-2, Main Schematic Diagram



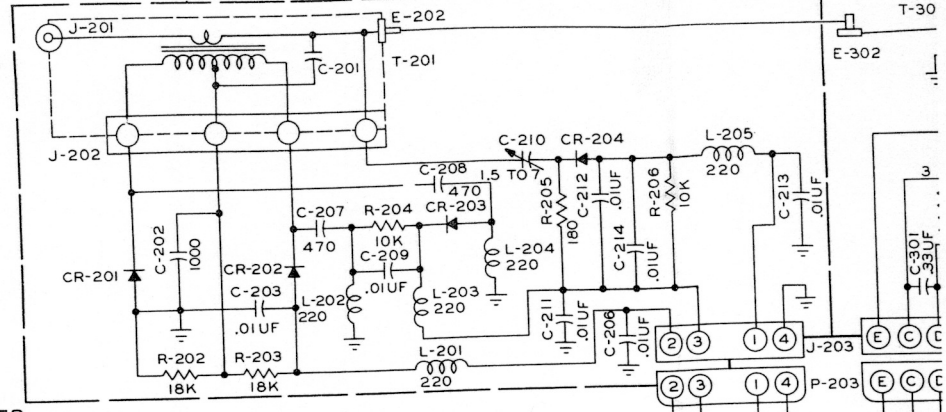




SWR INDICATOR

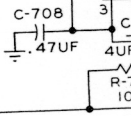
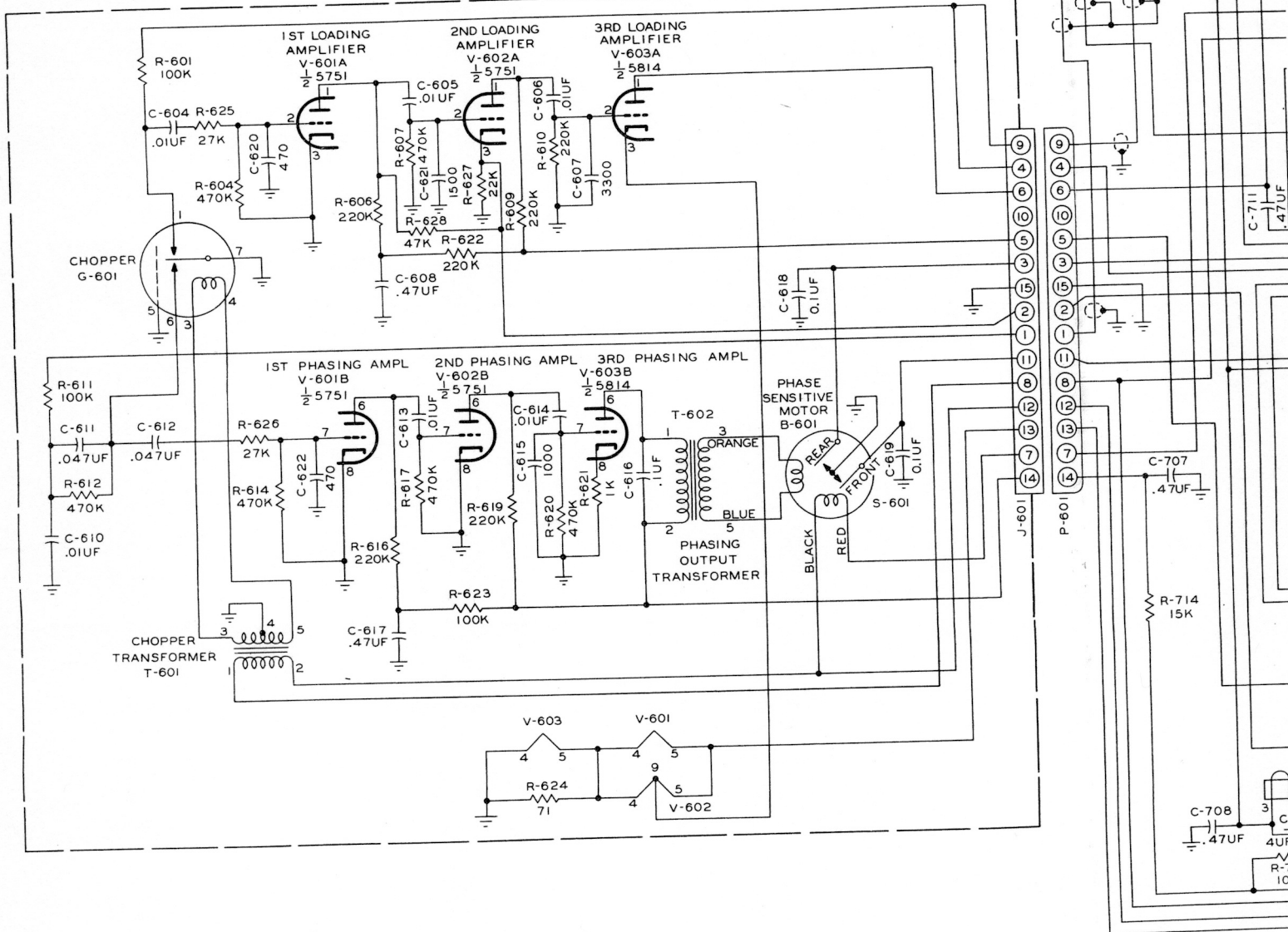


DISCRIMINATOR



R-F AUT

SERVO-AMPLIFIER



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