ITT

Operation and Maintenance Manual

Antenna Coupler MSR 4020

8.153

CONTENTS

SECTION			PAGE
1	GENERAL		1-1
	1.1	Scope	1-1
	1.2	Description	1-1
	1.3	Specifications	1-1
	1.4	Equipment Supplied	1-2
	1.5	Optional Equipment - Not Supplied	1-2
2	INSTALLATION		2-1
	2.1	General	2-1
	2.2	Unpacking and Inspection	2-1
	2.3	Reshipping	2-1
	2.4	Installation	2-1
	2.5	Power Requirements	2-9
	2.6	Tests After Installation	2-11
3	OPERATION		3-1
	3.1	General	3-1
	3.2	Operating Controls	3-1
	3.3	General Operating Procedures	3-1
4	THEORY OF OPERATION		4-1
	4.1	General	4-1
	4.2	Subassemblies	4-1
	4.3	Tuning Network	4-1
	4.4	Network Control	4-4
	4.5	Detector Assembly	4-4
	4.6	Control Board Assembly	4-9
	4.7	Connector Board Assembly	4-19
	4.8	Attenuator Assembly	4-23
5	MAINTENANCE AND REPAIR		5-1
	5.1	General	5-1
	5.2	Test Equipment	5-1
	5.3	Periodic Maintenance	5-1
	5.4	Detector Assembly Adjustments	5-7
	5.5	Control Board Troubleshooting	5-10
	5.6	Connector Board Assembly	5-16
	5.7	Attenuator Assembly	5-16
	5.8	Fault Isolation and Repair	5-17

LIST OF ILLUSTRATIONS

FIGURE	TITLE	PAGE
2.1	Dimensions	2-3
2.2	Shock Mounting Plate	2-4
2.3	Typical Whip Antenna Installation	2-5
2.4	Typical Longwire Antenna Installation	2-6
2.5	Typical Vehicle Installation	2-7
2.6	Typical Ground/Counterpoise Installation	2-8
2.7	Cable End Preparation	2-9
2.8	Socket Pin Preparation	2-9
2.9	Control Cable Connector Sealing	2-11
4.1	Subassemblies	4-2
4.2	Block Diagram	4-3
4.3	Detector Board Component Location	4-6
4.4	Detector Board Schematic	4-7
4.5	Control Board Component Location	4-10
4.6	Control Board Schematic	4-11
4.7	Control Board Schematic	4-12
4.8	Connector Board Component Location	4-20
4.9	Connector Board Schematic	4-21
4.10	Chassis Interconnect	4-22
4.11	Attenuator Board Component Location	4-25
4.12	Attenuator Board Schematic	4-25
5.1	Major Component Location	5-2
5.2	Major Component Location	5-3
5.3	Major Component Location	5-4
5.4	Ball Gap Assembly Adjustment	5-7
5.5	Detector Cable Construction	5-7
5.6	Detector Alignment Set up	5-8

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Coupler Control Cable	2-10
4.1	Voltage Groups	4-9
4.2	Power Supply Voltages and Test Points	4-13
5.1	Detector Assembly Outputs	5-7
5.2	Control Board Pin Input/Output	5-10
5.3	Control Board Test Points	5-15

SECTION 1
GENERAL

1.1 SCOPE

This instruction manual contains information necessary for the installation, operation, maintenance and the repair of the antenna coupler.

1.2 DESCRIPTION

The coupler is remote controlled and is designed to match antennas from 9 foot whips to 150 foot long wires over a frequency range of 1.6 to 30 MHz. The coupler may be configured to operate from either a 12 or a 28 volt system by installation of the appropriate motors and proper strapping connections on the control board. Designed for outside mounting near the antenna, the coupler is mounted in a fully gasketed watertight case.

1.3 SPECIFICATIONS

1.3.1 FREQUENCY RANGE: 1.6 - 30 MHz

1.3.2 ANTENNA MATCHING CAPABILITIES:

Whip, 9 Ft.	1.6 - 30 MHz
Whip, 16 Ft.	1.6 - 30 MHz
Whip, 23 Ft.	1.6 - 30 MHz
Whip, 35 Ft.	1.6 - 30 MHz
Longwire, 50 Ft.	1.6 - 30 MHz
Longwire, 150 Ft.	1.6 - 30 MHz

1.3.3 POWER HANDLING CAPABILITY:

150 Watt Average

1.3.4 INPUT IMPEDANCE: 50 ohm nominal

1.3.5 TUNING ACCURACY: 1.5:1 VSWR max. after tuning

1.3.6 RF TUNE POWER REQUIREMENT:

20 Watt Minimum
50 Watt Maximum

1.3.7 TUNE CYCLE: 30 seconds maximum (Includes Home Time)

1.3.8 STATUS LINES:

Coupler Ready
Excess VSWR (Tune Fault) or
Excess Tuning Time Fault
Tune-In Progress

1.3.9 SUPPLY VOLTAGE:

Group 001 - 11.9 to 14.5 VDC

Group 002 - 22.0 to 42.0 VDC

1.3.10 POWER REQUIREMENTS (MAXIMUM):

4 Watts, Coupler Tuned (Surveillance Disabled)
15 Watts, Coupler Tuned (Surveillance Enabled)
40 Watts, Tuning (Average)

1.3.11 DIMENSIONS:

Length	30.5 cm (12 in.)
Width	24.2 cm (9.5 in)
Height	16.3 cm (6.4 in.) - 19.8 cm (7.8 in.) with shock isolation kit

1.3.12 WEIGHT: 9.1 kg (20 lbs.)

1.3.13 TEMPERATURE: -30°C to +65°C

1.3.14 VIBRATION: MIL-STD-810C, Method 514.2, Fig. 6, Curve V (20 to 200 Hz) (with isolators)

1.3.15 SHOCK: MIL-STD-810C, Method 516.2, Figure 2, Procedure 1, (with isolators)

1.3.16 HUMIDITY: 95%, 50°C for 48 hours

1.3.17 ENCLOSURE: MIL-STD-108E, Table II, splash and rain proof, proof, (sealed), designed for exposed installations.

1.4 EQUIPMENT SUPPLIED

1.4.1 COUPLER, ANTENNA, - Part Number 600233-800-XXX

1.4.2 MANUAL, OPERATION/MAINTENANCE - Part Number 600216-823-001

1.4.3 CONNECTOR, CONTROL - Part Number 600274-606-004

1.4.4 CABLE CLAMP - Part Number 600274-606-001

1.4.5 SOCKET PINS, 20 - Part Number 600275-230-004 (ea.)

1.4.6 TOOL, EXTRACTION, - Part Number 600045-701-001

1.4.7 CONNECTOR, RF TYPE N (UG-536 B/U) - Part Number 600384-606-001

1.4.8 COAX SEAL - Part Number 600033-115-001

1.5 OPTIONAL EQUIPMENT - NOT SUPPLIED

1.5.1 KIT, SHOCK MOUNTING - Part Number 600233-817-006

1.5.2 CABLE, CONTROL (SPECIFY LENGTH) - Part Number 600069-102-009

1.5.3 ANTENNA WHIP, 9 FOOT - Part Number 600015-398-002 (Use with 1.5.4)

1.5.4 BUMPER MOUNT, MOBILE WHIP - Part Number 600020-398-001 (Use with 1.5.3)

1.5.5 ANTENNA, WHIP, 16 FOOT - Part Number 600015-398-001 (Use with 1.5.4)

1.5.6 SPRING, BUMPER, HEAVY DUTY - Part Number 600020-398-002 (Accessory for 1.5.4) (For 9 Foot Antenna)

1.5.7 ANTENNA, SELF-SUPPORTING, WHIP, 23 Foot - Part Number 600019-398-002

1.5.8 ANTENNA, WHIP, 23 FOOT - Part Number 600019-398-001

1.5.9 MOUNT, LAYDOWN, WHIP, 23 FOOT - Part Number 600019-398-003 (use with 1.5.8)

1.5.10 ANTENNA, WHIP, 35 FOOT - Part Number 600018-398-001

1.5.11 MOUNT, BASE, SELF-SUPPORTING, WHIP, 35 FOOT - Part Number 600018-398-007 (use with 1.5.10)

1.5.12 MOUNT, BASE, FEEDTHROUGH, WHIP, 35 FOOT - Part Number 600018-398-008 (use with 1.5.10)

1.5.13 KIT, ANTENNA, LONGWIRE, 150 FOOT - Part Number 600233-817-007

1.5.14 KIT, SPARE PARTS, DEPOT, COUPLER (12 VDC) - Part Number 600233-817-004

1.5.15 KIT, SPARE PARTS, DEPOT, COUPLER (24 VDC) - Part Number 600233-817-005

1.5.16 CABLE, RF, RG-58A/U (SPECIFY LENGTH) - Part Number 600016-102-001

1.5.17 CABLE, RF, RG-213U (SPECIFY LENGTH) - Part Number 600017-102-001 (Cable recommended for installations longer than 100 feet)

1.5.18 CONNECTOR, RF, TYPE N (UG-21 D/U) - Part Number 600028-606-001 (required with 1.5.17)

1.5.19 KIT, PC BOARD, SPARE (12 VDC) - Part Number 600233-817-002

1.5.20 KIT, PC BOARD, SPARE (24 VDC) - Part Number 600233-817-003

1.5.21 ANTENNA, MOBILE, 16 FT WHIP - Part Number 600018-398-009 (Use with 1.5.22)

1.5.22 KIT, ANTENNA SIDE MOUNT - Part Number 600233-817-008 (Use with 1.5.21)

1.5.23 MOUNT, BASE, FEEDTHROUGH - Part Number 600021-398-001 (Use with 1.5.3 or 1.5.5)

Gasket for Cover:

600073-628-001

SECTION 2
INSTALLATION

2.1 GENERAL

This section describes the installation procedure for the antenna coupler. Included within this section are procedures for unpacking, inspection and, if necessary, reshipping.

2.2 UNPACKING AND INSPECTION

Unpack the antenna coupler taking care not to damage the connectors or insulator. Retain the carton and packing materials until the contents have been inspected and checked against the packing list. If there is a shortage or any evidence of damage, do not attempt to use the equipment. Contact the shipper and file a shipment damage claim.

2.3 RESHIPPING

If it should become necessary to return the antenna coupler, a RM (Returned Material) number must first be obtained from the manufacturer. This number must accompany the returned equipment. When the manufacturer receives the equipment, arrangements will be made for expedicious repair or replacement.

When packing the coupler for reshipment, special attention should be given to providing enough packing material around the connectors and antenna insulator. Cardboard or other suitable material must be placed around the unit to protect against damage.

2.4 INSTALLATION

Careful attention to the following installation considerations will result in best coupler performance. Figure 2.1 and 2.2 provide overall coupler dimensions to aid in installation.

2.4.1 INSTALLATION CONSIDERATIONS

1) Antenna Site Location: For optimum characteristics and safety, the antenna should be mounted high enough to clear any surrounding obstructions. The antenna should also be located as far as possible from nearby objects such as power lines, buildings, etc. Typical installations can be seen in Figures 2.3, 2.4, 2.5, and 2.6.

2) Adequate Ground: Provide the best possible RF ground for the radio and the coupler. Use a flat copper strap, 1 inch wide or #6 gauge or larger wire and connect it to the ground terminal at the rear of the transmitter and coupler. Leads to the ground system should be as short as possible.

3) Cable Length: Provide maximum separation between the coupler output and the radio and its associated wiring. The coupler may be mounted up to 200 feet from the radio when RG-213U cable is used. For runs under 100 feet, RG-58 cable can be used. Use the UG-536 B/U RF connector (provided) with the RG-58 cable and a UG-21 D/U con-

nector (accessory, not provided) with the RG-213U cable.

4) Antenna Lead-In: The lead-in from the antenna coupler to the antenna must be insulated for at least 10 kV potential. The lead-in should not run parallel to metal objects which are bonded to the system ground. The tuner should be as close to the antenna as possible and never further away than 3 feet, as this will decrease antenna efficiency.

5) Antenna Compatability: The coupler can be used with 9, 16, 23 or 35 foot whip antennas, as shipped from the factory with no change. However, if a 50 to 150 foot longwire antenna is used, it will be necessary to cut the strap inside the coupler that is across the two 100 pF capacitors.

6) Low Level Modulation: Linear amplifiers with low level modulation will oscillate if the RF power output is radiated or conducted into the low level stages. Evidence of this situation is erratic or excessive power output. This is caused by the coupler and the antenna being too close to the transmitter and/or inadequate RF grounds.

7) Coupler Mounting: The coupler can be bolted to mounts at the base of the antenna in any position with four #10 bolts. Make sure that the ground strap going to the grounding lug of the coupler is adequate and secure. If the coupler is to be subjected to severe shock and vibration, it must be mounted on the optional shock mounting plate, Figure 2.2. The optional isolators supplied are "all attitude" type, that is the coupler may be mounted in any plane although it is recommended that the horizontal position be used if possible, as shown in Figure 2.2.

8) Post Installation: After all connections are made to the coupler, completely tape both of the plugs with coax sealant that is supplied. The application procedure is to roll off approximately 6 inches of plastic tape, remove the backing, wrap starting at the cable outer covering and work toward the fitting with 1/2 tape width overlap. After wrapping, gently knead to form a smooth surface and to force out any air.

2.4.2 REMOTE CONTROL CABLE FABRICATION

The following material is required and supplied for fabricating the control cable:

1) Connector, Assembly (P2) - 1 each
2) Pins, P2 - 20 each
3) Tool, Extractor - 1 each

2.4.2.1 The following material is required but not supplied for fabricating the control cable:

1) Solder
2) Cable, 12 conductor, #18 AWG, shielded and jacketed (optional item 1.5.2)
3) Wire, insulated, 2 1/2 inches long, #18 AWG
4) Vinyl Tape
5) RTV Sealant

2.4.2.2 It is recommended that the control cable for the coupler be purchased from the manufacturer. However, a shielded PVC jacketed cable with at least 12 #18 AWG wires

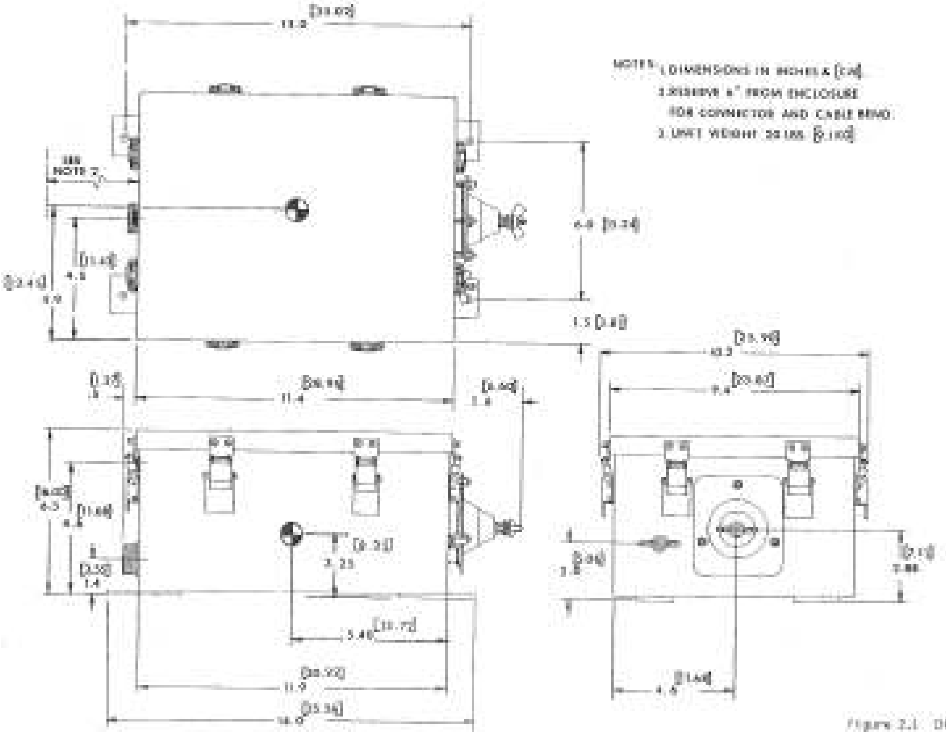
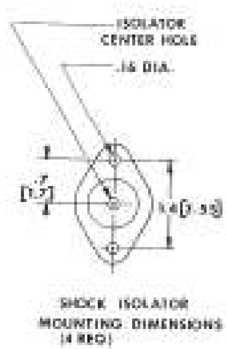


Figure 2.1 Dimensions

NOTES:

1. DIMENSIONS IN INCHES & [CM]



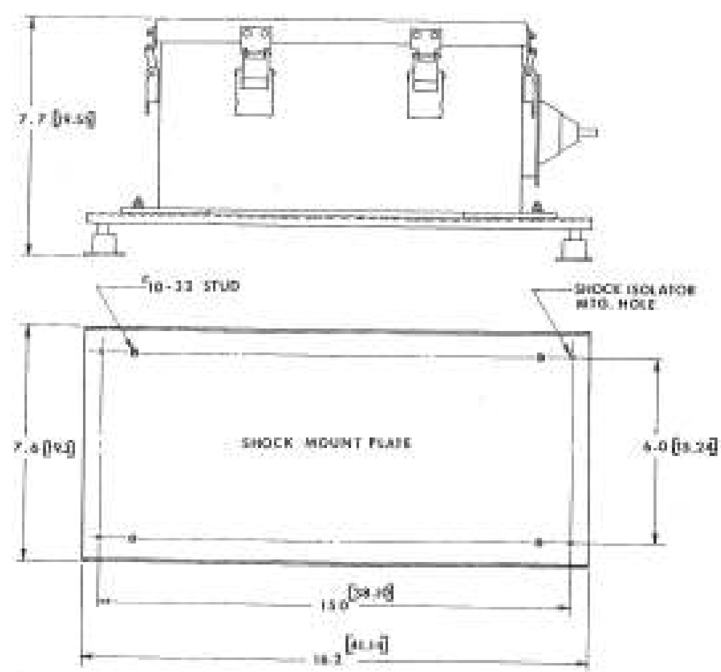


Figure 2.2 Shock Mounting Plate

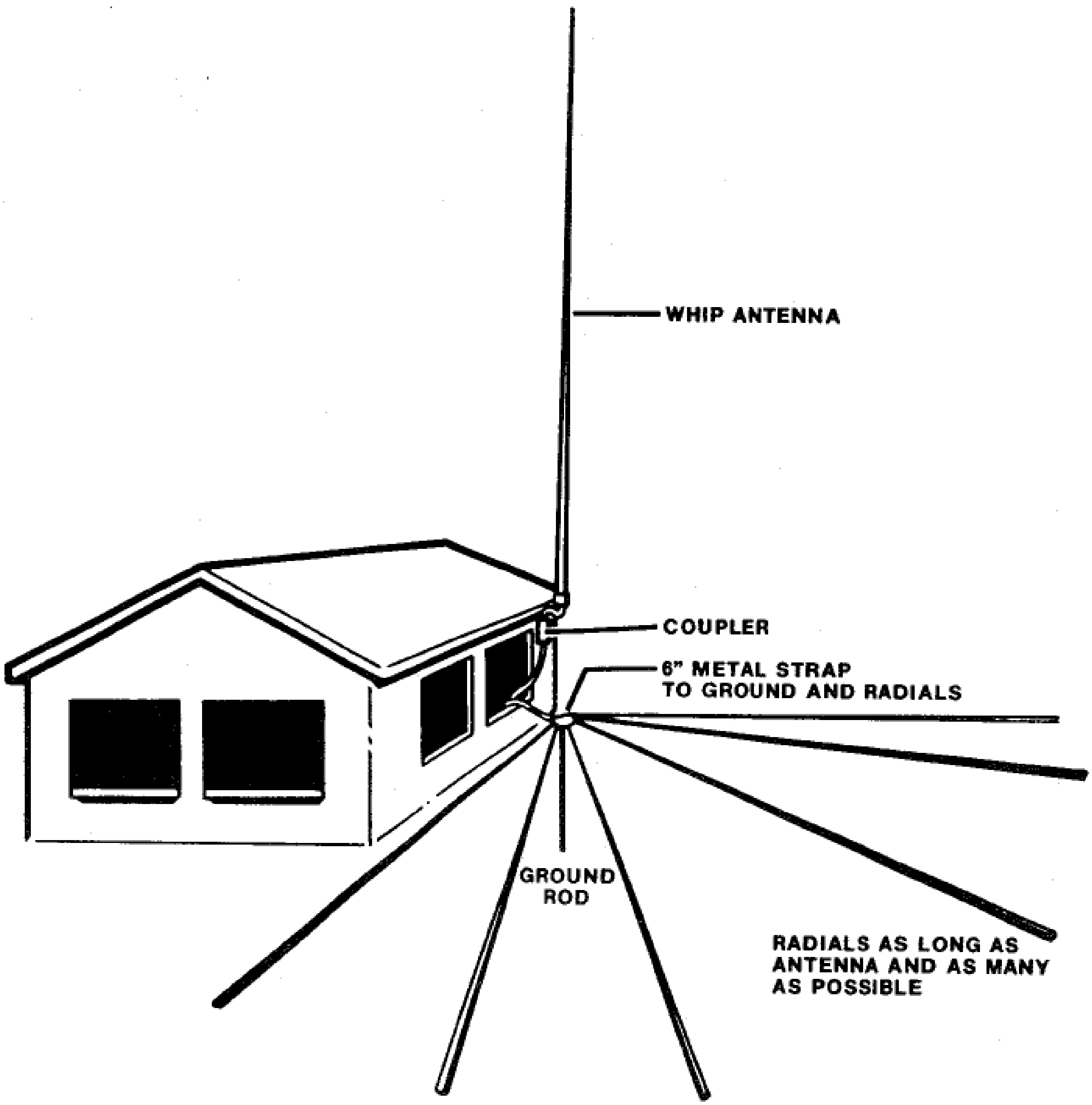


Figure 2.3 Typical Whip Antenna Installation

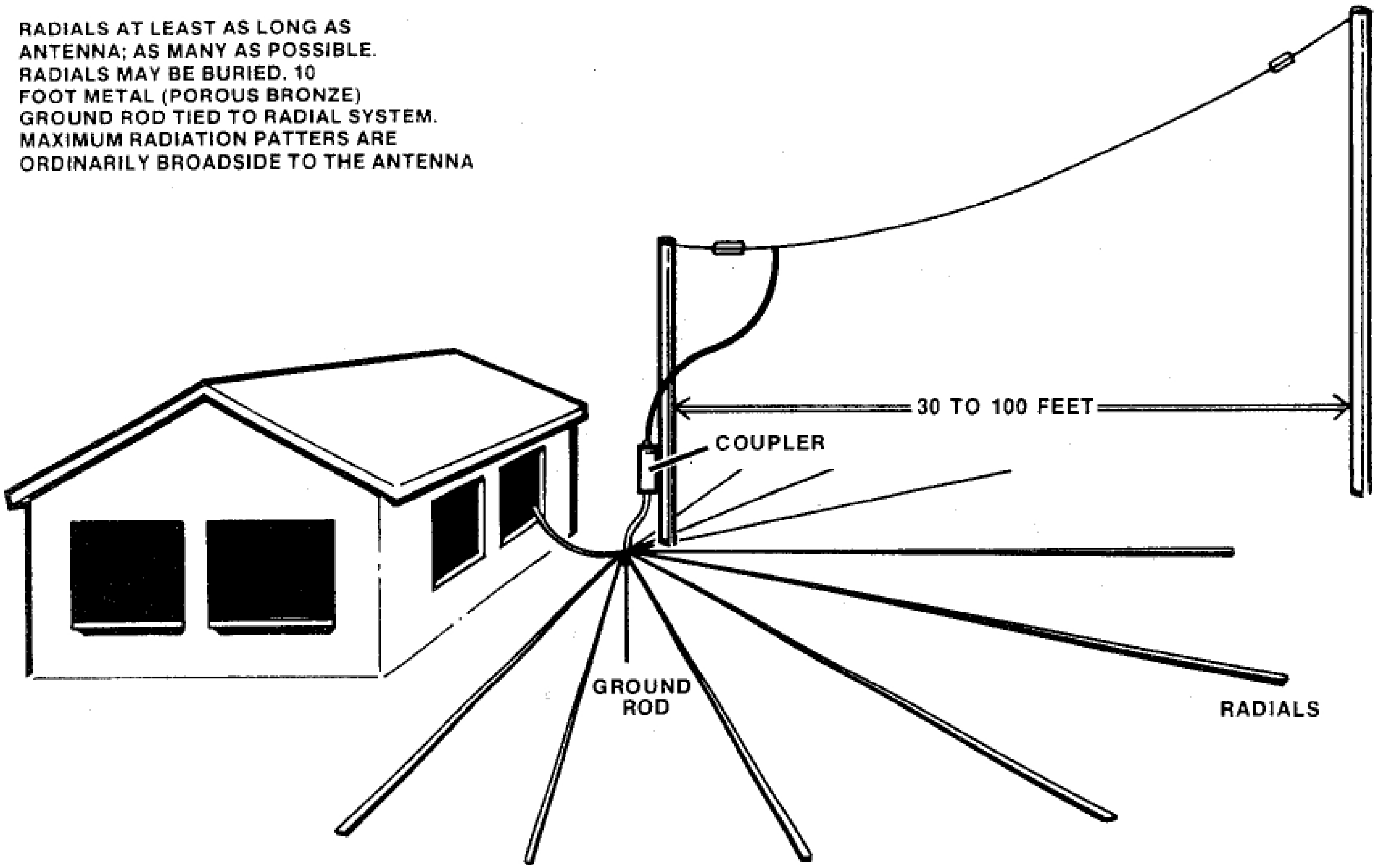


Figure 2.4 Typical Lo[illegible]e Antenna Installation

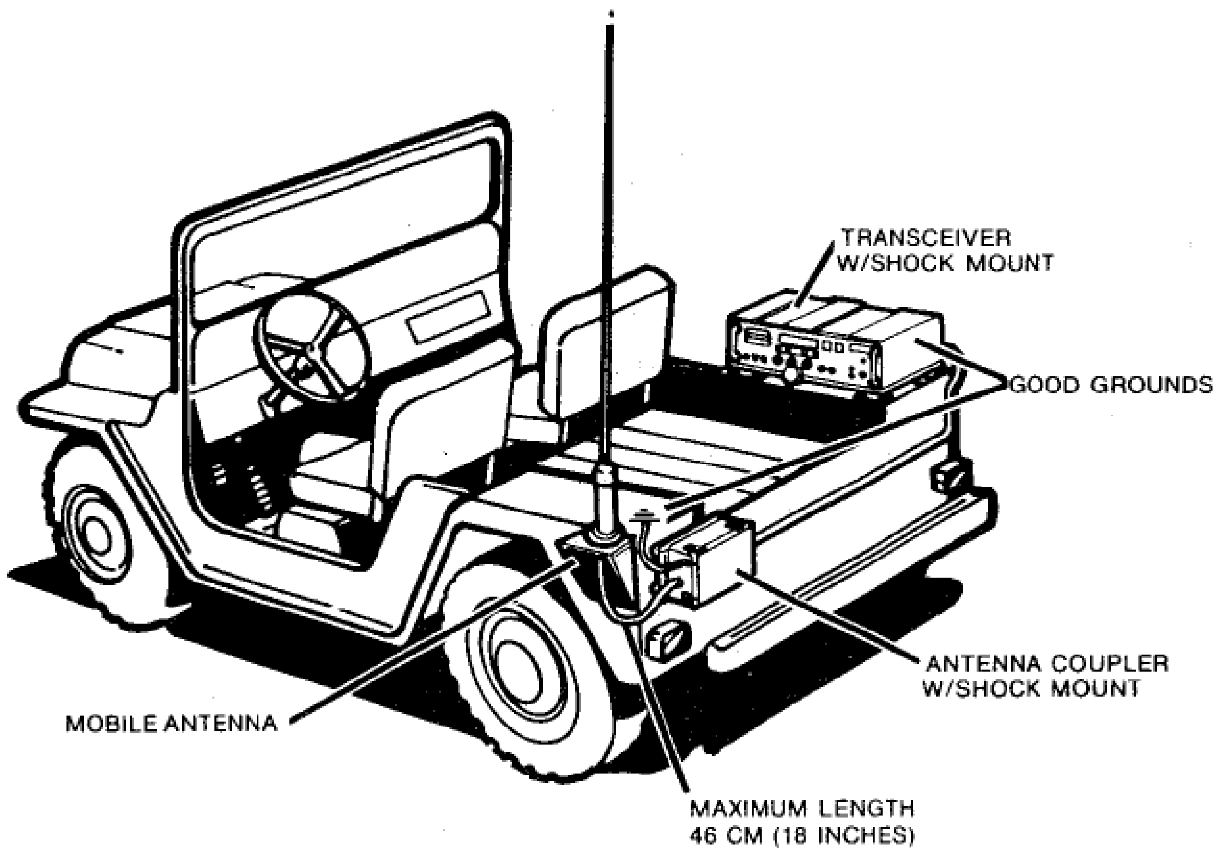


Figure 2.5 Typical Vehicle Installation

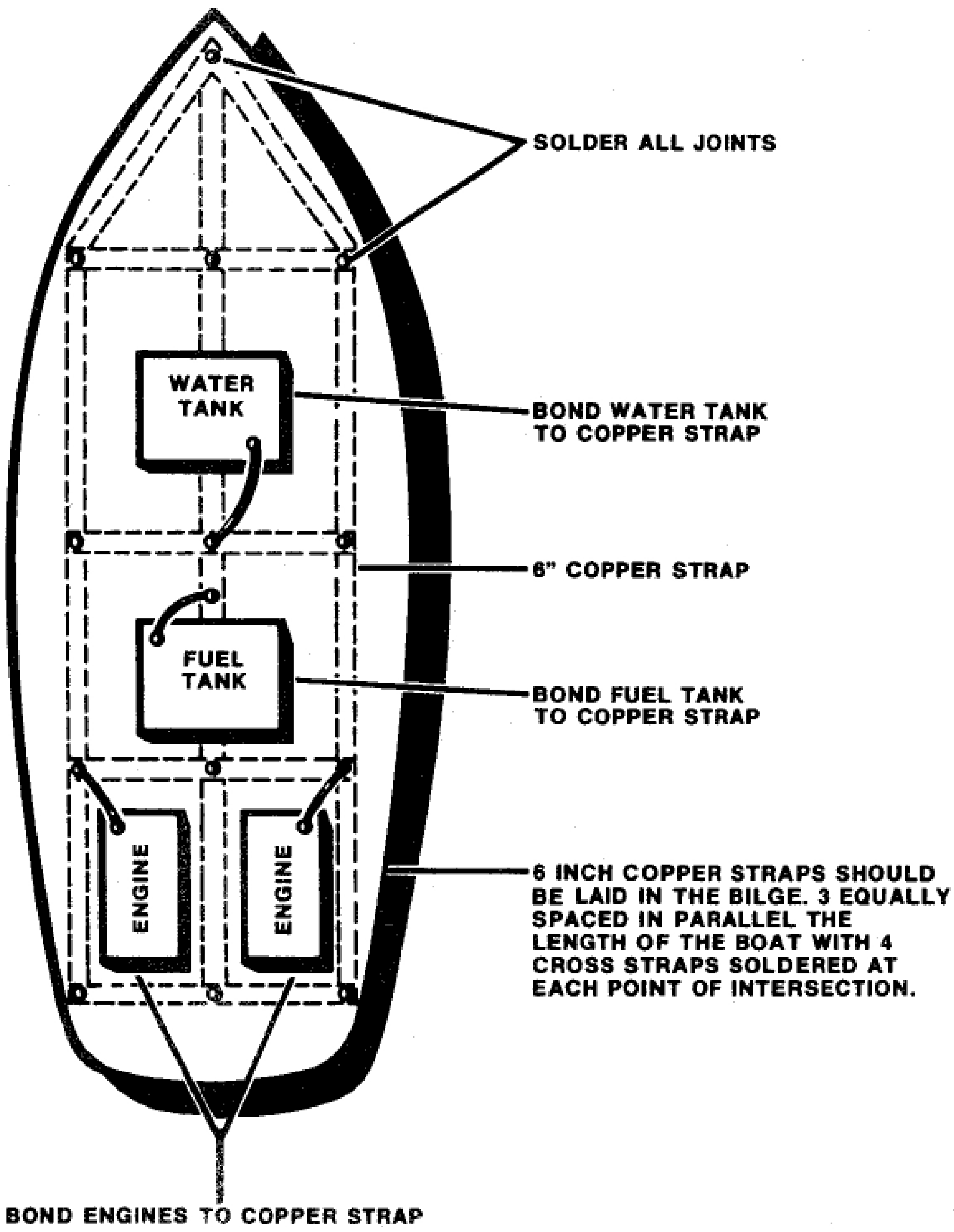


Figure 2.6 Typical Ground/Counterpoise Installation

can be substituted. Use Table 2.1 to fabricate the cable.

1) Strip approximately 1 1/8 inch of the vinyl jacket off of the control cable, Figure 2.7.

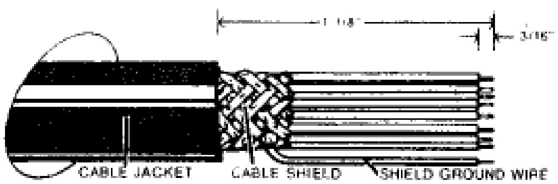


Figure 2.7 Cable End Preparation

2) Cut back the shield until there is just enough left to solder a 2 inch #18 AWG wire to the braid.

3) The socket pins can then be attached by stripping about 3/16 inch of insulation off of the end of each wire. Place the stripped end into the back of the socket pin, securing the wire by bending the ears on each pin with pliers. Then, solder each wire to its pin (Figure 2.8).

4) Push each pin into the plug body until it snaps into place. Push the extra pins into the unused positions of the connector according to Table 2.1.

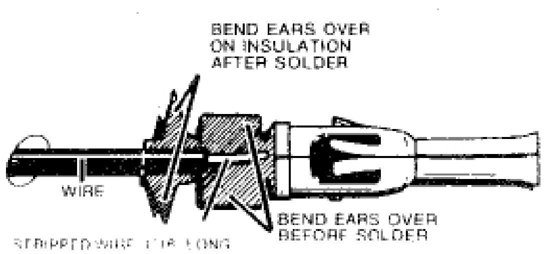


Figure 2.8 Socket Pin Preparation

NOTE

Do not push the wire into the barrel of the pin or let the solder flow too far into the barrel as this will prevent the mating pin in Connector J2, from entering the barrel.

5) With the vinyl tape, wrap behind the connector for about 3-4 inches. Before installing the plug clamp and back shell, fill the body of the plug and the shell with RTV sealant (Figure 2.9). Secure the shell and clamp and wipe the excess RTV off of the plug body.

NOTE

To remove the wire and the pin from the connector, use the extraction tool provided in the kit. Insert the tool into the front of the connector and push the barrel over the pin and push the plunger in. The tool and the pin will be ejected from the connector.

2.5 POWER REQUIREMENTS

The antenna coupler is manufactured to operate in two voltage ranges. Group 001 coupler can operate from 11.9 to 14.5V and Group 002 coupler can operate from 22 to 42 VDC. To change from one group to another requires that the DC motors be changed and some strapping be performed on the control PC board.

COUPLER (16 PIN CONNECTOR) — TRANSCEIVER or CONTROL BOX (37 PIN CONNECTOR)

PIN #	FUNCTION	PIN #
1	Reflected Power	R
2	Ground (Braid)	G
3	Forward Power	N/C
4	Ground	W
5	12 or 28 VDC	s
6	Tune Initiate	J
7	Fault	A
8	N/C	N/C
9	12 or 28 VDC	s
10	Ready	K
11	Surveillance Enable	D
12	N/C	N/C
13	12 or 28 VDC	r
14	Tune in Progress	M
15	N/C	N/C
16	Key Enable	B
	Ground	k
	Ground	C

Coupler
Control Plug, P2

Control Plug
From Transceiver
or Control Box
(Strap k & C to W)

TABLE 2.1
COUPLER CONTROL CABLE

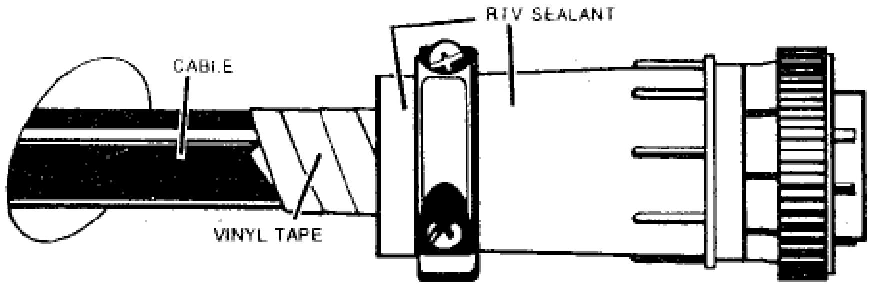


Figure 2.9 Control Cable Connector Sealing

2.6 TESTS AFTER INSTALLATION

2.6.1 ANTENNA CONSIDERATIONS

The input impedance of an antenna is influenced by many factors, such as earth conductivity, height above ground, effects of nearby conductors and dielectrics, and antenna length.

The antenna coupler contains two parallel connected 100 pf ceramic transmitting capacitors which are mounted on the rear support plate of the roller inductor. These capacitors, designated C1 and C2, may be connected in series with the output lead to the antenna and will effectively reduce the maximum value of series capacitance that is required to tune certain antennas.

2.6.2 INSTALLATION CHECKS

1) Whip Antennas: The coupler will tune whip antennas without the need for series capacitors C1 and C2. These capacitors should be shorted by a small piece of buss wire soldered across the capacitors.

NOTE

The coupler as shipped from the factory is connected for whip antenna operation (that is with the capacitors short circuited).

2) Longwire Antennas: Depending on the length and mounting configuration of longwire antennas, the insertion of C1 and C2 will normally be required. The small jumper wire across C1 and C2 need only be cut or removed to insert the capacitors in series with the output lead.

3) It is recommended that tuning be checked on the desired frequencies to ensure whether or not C1 and C2 are required for a given antenna.

2.6.3 TESTS

NOTE

It is assumed that the coupler control will come from its companion transceiver or another 125 watt transmitter with an external control head.

When the system installation is complete, perform the following tests:

1) Connect a wattmeter and a 50 ohm, 100 watt dummy load to the transceiver RF output.

2) Turn on the transceiver. The FAULT light should be illuminated (steady, non blinking).

3) Place the MODE switch on the transceiver in the AME or AM position. Key the microphone, and check forward power on several frequencies. The AME power output should be approximately 35 watts.

4) Press the TUNE button. The NOT TUNED light should be illuminated and the power output should be about 35 watts. Wait approximately 30 seconds. The transceiver should return to the receive mode and the FAULT light should start blinking.

5) Remove the dummy load and connect the wattmeter between the transceiver RF output and the RF input to the antenna coupler. Depress the TUNE button. The reflected power on the wattmeter should be less than 10 watts and the panel meter should indicate a reading on both FWD and RFL switch positions. The reflected power indicated on the wattmeter should change and finally drop to near zero. At this time, the READY light should be illuminated.

6) With the MODE switch in the AME position, key the transmitter. Check forward and reflected power to determine VSWR.

7) Check transceiver/coupler operation on all desired frequencies and note the reflected power.

2.6.4 DESICCANT INSPECTION

The coupler is protected from humidity by a rechargeable/replaceable desiccant cartridge. The cartridge has a humidity indicator located on the exposed side. The indicator should be inspected at least once every six months or, more often during adverse weather or humidity conditions.

When the center dot of the indicator turns from blue to pink, the desiccant cartridge must be replaced or recharged. Proceed as follows to recharge the desiccant:

a) Remove the cartridge from the antenna coupler.

b) Place the desiccant cartridge into an oven.

c) Heat at 300°F (149°C) for two or three hours or, until the indicator returns to its normal blue color.

d) After cooling, replace the desiccant cartridge. Ensure that the cartridge is securely tightened.

SECTION 3
OPERATION

3.1 GENERAL

This section contains information and instructions required for proper operation of the antenna coupler when used with its companion transceiver. Refer to the transceiver's technical manual for a complete technical description of coupler's operation with the transceiver.

3.2 OPERATING CONTROLS

The following controls and indicators are located on the front panel of the companion transceiver:

3.2.1 TUNE: Depressing this button initiates a tuning cycle. A momentary depression of this button is the only action required.

3.2.2 FAULT: This light is illuminated for the following conditions:

1) When the transceiver is initially turned on, a steady, non-blinking light comes on.

2) When the time delay runs out (approximately 30 seconds after initiation of a tune command) the light will blink.

3) Anytime the VSWR exceeds 2:1, except during a tuning cycle, the light will blink.

3.2.3 NOT TUNED: This light is illuminated only during a tuning cycle.

3.2.4 READY: This light is illuminated after a tuning cycle has been completed and the coupler has tuned to a VSWR less than 2:1.

3.2.5 TX POWER SWITCH

1) FWD: Indicates relative forward RF power at the input to the antenna coupler.

2) RFL: Indicates relative reflected RF power at the input to the antenna coupler. A null or low reading when transmitting indicates that the antenna is correctly matched to the transceiver.

3.3 GENERAL OPERATING PROCEDURES

Refer to the transceiver technical manual for all operating procedures.

SECTION 4
THEORY OF OPERATION

4.1 GENERAL

The automatic antenna coupler is designed to be used with the 100-150 watt class of transmitters or transceivers having a standard 50 ohm output impedance. The operation of the coupler is completely automatic and includes all network tuning, control, and monitoring functions.

4.2 SUBASSEMBLIES

The antenna coupler consists of several assemblies as described below and shown in Figure 4.1.

4.2.1 ENCLOSURE (1A1): The enclosure provides a watertight, protective environment for housing the coupler.

4.2.2 INTERFACE CONNECTOR ASSEMBLY (1A1A1): The interface connector assembly provides DC power and control line interconnections between the external control cable and coupler circuitry. A miniature slide switch for enabling the surveillance tuning feature is a part of this assembly.

4.2.3 ANTENNA INSULATOR ASSEMBLY (1A1A2): The antenna insulator assembly provides a mechanical and electrical connection between the coupler and antenna.

4.2.4 CHASSIS ASSEMBLY (1A2): The chassis assembly provides the required mounting surfaces for the other electrical and mechanical assemblies.

4.2.5 CONTROL BOARD (1A2A1): The control board contains all of the active coupler logic circuits, servo amplifiers, and the related power supply elements.

4.2.6 DETECTOR ASSEMBLY (1A2A2): The detector assembly contains the phase discriminator, magnitude discriminator, and forward and reflected power detectors.

4.2.7 ATTENUATOR ASSEMBLY (1A2A3): The attenuator assembly provides a series 3 dB pad and switching relay to limit impedance variations during the tuning cycle.

4.2.8. VARIABLE CAPACITOR (1A2A4): The variable capacitor assembly consists of the vacuum variable capacitor, its support and mounting brackets, limit switches, switch actuator, and associated hardware.

4.2.9 MOTOR/INDUCTOR ASSEMBLY (1A2A5): The motor/inductor assembly consists of the roller inductor and its limit switches, drive motors, associated belts, pulleys and idlers and the mounting surface for C1, C2, and L2.

4.3 TUNING NETWORK

The antenna tuning network consists of a series C, shunt L configuration with an auxilliary capacitor which may be inserted in series with the antenna under certain conditions. A block diagram of the antenna coupler is shown in Figure 4.2.

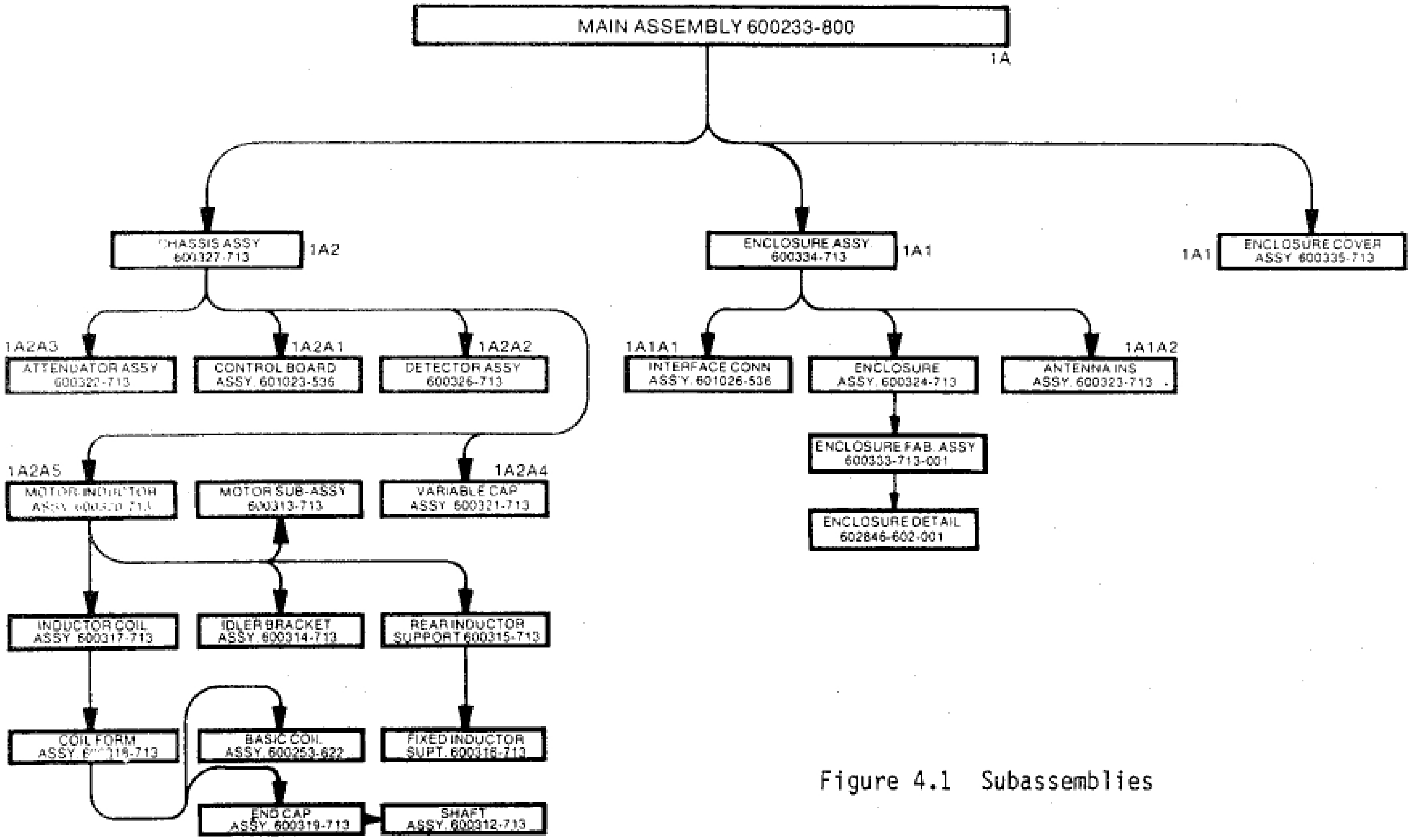


Figure 4.1 Subassemblies

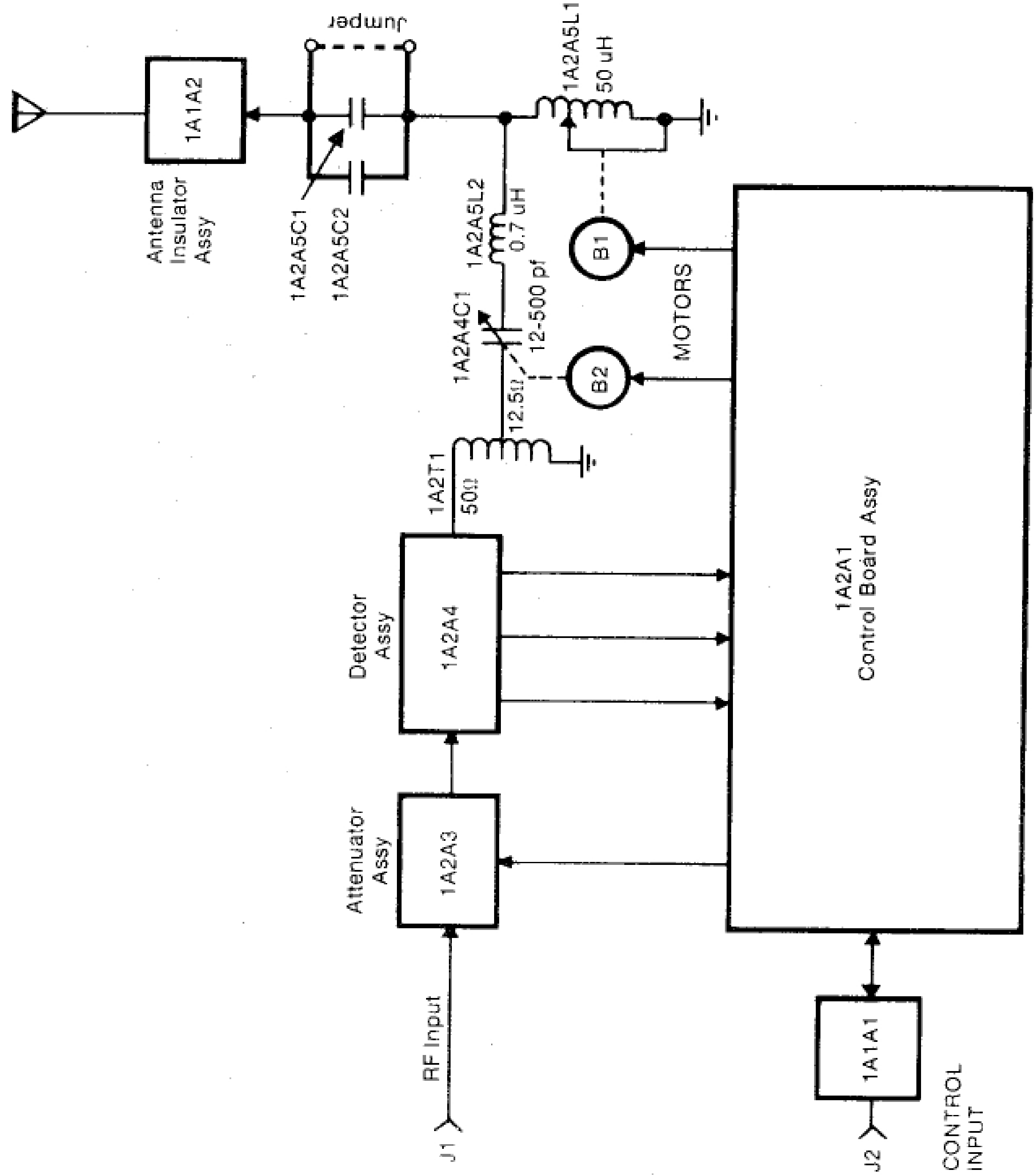


Figure 4.2 Block Diagram

C1, the series element, is a 12-500 pf vacuum variable capacitor, while L1, the shunt element, is a 0.1-50 μH variable inductor. The variable inductor has two tracking roller contacts to prevent possible self-resonances. C2 and C3 are parallel connected 100 pf ceramic transmitting capacitors that may be hard-wired in series with the antenna when using longwire type antennas. Fixed inductor L2 is a small 0.7 μH coil in series with C1 and has the effect of making the value of C1 "look" much larger at resonance. A 4:1 impedance matching transformer, T1, is used at the input of the network to provide a wider tuning range with the given values of L and C.

4.4 NETWORK CONTROL

The coupler's variable tuning elements are adjusted by two separate servo systems in accordance with the signal outputs from the detector assembly. The phase discriminator output controls the capacitor servo system and the magnitude discriminator output controls the inductor servo system. A power detector is used for metering forward and reflected power samples.

During the tuning cycle, a 3 dB attenuator is switched in series with the RF input to limit impedance variations.

4.5 DETECTOR ASSEMBLY

4.5.1 GENERAL

The detector board (Figure 4.3 and 4.4) (1A2A2) contains the phase (ϕ) discriminator, magnitude or (R) discriminator, and forward and reflected power detectors.

When the antenna has been properly tuned or matched by the reactive elements in the antenna coupler, the coupler will present a purely resistive 50 ohm load to the transmitter. If the antenna is not properly tuned, the impedance at this point may be something other than 50 ohms and either inductive or capacitive. The circuits on the detector board sense these conditions and direct the coupler's tunable elements to achieve a proper match.

4.5.2 PHASE (ϕ) DISCRIMINATOR

The function of the phase (ϕ) discriminator is to sense the reactive component and to provide a proportional DC output to the servo system that will drive the variable capacitor such that the condition is corrected.

The discriminator circuit is constructed such that the antenna current induces a voltage in transformer T1. The combination of C2 and R3 forms a divider which produces a reference voltage at the junction of R4 and R5 which is 90° out of phase with the line voltage. The combination of hot carrier diodes CR1 and CR2, along with R2, serve to limit the amplitude of this reference voltage which would change with power and frequency. The vector sum of the reference voltage and the induced voltage in T1 are detected by CR3 and CR4, filtered by C3 and C4 respectively, and summed in potentiometer R1. R1 is adjusted such that the circuit is perfectly symmetrical.

When adjusted properly, the phase discriminator output on pins 5 and 6 will be at a null (zero volts) when the antenna impedance presents a purely resistive load, as in a tuned condition. If the load is capacitive, a positive output results and causes the servo system to drive the vacuum capacitor toward maximum capacitance. If the load is inductive, the output is negative and the vacuum capacitor is driven toward minimum capacitance.

4.5.3 MAGNITUDE (R) DISCRIMINATOR

The function of the magnitude (R) discriminator is to sense the resistive component of the line impedance and to provide a proportional DC output to the servo system that will drive the variable inductor to achieve a resistive component of 50 ohms.

The discriminator circuit is constructed such that the antenna current induces a voltage in transformer T2. The combination of C1 and C6 form a divider which produces a voltage sample in phase with, and proportional to, the line voltage. L1 is provided for frequency compensation. This voltage is detected by CR5, peak filtered by C8, and will produce a positive voltage across R11 at the output. L2 is used strictly as a DC return path to ground.

When the load impedance is 50 ohms resistive, the voltage across T2 is twice the amplitude and 180° out of phase with the voltage sample produced by divider C1 and C6. The vector sum of the outputs from T2 and divider C1/C6 is detected by CR7, filtered by C9, and appears as a negative voltage across R12. Thus, when the line impedance is 50 ohms resistive, the positive voltage across R11 and the negative voltage across R12 are equal and opposite and the magnitude discriminator output on pins 11 and 12 will be at a null (zero volts), as in a tuned condition.

If the load impedance is higher than 50 ohms, a lower antenna current will result causing a lower voltage across T2 and less negative voltage across R12. The output from the discriminator will then be positive and cause the servo system to drive the variable inductor toward minimum inductance.

If the load impedance is less than 50 ohms, a higher antenna current will result causing a higher voltage across T2 and more negative voltage across R12. The output from the discriminator will go negative and cause the servo system to drive the variable inductor toward maximum inductance.

4.5.4 FORWARD AND REFLECTED POWER DETECTOR

The function of the power detector is to provide voltage samples of forward and reflected power for metering purposes and for use with the VSWR comparator on the control board.

As with the (R) discriminator, the power detector is constructed such that the antenna current induces a voltage in transformer T3. The combination of C2 and C12 forms a divider which produces a voltage sample in phase with and proportional to the line voltage. The voltage across C12 is in phase and equal in magnitude at 50 + j0 (the tune point) to the voltage developed at pin 1 of T3. These voltages, added vectorially, are rectified by CR8, peak filtered by C13, and appear as a positive DC voltage proportional to the forward power on pins 17 and 18.

The voltage across C12 is 180° out of phase with, and equal in magnitude to, the voltage developed at pin 2 of T3. These voltages are

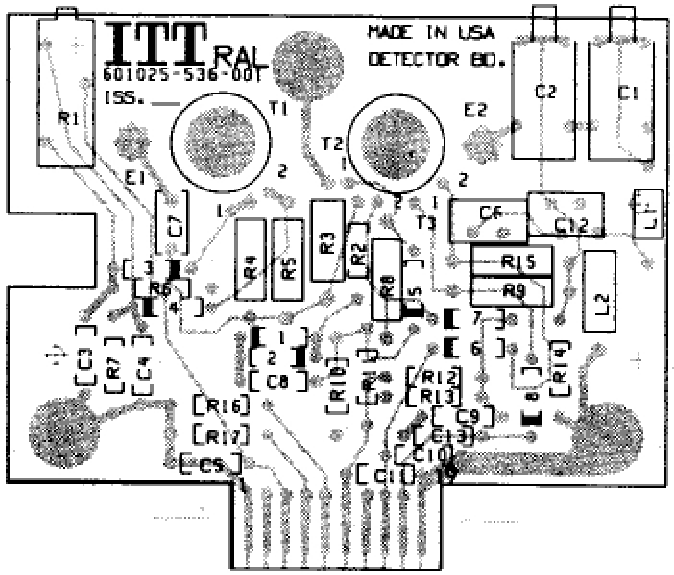
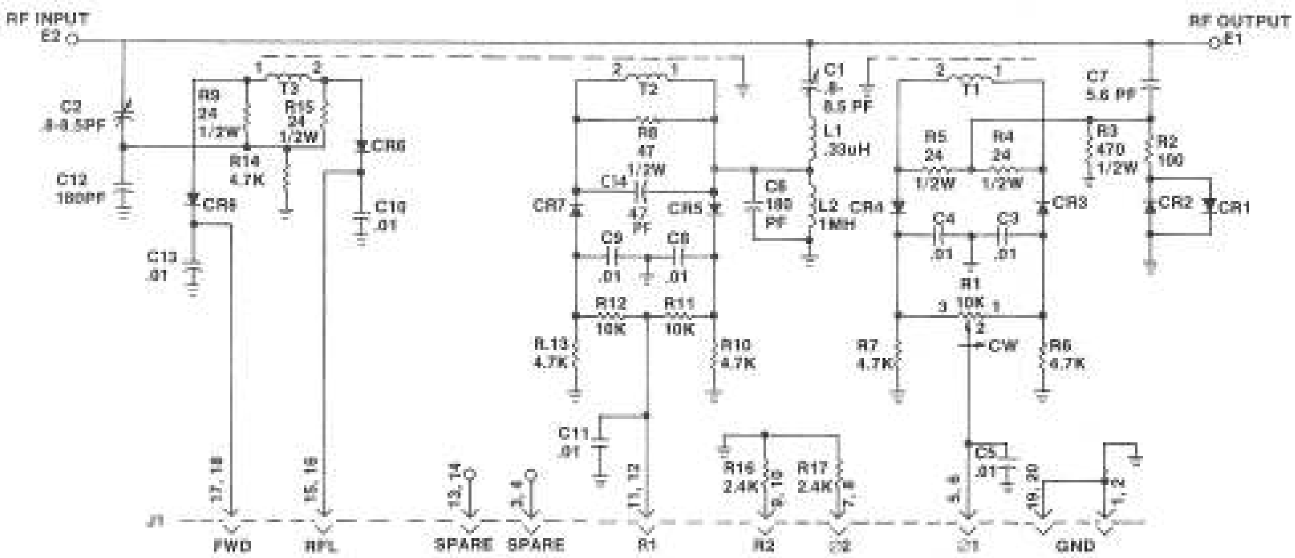


Figure 4.3 Detector Board Component Location

DETECTOR BOARD

SYMBOL	DESCRIPTION	PART NUMBER
C1, C2	Capacitor, variable, .8 - 8.5 pf	600058-217-001
C7	Capacitor, 5.6 pf	600269-314-006
C3 thru C5 C8, C11, C13	Capacitor, .01 uf, 50V	600272-314-002
C6, C12	Capacitor, 180 pf	618003-306-501
C14	Capacitor, 47 pf	647093-306-501
CR1, CR8	Diode, HP 2800	600118-410-001
L1	Coil, .33 uH	600125-376-001
L2	Coil, 1000 uH	600034-376-001
R1	Resistor, variable, 10K	600063-360-010
R2	Resistor, 100, 1/4W, 5%	610004-341-075
R3	Resistor, 470, 1/2W, 5%	647004-341-205
R4, R5, R9, R15	Resistor, 24, 1/2W, 5%	624094-341-205
R6, R7, R10, R13, R14	Resistor, 4.7K, 1/4W, 5%	647014-341-075
R8	Resistor, 47, 1/2W, 5%	647094-341-205
R16, R17	Resistor, 2.4K, 1/4W, 5%	624014-341-075
R11, R12	Resistor, 10K, 1/4W, 5%	610024-341-001
T1, T2, T3	Detector, toriod	600138-512-001



NOTES:
1. UNLESS OTHERWISE NOTED, ALL RESISTORS ARE IN OHMS AND ARE ¼ W ± 5%. CAPACITORS ARE IN MICROFARADS. ALL DIODES ARE HP-2900.
2. ALL REF. DESIGNATIONS ARE PRECEDED BY 1A2A2

Figure 4.4. Detector Board Schematic

added vectorially, and because they are 180° out of phase at 50 + j0, will cause a proportional phase shift or change in magnitude and be detected by CR6 as a reflected power voltage. This voltage is peak filtered by C10 and appears as a positive DC voltage on pins 15 and 16.

4.6 CONTROL BOARD ASSEMBLY

4.6.1 GENERAL

The control board (Figures 4.5, 4.6 and 4.7) (1A2A1) contains all of the active coupler logic circuits, servo amplifiers, and the related power supply elements. 1A2Q1, the series regulator for the power supply, is mounted external to the PC board to provide for heat dissipation requirements.

4.6.2 POWER SUPPLY

The DC input power originates from the companion transmitter/transceiver and is supplied to the coupler through the same multiconductor cable used for the control functions. From the connector board, DC power enters the control board through a 26 connector ribbon cable on connector P2, pins 23 through 26.

Because the coupler may be required to operate over a wide range of DC input voltages, the unit has been designed for the two voltage groups shown in Table 4.1.

Group	Voltage Range	Connections
001	11.9 to 14.5 VDC	E1 to E2
002	22.0 to 42.0 VDC	E2 to E3

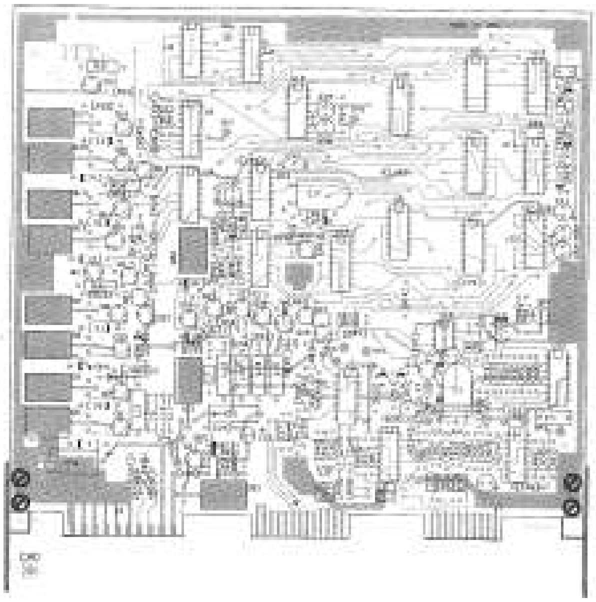
TABLE 4.1
VOLTAGE GROUPS

Configuration of a particular group requires the installation of the appropriate motors and proper strapping connections on the control board.

When operating with the Group 001 configuration, the primary power is applied directly to the servo drive system, attenuator relay, and the input to the +8V logic supply regulator, U21. The servo operating voltage is designated V_{CC}.

When operating with the Group 002 configuration, because of its wider range of input voltage, an on board 20 volt regulator is used for the V_{CC} supply. CR22 and CR23, R66 and R67, and Q31 comprise a constant current source for zener diode CR24. CR24 establishes a 20V reference voltage through Q32 to the base of the chassis mounted series regulator transistor, 1A2Q1. The regulated output from the collector of 1A2Q1 is applied, as was the primary power in Group 001, to the servo drive system, attenuator relay, and the input of U21.

The negative 5 VDC supply is obtained from a DC-DC converter and is used for powering the servo preamplifiers, comparators, and servo oscillator. IC timer U19 serves as a free running relaxation oscillator whose frequency is determined by R1, R2, and C1. The output of U19, a square wave having an amplitude of approximately 6 volts and a frequency of 125 kHz, is connected to a network consisting of C2, C3 and CR4. Series capacitor C2 causes the pulsed output to lose its ground reference before being rectified by CR3 and CR4, and filtered by C3 (the -5 VDC supply is enabled only when RF power is present. This is to insure that no noise is radiated during receive conditions).



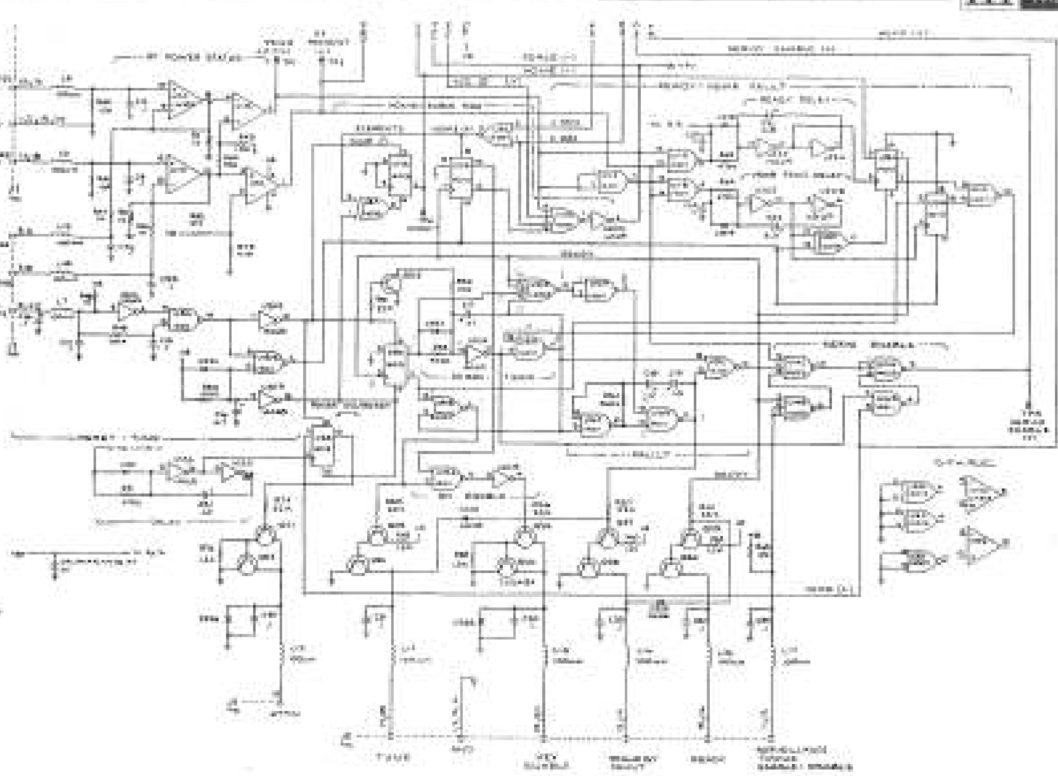
CONTROL BOARD

SYMBOL	DESCRIPTION	PART NUMBER
[illegible]	[illegible]	[illegible]

CONTROL BOARD (Continued)

SYMBOL	DESCRIPTION	PART NUMBER
[illegible]	[illegible]	[illegible]

 Figure 4.5 Control Board Component Location



LAST NO. USED:

CR29, C53, L19, E3, R98, Q26, TP9, U22

DESIGNATIONS NOT USED:

C7, C46, CR1, CR8, CR10, CR15, CR18, CR21

621023-538-001

Figure 4.6 Control Board Schematic

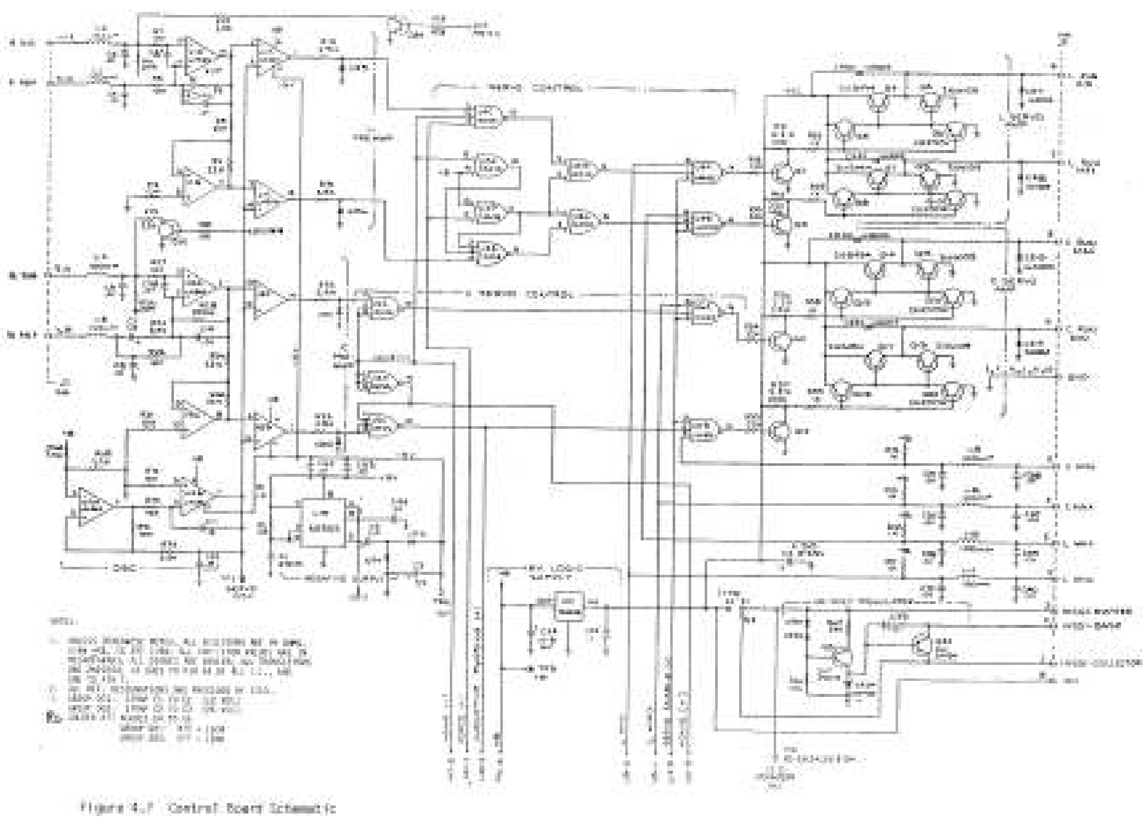


Figure 4.7 Control Board Schematic

All power supply voltages are referenced to chassis ground and can be checked at test points on the PC board as shown in Table 4.2.

TEST POINT	GROUP	VOLTAGE
TP4	001 002	12.9-14.5 DC 20.0 DC ±5%
TP5		+8 DC
TP9		-5 DC

TABLE 4.2
POWER SUPPLY VOLTAGES AND TEST POINTS

4.6.3 SERVO PREAMPLIFIER

Control information for the variable capacitor servo originates in the phase discriminator. This control signal enters the control board on P1 - pins 5 and 6 and is applied to the non-inverting (+) input of differential amplifier U5A. The inverting (-) input of U5A is connected to ground through a 2.4K resistor located on the detector board. In this manner, both inputs of U5A will be subject to the same amount of stray hum or noise pickup. Since U5A can respond only to differences between its two inputs, this unwanted noise will not be amplified.

Inductors L3 and L4, and capacitors C8 and C9 serve to remove any RF on the input lines to U5A.

The voltage gain of U5A is basically determined by the ratio of R28 to R25; therefore, the voltage gain of the preamplifier is 20. C7 and R24 comprise a damping network while C10 is used to insure that any AC on the preamp input is not amplified.

The control signal at the non-inverting input of U5A can be positive or negative as a function of the discriminator output. The output of U5A is applied through R29 to the inverting input of U5C. Since R29 and R30 are equal in value, U5C has unity gain; therefore, the voltage outputs from U5A and U5C will be equal but of opposite polarity. The outputs from U5A and U5C are also connected to the inverting inputs of comparators U5B and U5D.

The servo oscillator, made up of U12A, U12B, and associated components, produces a triangular shaped waveform having a frequency of about 300 Hz. This signal is applied to the non-inverting inputs of comparators U5B and U5D. Whenever the error signal at the inverting input of U5B or U5D exceeds the voltage at the non-inverting input, a low logic level is produced at the respective comparator's output.

A low logic level will be produced only during the period of time that the error signal exceeds the triangular signal. In this way, the analog error signal is converted into a time modulated signal whose pulse width is directly proportional to the error signal. Depending on the polarity of the error signal, this variable pulse width signal will be present on the output of either U5B or U5D. With no error signal, both outputs from U5B and U5D will be high. R32/CR11 and R33/CR12 serve to remove the negative voltage swing from the comparator's output to prevent damage to the inputs of the following CMOS IC's. Because -5 VDC is used in these circuits, they are operational only when RF power is present.

Signal input to the servo preamp for the variable inductor originates in the magnitude discriminator. Its operation is identical to that of the variable capacitor servo preamp with the exception of the RC damping network and a lower voltage gain.

4.6.4 SERVO CONTROL LOGIC

The servo control logic is used to force the servo amplifiers to drive the tuning elements in a particular direction in response to a homing or forcing signal, to disrupt the drive when the elements are at their limits, and to remove drive entirely in response to the limits or to the servo enable/disable signal. Under tuning conditions, the control logic routes the output signals from the preamplifier/comparators to the servo amplifiers.

The control logic for the capacitor servo is comprised of IC's U2A/C and U6. When a homing signal is received, the output of U6C is forced high while the output of U2C is forced low. Consequently, the output of U6B will be high and, assuming the servos are enabled and the capacitor is not at its maximum limit, the output of U6A will be low. These signals, applied to the C servo amplifier, will drive the capacitor toward its home position.

The control logic for the inductor servo is comprised of IC's U2B, U3, and U4. It is important to note that a homing and forcing function cannot occur simultaneously. By following the logic paths, it can be seen that when homing, the output from U3A is low while the output from U3B is high. Consequently, the output of U4B will be high and, assuming the servos are enabled and the inductor is not at its minimum limit, the output of U4B will be low. These signals, applied to the L servo amplifier, will drive the inductor toward its home position. When a forcing signal is applied, the output states of U4A and U4B are reversed and the inductor will be driven in the opposite direction, toward maximum inductance. Under tuning conditions, as with the capacitor servo logic, the output signals from the preamplifier/comparators are routed unchanged to the L servo amplifier.

4.6.5 SERVO AMPLIFIER (MOTOR DRIVER)

The capacitor servo amplifier consists of two complementary power transistor pairs, Q14/Q15 and Q17/Q19, that control the motor for the vacuum variable capacitor. Q13/Q16 and Q18/Q20 combine with the power transistors to form a darlington configuration. Q11 and Q12 translate the +8 volt CMOS logic levels up to V_{CC} for driving Q13/Q16 and Q18/Q20 respectively.

The two complementary transistor pairs form a bridge type circuit with the motor connected across the emitter junctions of Q14/Q15 and Q17/Q19. With no positioning signal, the bases of Q11 and Q12 are supplied with high logic levels through R34 and R35 respectively. With Q11 and Q12 turned on, no drive signals are applied to the bridge circuit and no voltage will appear across the motor.

Assuming Q11 is turned off and Q12 is turned on, then the bases of Q13/Q16 will be near V_{CC} potential and the bases of Q17/Q19 will be near ground potential. This will bias on power transistors Q14 and Q19 and bias off Q15 and Q17. The servo motor will then turn in the direction that runs the capacitor toward its home position of maximum capacitance. When Q11 is turned on and Q12 is turned off, the situation is reversed and the motor will run in the opposite direction.

During normal operation, the bases of Q11 and Q12 will often have time modulated drive voltages applied to them. The pulse width will control the speed, since the motor will integrate the pulses across it into an average voltage. By employing this type of servo, maximum motor efficiency and proportional control are maintained, even at low error voltage levels.

Operation of the servo amplifier for the variable inductor is identical to that of the capacitor servo just described.

4.6.6 POWER ON RESET PULSE GENERATOR

Upon an initial application of power, capacitor C16 charges through resistor R50. During this time, the outputs of U20D and U15B are high and are used to reset flip-flops U13, U17, and U18. After approximately 400 ms, the voltage across C16 becomes high enough to cause the outputs of U20D and U15B to go low, thus terminating the reset pulse. Diode CR20 is used for fast recovery in the event of a momentary power disruption.

4.6.7 TUNE INITIATE

A tuning cycle is initiated by a closure to ground originating at the compatible transmitter/transceiver. A short, positive going pulse is generated on the control board that resets the fault circuitry and 30 second timer, places the sequencer in the homing mode, switches in the 3 dB attenuator, and lights the tune light.

Initially, pin 9 of U15 is low and pin 8 is high. When momentary ground is placed on P2, pins 21 and 22, pin 9 of U15C immediately goes high, resulting in a low level at its output on pin 10. At the same time, C15 is discharged to ground through R49. As soon as the voltage across C15 has decreased below the logic 1 threshold, the output of U15C returns to its high state. The duration of this negative going pulse is determined by the RC time constant of R49 and C15, which is 10 ms. This "tune" pulse is inverted by U20E to become a positive going pulse.

During the 10 ms that the tune pulse is high, transistor Q33 is biased on and allows the timer capacitor, C17, to discharge through R52 to ground. With flip-flop U18A now set, C17 recharges through R53. If the coupler tunes successfully within the 30 seconds allowed, the ready line going high will reset U18A and allow C17 to quickly discharge through CR27 to ground. Should no ready signal appear, C17 will eventually be charged enough to force the output of U20F low, signifying a time out fault.

Pin 13 of U15D will go low only if a VSWR fault occurs. Thus, the output of U15D going high will indicate a general fault condition for either a time out or VSWR fault. This high level on the output of U15D enables the free running oscillator, consisting of U16C and U16D, R54, C18 and C19, and causes the fault light to blink, indicating a true fault condition.

At the same time that U18A is set, both inputs to U9B are low causing its output to be high. This, in turn, biases on transistor pair Q23/Q24 and causes the tune light to light. Should a fault occur, pin 6 of U9B goes high and the tune light will extinguish.

4.6.8 ELEMENTS HOME LOGIC

Upon receiving a positive tune pulse, flip-flop U17A is set, resulting in its Q output going low. This homing instruction, which may be checked on TP6, is used in the servo control logic to steer the tuning elements toward their home positions of maximum capacitance and mimimum inductance. When the elements are home, their limit switches make a closure to ground which is applied to the inputs of U9A causing its output to go high. This high level passes through U8A and resets U17A, thereby terminating the homing function. U8A is also used to pass the power on reset pulse to ensure the correct state of U17A at initial turn on.

4.6.9 FORCE LOGIC

The conditions required to generate the force function will normally occur only during an initial tuning operation in the low frequency range. When the elements are at their home positions, the mismatch appears as such a high impedance load that very little line current is produced. Therefore, insufficient voltage is induced in the toroidal transformers of the discriminators and no output results. To correct this condition, the variable inductor is forced to run toward maximum inductance until the line impedance changes enough to provide an output from the phase discriminator or until the VSWR falls below its 2:1 threshold. At this point, the capacitor and inductor will be actively driven from the discriminator outputs and normal tuning will be completed.

The actual circuit operation of the force function is as follows:

At the same time that U17A is reset by the elements at home signal, U17B is set, making its Q output on pin 12 low. Assuming that the VSWR is above 2:1, the output of the phase discriminator is not indicative of an inductive reactance, and the capacitor is at its home position, all four inputs of U10A will be low. The output of U10A will be high and is inverted by U20A to result in a low level. This force instruction, which may be checked on TP7, is used in the servo control logic to force the variable inductor to run toward maximum inductance. As previously mentioned, when the capacitor moves off its limit switch or the VSWR goes below 2:1, the appropriate input of U10A goes high and the force instruction is terminated. Because there is a small time delay before the capacitor actually leaves its limit switch, an output from the capacitor drive-to-minimum control logic is also applied to the input of U10A to disrupt the forcing function. By gradually removing the forcing of the inductor as the phasing goes inductive, smoother, less violent movement is achieved. When the coupler has successfully tuned, U17B is reset by a low to high transition of the ready line applied to its clock input on pin 11.

4.6.10 RF POWER STATUS

This circuit monitors both the forward and reflected power levels, as sampled in the detector module, and provides four outputs: two metering outputs and two logic outputs. U7D and U7C buffer the forward and reflected power samples respectively for the metering lines.

The forward and reflected power levels are compared in U7B. The values of R44 and R45 have been chosen such that VSWR levels less than 2:1 will produce a high logic level at the output of U7B called VSWR <2:1 (+). This level may be checked at TP1.

The RF present (+) threshold is established by the reference voltage from divider R42 and R43 at the inverting input of comparator U7A. U7A compares the forward power output of U7D with the reference voltage to produce a high logic level at its output whenever the forward power sample exceeds this reference. This logic level may be checked at TP2. This RF present signal is used to enable the servos when RF power is applied. The amount of RF power required is set at approximately 10 watts. This power threshold may be increased by raising the reference voltage to U7A. This could become necessary if the effects of a nearby transmitter causes mistuning when operating in the surveillance mode.

4.6.11 READY/FAULT LOGIC

To allow the coupler to achieve optimum matching, the elements are allowed to fine tune for approximately 2 seconds after the VSWR goes below 2:1. After this delay, the ready light will light and the servos will be switched off.

The VSWR fault circuit also has a delay in order to reject minor VSWR excursions during the final phase of the tuning cycle. A VSWR fault will occur whenever the VSWR exceeds 2:1 for approximately 1 second. This short time delay allows the surveillance tuning action to operate over a wider range of mismatch than if no delay were present. During an actual tuning cycle, the VSWR is expected to exceed 2:1 and is not considered to represent a fault condition. If a matched, ready condition is not achieved within approximately 30 seconds after a tuning cycle has been initiated, a fault condition will be indicated and the servos disabled. Likewise, failure of the elements to reach their home positions will also cause a fault condition. A fault condition, for whatever reason, is indicated by a blinking of the fault light.

When DC power is initially applied, the tuned, ready/fault status of the coupler is unknown and retuning may or may not be necessary. This condition is indicated by a steady, non-blinking illumination of the fault light. When RF is applied, the fault light will start blinking if the VSWR exceeds 2:1 or, if the coupler is already tuned, the ready light will light. The ready/fault detectors are always enabled and will display the coupler's tuned status as conditions dictate.

The actual circuit operation of the ready/fault logic is as follows:

U22A and U22F, CR18, R63, and C21 comprise the ready delay. When the VSWR goes below 2:1, pin 13 of U11D goes high. Pin 12 of U11D is also high whenever sufficient RF power is present. When the output of U11D goes low, C21 is allowed to discharge through R63. Eventually, as determined by the RC time constant of R63 and C21, the output of U22F goes high and clocks U13A. Assuming the data input of U13A is high, as is always the case except during homing, the Q output of U13A goes high, turns on transistor pairs Q29/Q30, and places the coupler in the ready mode. CR18 is used to quickly recharge C21 when the output from U11D returns high.

U22B and U22E, CR19, R64 and C22 comprise the VSWR fault delay which operates identically to the ready delay circuit only when RF power is present. U11A inverts the VSWR line so that the output of U11B goes low when the VSWR exceeds 2:1.

Assuming a ready status already exists or the coupler has just been turned on, should the VSWR exceed 2:1, the output of U22E goes high and clocks U13B. If the data input of U13B is high, as is always the case except during a tuning cycle, the Q output of U13B will go high. The data input of U13B is held low during a tuning cycle to inhibit a false VSWR fault indication.

At the same time U13B is clocked, U13A is reset. This action will remove the ready signal, if present, and make Q high. With both inputs of U11C now high, its output will go low signifying a VSWR fault.

4.6.12 ATTENUATOR CONTROL LOGIC

During the tuning cycle, a 3 dB attenuator is switched in series with the RF input to the coupler. This provides protection for the transmitter/transceiver by limiting the impedance variations while tuning. The attenuator is switched out of the circuit just prior to the completion of the tune cycle.

The actual operation of the attenuator control logic is as follows:

U18B is set by the tune pulse and turns on transistor pairs Q21/Q22. This, in turn, activates the relay on the attenuator board by completing a circuit-to-ground through Q22. Should the VSWR go below 2:1 for approximately 0.5 seconds, as determined by the time delay consisting of U22C and U22D, CR2, R3, and C51, U18B will be reset and Q22 switched off. The time delay prevents the attenuator from being removed prematurely due to minor VSWR perturbations. Likewise, the data input of U18B is held high during homing for additional protection against premature attenuator removal.

4.6.13 KEY ENABLE LOGIC

The key enable logic functions to automatically force the compatible transmitter/transceiver to produce an unmodulated carrier for tuning purposes.

The key enable condition occurs after the tuning elements have reached their home positions after a tune cycle has been initiated. The keying signal is removed after the coupler has switched to the ready mode or has faulted because of a failure to tune within the allotted time.

The key enable condition is generated at the output of U15A when both of its inputs go high. Pin 2 of U15A goes high with the tune signal while pin 1 goes high when U17B is set by the elements home signal. The output of U15A is inverted by U20B and is used to bias on transistor pair Q25/Q26.

4.6.14 SERVO ENABLE LOGIC

The servo enable logic is used to turn the L and C servo systems on and off as required. The servo system is enabled during homing and tuning, and is disabled whenever power is initially applied, if a fault condition exists, or in the absence of sufficient RF power. The servo system is normally switched off after the coupler has tuned and the ready light lights. However, should the surveillance tuning feature be enabled, the servos will remain on.

The actual operation of the servo enable logic is as follows:

U9C produces a low level at its output whenever a fault condition exists or when the coupler is initially turned on. As a result, the output of U14C and pins 1 and 2 of U14A will be forced high.

During a homing condition, both inputs to U16B will be high; therefore, the output of U16B and pin 8 of U14A will be low. This forces the output of U14A high and the servo system is enabled to allow the elements to run toward their home positions. If the elements fail to home within the allotted time, pin 6 of U16B will go low and the output of U16B will go high. With all inputs of U14A now high, the output of U14A will go low and the servo system will be switched off.

At all times other than homing, pin 5 of U16B will be low, resulting in pin 8 of U14A being high. Consequently, the servo system will be controlled by the output status of U14C. A low on any input of U14C will turn the servos off.

As mentioned previously, pin 11 of U14C will be high in the absence of a fault or initial power on and pin 12 will be high whenever sufficient RF is present. The logic state of the remaining input of pin 13 is determined by the output status of U14B. If the surveillance tuning feature is disabled, pin 4 and 5 of U14B will be pulled high through R65. When a tuning cycle is underway, the output of U14B will still be high since pin 3 of U14B will be low. However, after the coupler is tuned, pin 3 will go high with the ready signal, the output of U14B will go low, and the servos will be switched off. Should the surveillance tuning feature be enabled, either by an external switch closure to ground or by the miniature slide switch on top of the connector board, pins 4 and 5 of U14B will be pulled low and the output of U14B will be forced high.

4.6.15 SURVEILLANCE MODE

The surveillance ON/OFF switch is located on the connector assembly, 1A1A1 (see Figure 4.8). The unit is shipped from the factory with the surveillance switch in the OFF position.

When the surveillance mode is enabled (switch ON), the coupler has the capability to continuously monitor the antenna VSWR and retune the antenna whenever the VSWR exceeds a 2:1 ratio. Since RF power must be present for this to occur, this mode works best in the AME or FSK modes where a continuous carrier is present.

If a frequency or antenna VSWR change occurs which is outside the recovery range, a fault will occur.

4.7 CONNECTOR BOARD ASSEMBLY

The connector board (1A1A1, Figures 4.8 and 4.9) provides DC power and control line interconnections between the external control cable and the coupler circuitry. The control line connector is mounted on the PC board and is secured to the case by 6-32 threaded studs.

The connnector board is connected to the control board by a plug on 26 conductor ribbon cable. All lines are bypassed by axial lead capacitors on the connector board (See Figure 4.10 for all chassis interconnections).

In addition, a miniature slide switch is mounted near the top edge of the connector board. This switch provides a user serviceable method of selecting the surveillance tuning feature if an external switch is not used.

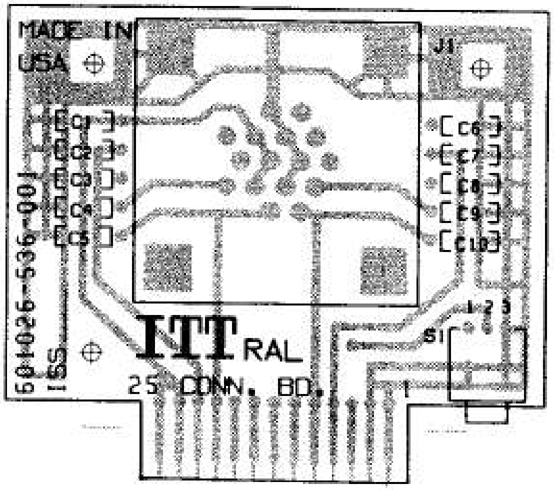
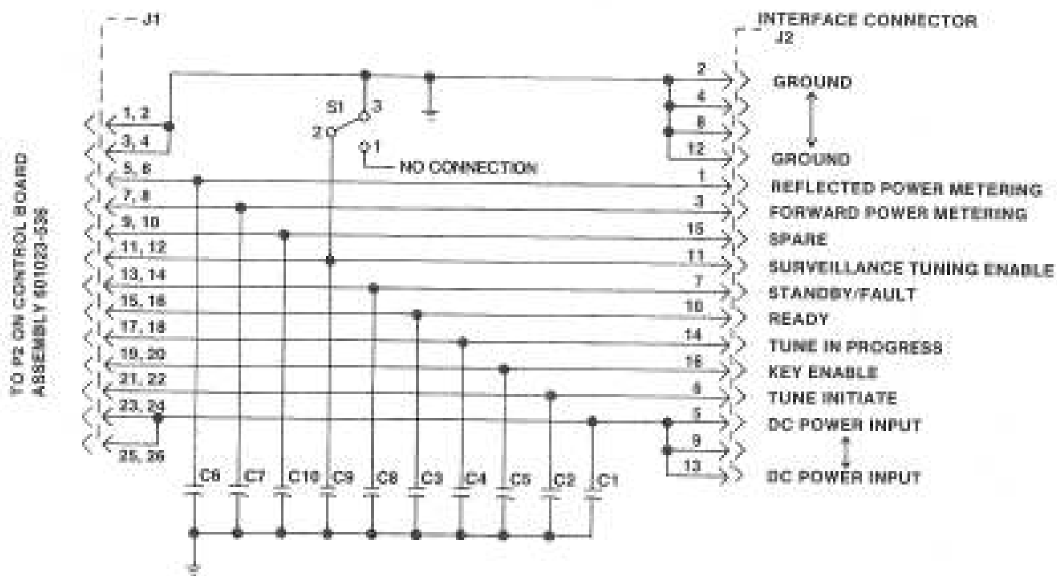


Figure 4.8 Connector Board Component Location

CONNECTOR BOARD

SYMBOL	DESCRIPTION	PART NUMBER
C1-C10	Capacitor, .1 uF, 50V	600272-314-001
J1	Connector	600363-606-001
S1	Switch, slide, SPDT	600276-616-001



NOTES:

1. ALL CAPACITORS ARE .1 uF.
2. ALL REF. DESIGNATIONS ARE PRECEDED BY 1A1A1.

Figure 4.9 Connector Board Schematic

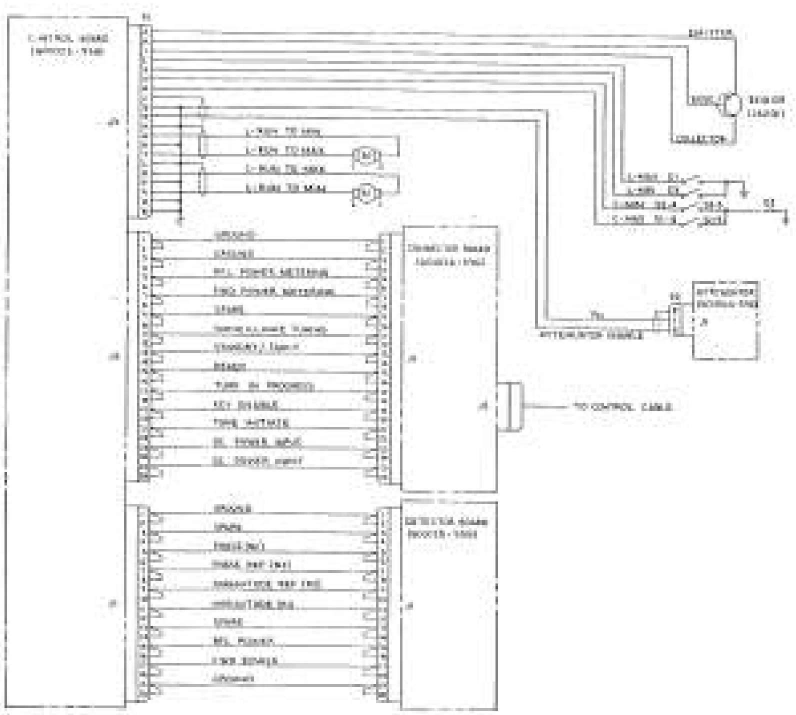


Figure 4.10 Chassis Interconnect 600327-713-301

4.8 ATTENUATOR ASSEMBLY

4.8.1 GENERAL

The function of the attenuator in the coupler (Figures 4.11 and 4.12) is to provide a series 3 dB pad to limit impedance and VSWR variations during the tuning cycle.

The attenuator pad is designed to operate over the frequency range of 1.6-30 MHz. It consists of RF input and output terminals, a relay to control the routing of the RF, a 3 dB resistor L pad, and a relay control terminal.

4.8.2 RELAY

A DPDT relay is used to route RF power from the input (E1) to the output (E2) of the attenuator board. When the relay is de-energized, it provides a direct, low loss path from E1 to E2. However, during the coupler tuning cycle, the relay is closed, routing the RF power through the 3 dB resistor pad before going to the tuning elements.

4.8.3 3 DB ATTENUATOR PAD

The 3 dB pad used in the attenuator board consists of six, 10 watt, non-inductive resistors. They are used in an L pad configuration that gives approximately 3 dB of loss, and limits worst case VSWR to a nominal 3:1. The 1k, 10W resistor, R7, serves as a wide band load for the harmonious from the amplifier. The pad has a total power handling capability of 60 watts and is required to dissipate 25 watts average power during the tuning cycle (50 watts -3 dB).

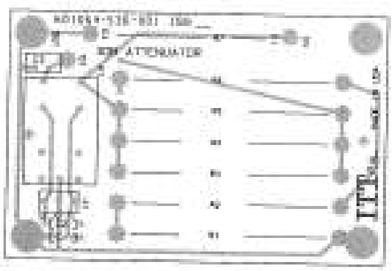
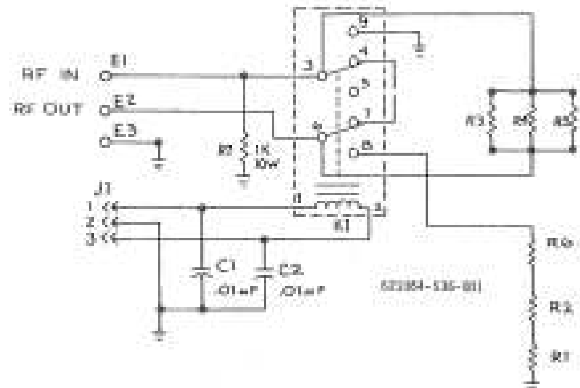


Figure 4.11 Attenuator Board Component Location

SYMBOL	DESCRIPTION	PART NUMBER
C1, C2	Capacitor, .01 uF, [illegible]	[illegible]
J1	Connector, 3 position	[illegible]
K1	Relay, DPDT, [illegible]	[illegible]
R1 thru R6	Resistor, 50 ohm, [illegible]	[illegible]
R7	Resistor, 1K, [illegible]	[illegible]



NOTES:

1. ALL RESISTORS ARE 50 OHM 10 WATT.
2. ALL REF. DESIGNATIONS ARE PRECEDED BY [illegible].

Figure 4.12 Attenuator Board Schematic

SECTION 5
MAINTENANCE AND REPAIR

5.1 GENERAL

This section provides test procedures for routine maintenance and evaluation of overall coupler performance. A fault analysis table is included to aid in the isolation and repair of a defective assembly or circuit board. Figures 5.1, 5.2 and 5.3 identify major components.

CAUTION

RF from the transmitter can cause high voltages within the coupler. Care should be taken to avoid RF burns.

5.2 TEST EQUIPMENT

The following test equipment or equivalent is required for troubleshooting and repair of the coupler:

1) Companion transceiver or equivalent source of RF power
2) Wattmeter: Bird Model 43 with 50 watt, 2-30 MHz element
3) Dummy Load: 50 ohm, 100 watt
4) HP410B VTVM or equivalent
5) Detector RF Cable Assembly (Figure 5.5)

5.3 PERIODIC MAINTENANCE

In order to assure continued trouble-free operation, the coupler should receive periodic inspection and maintenance. The desiccant should be inspected every six months following the procedure outlined in paragraph 2.6.4. In addition, the following maintenance should be performed every twelve months on the remaining components of the coupler.

5.3.1 EXTERNAL INSPECTION

Inspect the coupler for dust and other foreign particle accumulation on the antenna insulator, loose electrical connections, and evidence of arcing or corrosion. The unit should be cleaned as required using a soft cloth moistened in a mild detergent.

5.3.2 INTERNAL INSPECTION

1) The cover for the coupler is secured to the lower enclosure by 8 spring type latches.

   CAUTION

   Care should be exercised when releasing the latches to prevent their snapping up against hands or fingers.

   Inspect the neoprene cover gasket for signs of deterioration and possible water leaks.

2) Check all hardware and retighten if necessary.

3) Apply a small amount of Aero Lubriplate grease to the threaded shaft and thrust bearing assembly of the vacuum variable capacitor. The capacitor sleeve should be lubricated with 2 or 3 drops of a light machine oil.

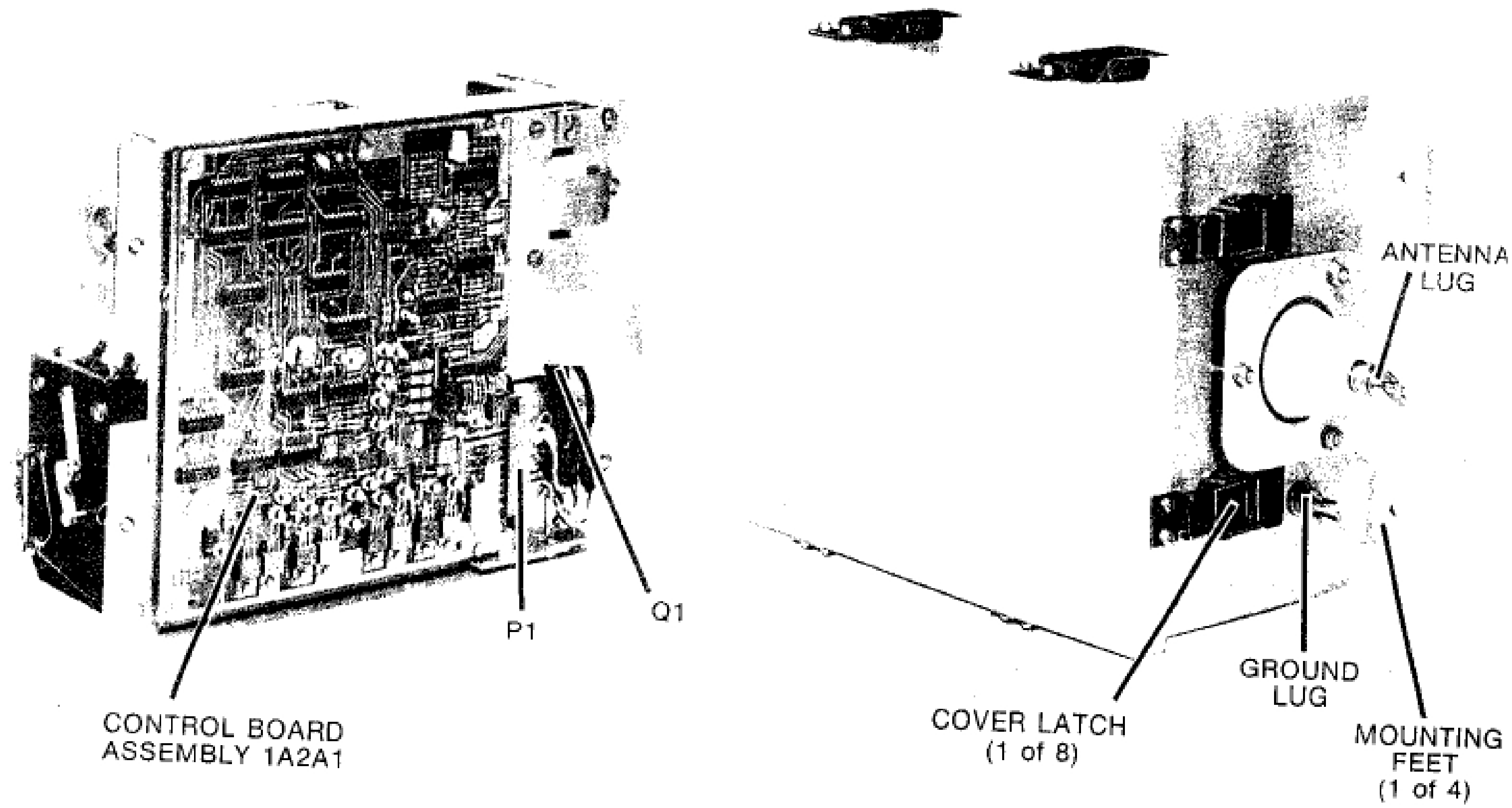


Figure 5.1 Major Component Location

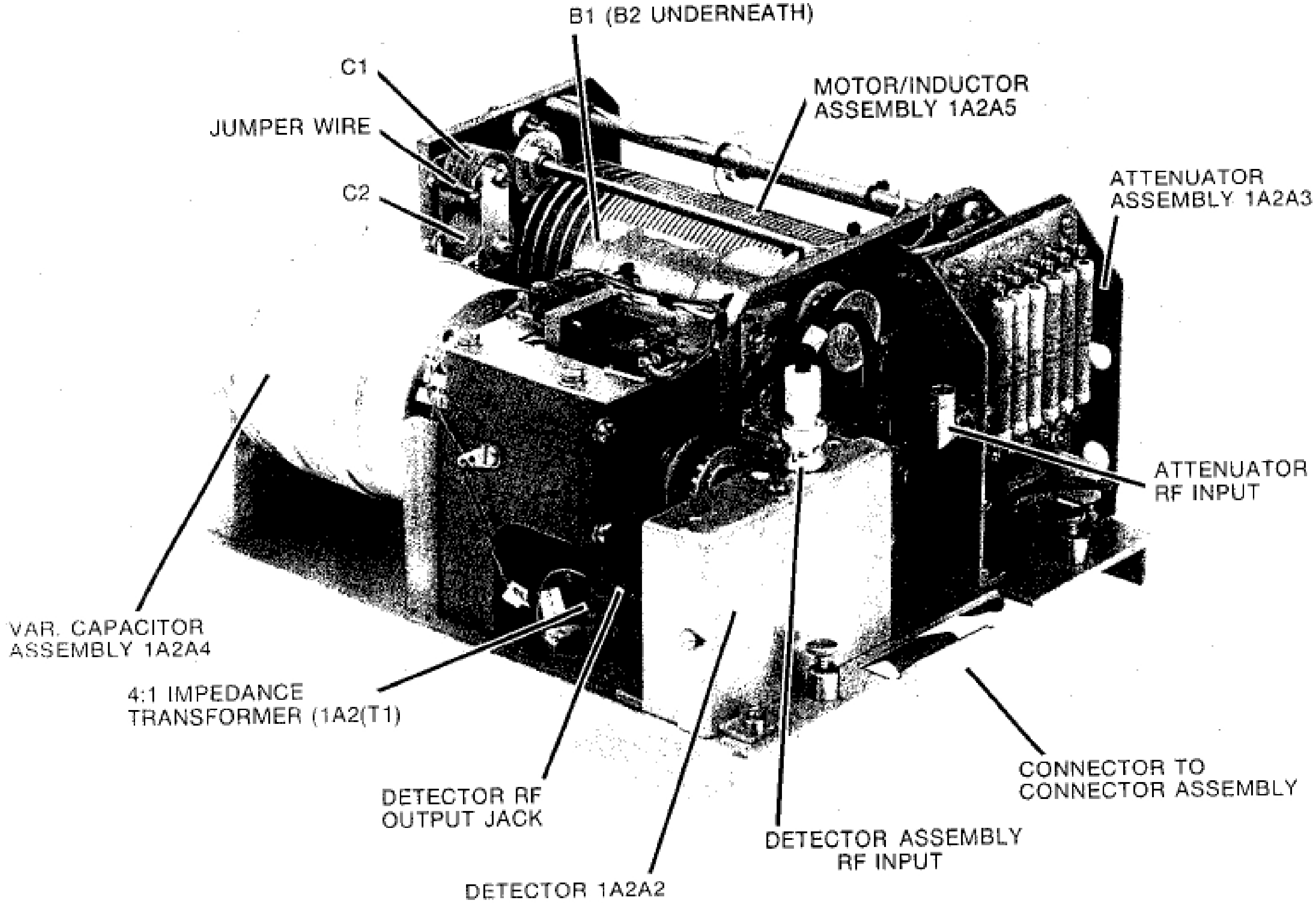


Figure 5.2 Major Component Location

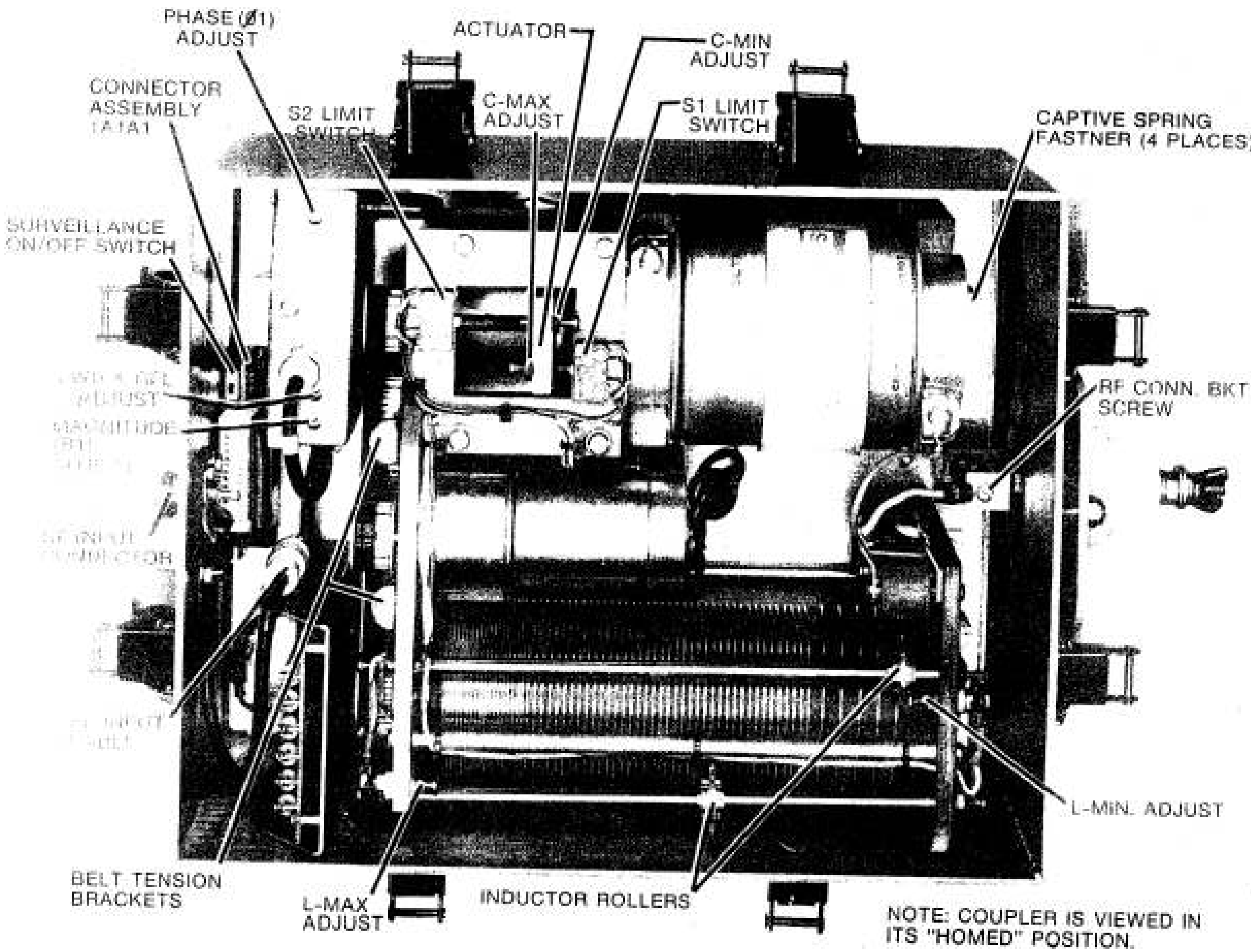


Figure 5.3 Major Component Location

4) Inspect the drive belts for wear and adjust tension if necessary. Tension adjustment will necessitate chassis removal as outlined below.

5) Lubricate the ground rods and the contact point on the rotary inductor with a small amount of cramolin paste.

5.3.3 CHASSIS REMOVAL

The chassis assembly may be removed from the lower enclosure by following the procedure:

1) Loosen the screw on the RF connection bracket that is mounted on the antenna insulator assembly and remove output wire terminal.

2) Unfasten the coaxial RF input cable at the right angle BNC connector on the attenuator assembly.

3) Loosen the 4 captive spring fasteners at each corner of the chassis with a long screwdriver.

4) Remove the ribbon connector from the interface connector board.

5) The chassis may now be lifted straight up and out of the enclosure. (The center support rod of the roller inductor and the rear end of the vacuum variable capacitor make convenient lift points.)

6) Reverse the procedure for reinstalling the chassis assembly into the enclosure.

CAUTION

Make sure that the rollers on the rotary inductor have not been moved off their respective turns.

5.3.4 BELT REPLACEMENT AND ADJUSTMENT

Belt tension for the vacuum variable capacitor and roller inductor is identical. If an adjustment is required or a belt needs replacing, the detector and attenuator assemblies may be temporarily removed for improved belt access.

Belt replacement can be achieved without the need for removing any pulleys. To remove a frayed or otherwise defective belt, loosen the two screws securing the idler bracket and work the belt off the pulleys in a manner similar to changing speed of a pulley/belt type drill press. Likewise, a new belt may be installed without removing any parts.

CAUTION

When removing and installing belts, be sure not to rotate the capacitor or inductor in a direction such that limit switch damage or a "jumped" roller may result.

Belt deflection at the center of the longest run (measured prependicular to the belt) should be between 1/8-3/16 inch. To adjust belt tension, loosen the idler bracket and press downward on the bracket's tab. Retighten the adjustment screws. If a force gage is available, belt tension may be adjusted by applying 10 ± 1 pounds of force on the idle bracket tab.

5.3.5 CAPACITOR LIMIT SWITCH ADJUSTMENTS

5.3.5.1 C Maximum Adjustment

Loosen the C maximum adjustment screw away from S1. Hand rotate the capacitor shaft counterclockwise (viewed from the pully end) until the plunger is all the way into the body of the capacitor and the actuator is flush against the capacitor body. Back the plunger out about 1/2 turn and adjust the limit switch adjustment screw to just close the switch. A switch closure may be observed by a distinct clicking sound or by a short circuit reading on an ohmmeter connected between terminal 4 of the switch and chassis ground. Tighten down the adjustment screw and back the plunger out until the switch opens. Rotate the shaft counterclockwise again until the switch just closes. There should be a small amount of play between the actuator and capacitor body of about .05 inches (1-2 mm). Readjust if necessary.

5.3.5.2 C Minimum Adjustment

From the maximum capacitance position (plunger in and C maximum switch just closed), rotate the shaft 23 1/2 turns in the clockwise direction. Set the other adjustment screw to just close the switch. Ohmmeter connections to this switch are also between terminal 4 and chassis ground. (This adjustment is not as critical as that for the C maximum limit.)

5.3.6 INDUCTOR LIMIT SWITCH ADJUSTMENTS

Refer to Figure 5.3 for the following adjustments.

5.3.6.1 L Minimum Adjustment

Connect an ohmmeter between the L minimum screw contact and chassis ground. Hand rotate the inductor clockwise (viewed from the pulley end) until the primary roller, nearest the antenna terminal, strikes the L minimum contact and the ohmmeter reads a short. Note the distance between the roller and the end of the wire on the coil form. About 5 cm (2 inches) of wire should remain on the form. If necessary, adjust the screw contact for this distance. This adjustment is very important, as too little distance may cause the roller to leave the wire and too great a distance will increase the minimum value of inductance and prevent tuning at the higher frequencies. The secondary roller should be 20 turns down from the primary roller.

5.3.6.2 L Maximum Adjustment

Connect the ohmmeter between the L maximum screw contact and chassis ground. Rotate the inductor counterclockwise until the secondary roller strikes the L maximum contact and the ohmmeter reads a short. About one turn of wire should remain on the coil. This adjustment is not as critical as the L minimum adjustment. With the secondary roller at its L maximum limit, the primary roller should be on the last active turn before the more closely spaced shorted turns section.

5.3.7 BALL GAP ADJUSTMENT

Refer to Figure 5.4 for this adjustment. The gap between the acorn nut on the antenna terminal stud and the acorn nut on the grounded bracket, should be adjusted to approximately 3 mm (.125 inches). The gap clearance is adjusted by raising or lowering the screw attached to the brackets. This adjustment is best made with the chassis assembly removed from the enclosure.

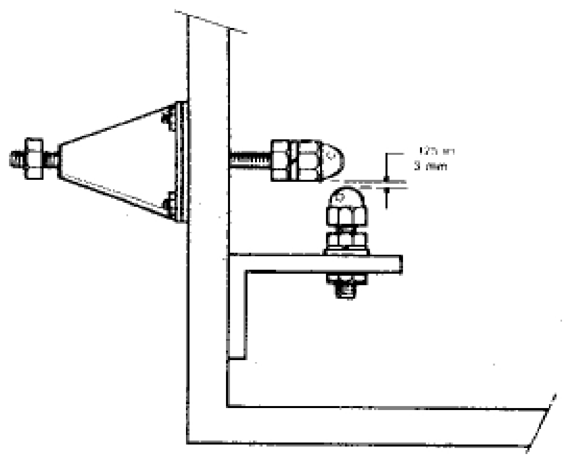


Figure 5.4 Ball Gap Adjustment

5.4 DETECTOR ASSEMBLY ADJUSTMENTS

NOTE

The adjustment of the discriminators in the detector assembly is very critical to the tuning accuracy of the antenna coupler. It should not be necessary to adjust the discriminators unless the assembly has been tampered with or components have been replaced.

5.4.1 ALIGNMENT SET UP

1) Remove the coupler chassis from the coupler case. Disconnect the banana plug jack, the RF connector from the detector assembly and the ribbon cable plug from the bottom of the detector board.

2) Construct a detector assembly cable as shown in Figure 5.5. Connect the banana plug end into the detector, connect the alligator clip to ground, and hook the RF connector up to a 50 ohm load. (It is not necessary to remove the detector assembly from the coupler chassis.)

3) Connect the test set up as indicated in Figure 5.6. Detector assembly outputs are listed in Table 5.1.

4) All adjustments are made while running 15 watts at 15 MHz with the detector assembly terminated into 50 ohms. All measurements are made at the pins of the detector board with a VTVM.

SYMBOL	DESCRIPTION	PINS
$\phi 1$	Phase Discriminator	5,6
R1	Magnitude Discriminator	11,12
FWD	Forward Power Detector	17,18
RFL	Reflected Power Detector	15,16

TABLE 5.1
DETECTOR ASSEMBLY OUTPUTS

FIG 5.5

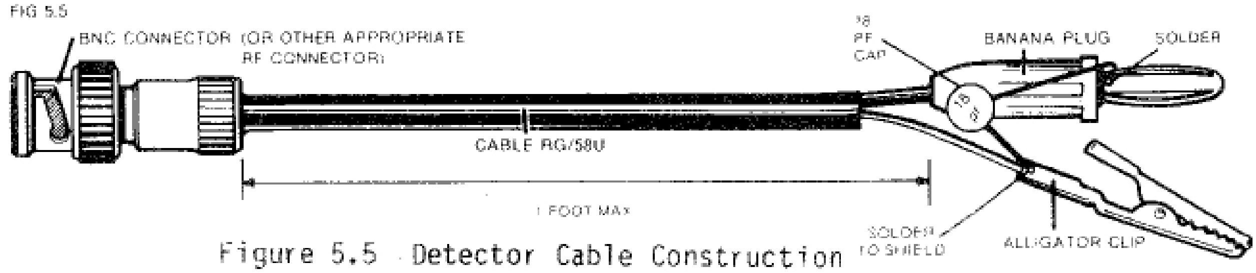


Figure 5.5 Detector Cable Construction

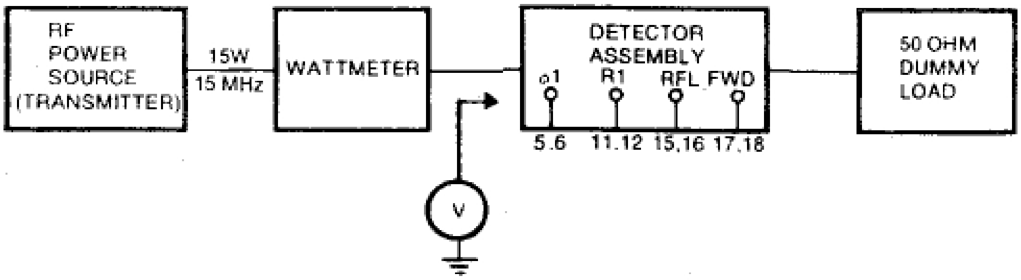


Figure 5.6 Detector Alignment Set-up

5.4.2 PHASE (ϕ1) DISCRIMINATOR ADJUSTMENT

With the RF on, check pins #5 or 6 (on the detector board) and adjust R1 for a DC null (0 VDC).

5.4.3 MAGNITUDE (R1) DISCRIMINATOR ADJUSTMENT

Check pins #11 and 12 and adjust C1 for a DC null.

5.4.4 FORWARD AND REFLECTED POWER ADJUSTMENT

Measure pin #17 or 18 and adjust C2 for 1.5 VDC output. Check pin #15 or 16 for less than 50 mv, which indicates that the reflected power is properly nulled.

5.4.5 DETECTOR OUTPUTS CHECK

To check the error output accuracy from the detector, a reactive load is needed. To accomplish this, hook the banana plug back into the detector assembly and make sure that the vacuum capacitor is in "homed" position (C maximum). Short to ground the far end of this capacitor (antenna side) and reapply the 15 watts of RF at 15 MHz. Check the four outputs for the following minimum readings: ϕ1 = -1 VDC; R1 = -.25 VDC; FWD = +1.5 VDC; and RFL = +1.5 VDC.

5.4.6 DETECTOR ASSEMBLY REMOVAL STEPS

The detector assembly may be removed from the chassis assembly by following the procedure outlined below:

1) Disconnect the RF input cable on the top of the detector enclosure that goes to the attenuator assembly.
2) Unplug the banana plug that is connected to the 4:1 impedance transformer from the RF output jack on the rear of the detector enclosure.
3) Unplug the 20 conductor ribbon cable from the bottom side of the chassis.
4) Remove the three 8-32 screws and hardware securing the detector assembly to the chassis.

NOTE

Reverse the procedure for reinstalling the detector assembly on the chassis.

5.4.7 DETECTOR ASSEMBLY SPECIFICATIONS

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
P1-19,20	--	GND	
P1-17,18	Output	V_{FWD} Forward Power	0 to 5 VDC, determined by RF power
P1-15,16	Output	V_{REL} Reflected Power	0 to 5 VDC, determined by RF power
P1-13,14	--	Spare	
P1-11,12	Output	R1 Magnitude Signal	-2 VDC to +2 VDC, proportional to magnitude error - No error = 0 VDC
P1-9,10	Output	R2 Magnitude Reference	0 VDC, used for noise cancellation on R1 line
P1-7,8	Output	ϕ2 Phase Reference	0 VDC, used for noise cancellation on ϕ1 line
P1-5,6	Output	ϕ1 Phase Signal	-2.5 VDC to +2.5 VDC, proportional to phase error - No error = 0 VDC
P1-3,4	--	Spare	
P1-1,2	--	GND	

5.5 CONTROL BOARD TROUBLESHOOTING

There are no adjustments on the control board. However, because the control board contains all of the active coupler logic circuits, servo amplifiers, and power supplies, it is a likely suspect should coupler trouble develop.

To aid control board troubleshooting, Table 5.2 contains the specifications and input/output functions of all pins on the three edge connectors.

5.5.1 CONTROL BOARD SPECIFICATIONS

1) All interface input logic functions are selected by a closure to ground (<0.5 VDC).

2) All interface logic outputs are open collector and can withstand up to +36 VDC. A circuit completion to ground (<0.5 VDC) selects the particular output function.

3) All internal logic functions are performed with CMOS devices operating from a +8 VDC supply. All CMOS IC output voltages should be either +8 VDC supply or ground, depending on logic state.

5.5.2 CONTROL BOARD TEST POINTS

Nine test points are provided on the control board to aid in troubleshooting (Table 5.3).

TABLE 5.2
CONTROL BOARD PIN INPUT/OUTPUT

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
P1-1,2	--	GND	
P1-3,4	--	Spare	
P1-5,6	Input	ϕ1 Phase Signal	-2.5 VDC to +2.5 VDC, proportional to phase error from detector module. No error = 0 VDC
P1-7,8	Input	ϕ2 Phase Reference	0 VDC used for noise cancellation of ϕ1 line
P1-9,10	Input	R2 Magnitude Reference	0 VDC used for noise cancellation on R1 line

TABLE 5.2 (continued)

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
P1-11,12	Input	R1 Magnitude Signal	-2 VDC to +2 VDC, proportional to magnitude error from detector module. No error = 0 VDC
P1-13,14	--	Spare	
P1-15,16	Input	Reflected Power	0 to +5 VDC, proportional to reflected power from detector module
P1-17,18	Input	Forward Power	0 to +5 VDC, proportional to forward power from detector module
P1-19,20	--	GND	
P2-1,2	--	GND	
P2-3,4	--	GND	
P2-5,6	Output	Reflected Power Metering	0 to +5 VDC, proportional to reflected power from detector module
P2-7,8	Output	Forward Power Metering	0 to +5 VDC, proportional to forward power from detector module
P2-9,10	--	Spare	
P2-11,12	Input	Surveillance Tuning	Surveillance tuning enable = GND Surveillance tuning disable = OPEN. (+8 VDC)
P2-13,14	Output	Standby/Fault Status	Standby = continuous GND

TABLE 5.2 (continued)

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
			Fault = Alternating GND to open circuit at 1 Hz rate
			See 5.5.1 (2)
P2-15,16	Output	Ready Status	Ready = GND
			See 5.5.1 (2)
P2-17,18	Output	Tune In Progress	Tune = GND
			See 5.5.1 (2)
P2-19,20	Output	Key Enable	Key enable = GND
			See 5.5.1 (2)
P2-21,22	Input	Tune Initiate	Tune initiate = momentary GND
			See 5.5.1 (1)
P2-23,24	Input	DC Power Input	Group 001: 11.9 to 14.5 VDC
			Group 002: 22.0 to 42.0 VDC
P2-25,26	Input	DC Power Input	Same as P2-23,24
P3-A	Output	Transistor 1A2Q1, Base	Group 001: 8.5 VDC ±5% (NOT USED)
			Group 002: 20.0 VDC ±5%
P3-1	Output	Transistor 1A2Q1, Collector	Same as P3-1
P3-2	Output	Transistor 1A2Q1, Emitter	Same as P2-23 to 26

TABLE 5.2 (continued)

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
P3-B	Output	Servo Power Supply (V_{CC}) Attenuator Relay	Group 001: 11.9 to 14.5 VDC Group 002: 20.0 VDC ±5%
P3-C	Input	Limit Switch, L Maximum	L at maximum = GND Otherwise = +8 VDC Logic Supply
P3-3	Input	Limit Switch, L Minimum	L at minimum = GND Otherwise = +8 VDC Logic Supply
P3-D	Input	Limit Switch, C Minimum	C at minimum = GND Otherwise = +8 VDC Logic Supply
P3-4	Input	Limit Switch, C Maximum	C at maximum = GND Otherwise = +8 VDC Logic Supply
P3-E, F, H, J, K, L, 10	--	GND	
P3-5	Output	Attenuator Relay	Attenuator in = GND Attenuator out = OPEN See 5.5.1 (2)
P3-6	Output	L Servo, Run to Minimum	Logic 0 < 1.5 VDC Logic 1 > V_{CC} -1.5 VDC See P3-B May have variable pulse width deter mined by error signal on P1-11,12 +.15VDC causes 50% duty cycle output for group 001 +.19VDC for group 002

TABLE 5.2 (continued)

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
P3-9	Output	C Servo, Run to Minimum	Logic 0 < 1.5 VDC Logic 1 > V_{CC} -1.5 VDC May have variable pulse width determined by error signal on P1-5, 6. -.12 VDC causes 50% duty cycle output for both groups.

TABLE 5.3
CONTROL BOARD TEST POINTS

PIN	INPUT OR OUTPUT	FUNCTION	SPECIFICATION
TP1	--	VSWR < 2:1 (+)	+8 VDC, See 5.5.1 (3)
TP2	--	RF PRESENT (+)	+8 VDC, See 5.5.1 (3).
TP3	--	Servo Oscillator	Triangular waveform, ≈ 4V P-P signal Frequency ≈ 300 Hz Low Point ≈ 0 VDC High Point ≈ 4 VDC, Present only when RF power is applied
TP4	--	Servo Power, V_{CC}	Group 001: 11.9 to 14.5 VDC Group 002: 20.0 VDC ±5%
TP5	--	Logic Power	+8 VDC, ±5%
TP6	--	Home Instruction (-)	GND, See 5.5.1 (3)
TP7	--	Force Instruction (-)	GND, See 5.5.1 (3)
TP8	--	Servo Enable (+)	+8 VDC, See 5.5.1 (3)
TP9	--	Negative Power	-5 VDC, ±5%, Present only when RF power is applied

5.5.3 CONTROL BOARD ASSEMBLY REMOVAL STEPS

To remove the control board, follow the procedure below:

1) Disconnect the two ribbon cables and 20 pin PC edge connector from the board.
2) Remove the seven 6-32 screws and washers securing the board to the chassis assembly.
3) Loosen the four 4-40 screws securing the hinge brackets to the chassis.
4) Remove the board by working the two board supports off of the hinge brackets. If necessary, one of the hinge bracket screws may be removed to allow easier board removal.

NOTE

Reverse the procedure for reinstalling the board to the chassis.

5.6 CONNECTOR BOARD ASSEMBLY

There are no adjustments on this board. Troubleshooting should require little more than a visual inspection for continuity or shorts between adjacent tracks. With the ribbon cable disconnected, an ohmmeter may be used to check for shorted bypass capacitors and proper switch operation.

5.6.1 CONNECTOR BOARD ASSEMLBY REMOVAL STEPS

Once the chassis assembly has been removed from the enclosure, the connector board assembly may be removed by the following procedure:

1) Remove the four 6-32 hex nuts and four #6 lockwashers from the studs securing the board to the enclosure.
2) Gently press on the connector from the outside of the enclosure and wiggle the board slightly to slide over the mounting studs.

NOTE

Reverse the procedure for reinstalling the board into the enclosure.

NOTE

Make sure that the gasket is properly positioned over the studs before reinstalling the board. The nuts should be tightened sufficiently and evenly to insure watertight integrity around the gasket.

5.7 ATTENUATOR ASSEMBLY

Because there are few components and no adjustments on the attenuator board, troubleshooting should require only a visual inspection and an ohmmeter check of the power resistors. Resistors R3-R5 are parallel connected and should measure about 17 ohms. Resistors R1, R2 and R6 may be checked individually and should measure about 50 ohms each.

For a quick troubleshooting check, the attenuator can be bypassed entirely by connecting the RF input cable to the detector module RF input. Be careful, as this check removes the 3 dB pad which is designed to protect the transmitter from a high reflected power.

The relay may be checked by applying between 10 and 20 VDC across connector J1, pins 1 and 3. When the relay is energized, the resistance between the RF input (E1) and ground should measure 165 $\pm$20 ohms. When relay voltage is removed, the ohmmeter should indicate an open circuit to ground and a direct short between input terminal E1 and RF output terminal E2.

5.7.1 ATTENUATOR BOARD SPECIFICATIONS

PIN	FUNCTION	SPECIFICATION
E1	RF Input	Provides RF path to Relay Contacts.
E2	RF Output	Provides RF path out of Relay Contacts.
E3	Ground	
J1-1	Relay Coil	Supplies either voltage input or logic ground to relay coil.
J1-2	Ground	
J1-3	Relay Coil	Supplies either voltage input or logic ground to relay coil.

5.7.2 ATTENUATOR ASSEMBLY REMOVAL STEPS

Normally, the attenuator assembly will only require removal when it becomes necessary to replace the roller inductor timing belt or to adjust belt tension.

To remove the attenuator assembly from the chassis, follow the steps below:

1) Disconnect the RF input cable from the right angle BNC connector.
2) Disconnect the 3 pin plug going to connector J1 on the attenuator PC board.
3) Remove the three 8-32 screws and hardware from the chassis bottom. The attenuator assembly may now be repositioned to gain access to the inductor timing belt. If complete assembly removal is necessary, disconnect the attenuator RF output cable from the detector assembly and remove the securing cable clamp from the side of the detector's enclosure.

NOTE

Reverse the procedure for reinstalling the attenuator assembly on the chassis.

5.8 FAULT ISOLATION AND REPAIR

Should a failure occur in the coupler, reference to the following troubleshooting chart should help to isolate the problem. This action should result in less time and effort to repair the unit.

5.8.1 TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE
No steady fault light at initial power turn on	1) Coupler not properly connected to transceiver. 2) Fault light burned out. 3) Power on reset circuit not working (U15B and U20C). 4) Q28 detective.
No tune light when tune cycle is initiated	1) Tune light burned out. 2) Tune pulse generator not working (U15C and U20C). 3) Q24 defective.
Tune light comes on when tune cycle initiated but tuning elements do not run	1) Motor is bad. 2) Elements already homed but coupler fails to tune (see next symptom). 3) Servo supply voltage, V_{CC}, not present or too low. (Check TP4, Group 001, Group 002.) 4) No servo enable signal. (Check TP8 for Logic 1.) 5) No homing signal. (Check TP6 for Logic 0.) 6) Pulleys loose on their shafts.
Coupler fails to tune once elements have homed	1) Key enable signal from coupler not present. 2) Q26 defective. 3) RF output from transceiver not present or too low. 4) Attenuator faulty. 5) Rollers off coil wire. 6) Excessive RF present on power or control lines.
Vacuum capacitor goes to home and shaft begins to unscrew	1) C Maximum limit switch defective. 2) Switch actuator screw improperly adjusted. 3) Broken wire to switch. 4) U6 defective.
Coupler will not tune below 4 MHz and time delay runs out	1) Inductor forcing function not operating. (Check TP7 for Logic 0.) 2) Series capacitors 1A2A5C1-C2 needs to be inserted.

5.8.1 TROUBLESHOOTING CHART (continued)

SYMPTOM	PROBABLE CAUSE
Couplers goes ready but faults on SSB or CW	1) Antenna or lead-in arcing. 2) Coupler arcing internally. 3) Improper grounding.
Excessive reflected power on all frequencies	1) Detector assembly out of alignment.
Excessive reflected power above 20 MHz	1) Roller inductor L minimum limit actuator improperly adjusted. 2) Vacuum capacitor C minimum limit actuator improperly adjusted. 3) Secondary roller not properly positioned on roller coil. 4) Series capacitor 1A2A5C1-C2 may have to be removed.
Coil rollers hit end of wire and leave track	1) Limit actuator improperly adjusted. 2) U4 defective.
Elements oscillate excessively back and forth near tuning completion	1) Loose or defective belts. 2) Excessive tuning power.
Coupler tunes properly but no FWD or RFL power readings	1) Trouble with transceiver metering circuits. 2) R47 or L19 open if no RFL power. 3) Broken cable wires.
Coupler elements go home, but will not tune or coupler faults before 30 second timer expires	1) External power supply getting excessive RF on lines or dropping out of regulation.
Rotary inductor will not move in a CW and/or CCW direction	1) Q4, Q5, Q7 or Q9 is defective on the control board. 2) Q3, Q6, Q8 or Q10 is defective.
Vacuum capacitor will not move in a CW and/or CCW direction	1) Q14, Q15, Q17 or Q19 is defective on the control board. 2) Q13, Q16, Q18 or Q20 is defective.

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