



TRANS WORLD COMMUNICATIONS, INC.

AUTOMATIC ANTENNA TUNER

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# AUTOMATIC ANTENNA TUNER

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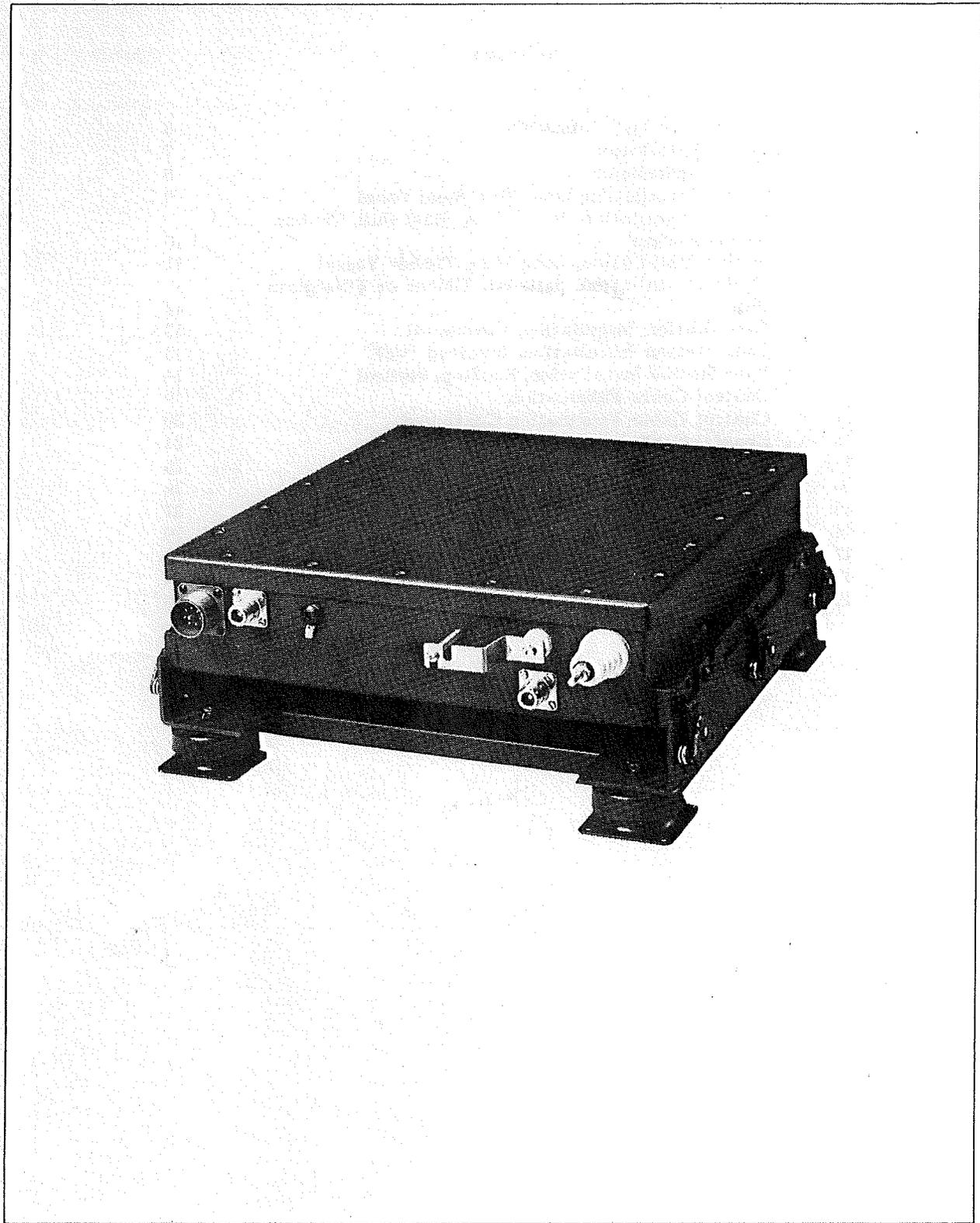
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**FIGURE 1-1. The Automatic Antenna Tuner.**

## SECTION 1

### GENERAL INFORMATION

#### 1.1 INTRODUCTION

This manual contains the information required for the installation, operation, and maintenance of the Automatic Antenna Tuner. All pertinent installation instructions, operating procedures, schematic diagrams, parts lists and servicing data are included.

#### 1.2 GENERAL DESCRIPTION

The Automatic Antenna Tuner is designed to automatically match the 50 Ohm output of the transceiver into a variety of antennas for mobile, marine and base station applications over the frequency range of 2-30MHz. All operation, including network tuning and VSWR monitoring is fully automatic and micro-processor controlled. Tuning time is typically two to three seconds.

The Automatic Antenna Tuner is designed to provide tactical security by permitting remote location of the antenna up to 250 feet from the associated transceiver. Since a radiating antenna is always a potential target under combat conditions, the transceiver and operator can be protected at a safe distance from the antenna.

#### 1.3 PHYSICAL DESCRIPTION

The Automatic Antenna Tuner is designed for continuous operation under the most severe environmental conditions.

It is contained in a rugged, waterproof, metal case which may be clamped immediately on top of the transceiver, or mounted directly to any convenient remote surface and oriented in any attitude.

#### 1.4 ELECTRICAL DESCRIPTION

The Automatic Antenna Tuner has a tuning network consisting of 9 capacitors and 11 inductors in a binary coded sequence. The tuner is configured as an L-Network with a capacitive series arm and an inductive output shunt leg. Each inductor and capacitor is inserted into the network by a relay with the inductance variable from 1.8uH to 50.0uH in 0.04uH increments, and the capacitance variable from 40pF to 800pF in 2.3pF increments.

Tuning is fully automatic. The tuner is connected to the transceiver by a 5-wire control cable. Supply voltage is 12 VDC and is normally supplied by the transceiver. Upon receipt of an INITIATE TUNE pulse from the transceiver, the tuning elements are all switched to a HOME position. The tuner generates a KEY signal which enables both the transmitter carrier output and the low-power ALC. At this time, a signal is also provided which illuminates the TUNING light on the transceiver (or activates the transceiver "tune tone"). When RF tune power is received, the tuner automatically matches the antenna to a VSWR of 1.5:1 or less within 10 seconds (typically, 2 to 3 seconds).

When tuning is completed, the coupler releases the KEY signal and disables the Tuning light (or tone) on the transceiver; normal transmissions from the transmitter are then allowed.

#### 1.5 TECHNICAL SPECIFICATIONS

Table 1 lists the technical specifications of the Automatic Antenna Tuner.

#### 1.6 SEMICONDUCTORS

Table 2 defines the semiconductors used in the Automatic Antenna Tuner.

**Table 1. Technical Specifications.**

Frequency Range:	2-30 MHz.
Tuning Capability:	
Whips	2.5-10.7M.
Long Wires	23 -46M.
Doublets	Greater than or equal to 3:1 VSWR at operating frequency.
Rated RF Input Power:	150W.
Tuning Mode:	Fully Automatic.
Tuning Accuracy:	Greater than or equal to 1.5:1 VSWR referenced to 50 ohms.
RF Efficiency:	Typically 40 to 90% depending on antenna type and frequency.
Tuning Time:	Typically 2-3, 10 second max.
RF Tune Power:	6-10 Watts Forward power throughout tuning cycle.
Primary Power Requirements:	12VDC @ 1.5A (peak), or 600A (Average).
Operating Environment:	Waterproof (sealed), designed for exposed installations.
Temperature Range:	-30° to +55°C.
Weight:	5.34 kg.
Size:	35.6 X 33.5 X 8.3cm.
RF Connections:	
Input	UG-21C type-N.
Output-doublet	UG-21C type-N.
Output-whips, wires	High voltage ceramic insulator.
Input Control Connector:	MS3106F-8-27P.
Control Lines:	
ATU Initiate	Positive-going pulse from radio enables tune cycle.
Key	Ground from tuner during tune cycle.
Ground Connection:	Ground Lug.

Table 2. Semiconductors.

<u>Designator</u>	<u>Type</u>	<u>Function</u>
D1	1N4148	Diode
D2	1N4148	Diode
D3	1N4148	Diode
D4	1N4148	Diode
D5	1N4148	Diode
D6	1N4148	Diode
D7	1N4148	Diode
D8	1N4148	Diode
D9	1N4148	Diode
D10	1N4148	Diode
D11	1N4148	Diode
D12	1N4148	Diode
D13	1N4148	Diode
D14	1N4148	Diode
D15	1N4148	Diode
D16	LED	Indicator
D17	LED	Indicator
D18	LED	Indicator
D19	LED	Indicator
D20	LED	Indicator
D21	LED	Indicator
D22	LED	Indicator
D23	LED	Indicator
D24	LED	Indicator
D25	LED	Indicator
D26	LED	Indicator
D27	LED	Indicator
D28	LED	Indicator
D29	LED	Indicator
D30	LED	Indicator
D31	LED	Indicator
D32	LED	Indicator
D33	LED	Indicator
D34	LED	Indicator
D35	LED	Indicator
D36	LED	Indicator
D37	LED	Indicator
Q1	2N4124	Detector Output Buffer
Q2	2N4124	Detector Output Buffer
Q3	2N4124	Detector Output Buffer
Q4	2N4124	Detector Output Buffer
Q5	2N4124	Relay Driver
Q6	2N4124	Relay Driver
Q7	2N4124	Key Line Transistor Driver
Q8	TIP31	Key Line Transistor
Q9	2N4124	Initiate Tune Buffer
Q10	2N4124	Reset Buffer
Q11	2N4124	Reset Buffer

**Table 2. Semiconductors, Continued.**

<u>Designator</u>	<u>Type</u>	<u>Function</u>
Q12	2N4124	Test Panel Switch
Q13	2N4124	Test Panel Switch
U1	MC1458	Op Amp; Detector Comparator
U2	MC1458	Op Amp; Detector Comparator
U3	ULN2003A	Relay Driver
U4	74LS377	Octal D Flip-Flop
U5	ULN2003A	Relay Driver
U6	74LS377	Octal D Flip-Flop
U7	ULN2003A	Relay Driver
U8	74LS377	Octal D Flip-Flop
U9	COP402N	Microprocessor
U10	74LS373	Octal Latch
U11	2716	16K bipolar PROM
U12	4013BCP	Dual D Flip-Flop
U13	7805	5 VDC Regulator

## SECTION 2

### ANTENNA TYPES

#### 2.1 GENERAL

The Automatic Antenna Tuner is designed primarily for use with end fed unbalanced antenna such as whips and long wires. The radiating portion of the antenna is connected directly to the tuner through a high-voltage ceramic insulator. It is extremely important that the antenna type, site location, and grounding technique be correctly chosen so that the system will radiate effectively.

Broad-band resonant antennas (e.g., log periodic) that cover the full range of the system may be used with the tuner if desired. Narrow-band resonant antennas, such as dipoles, may only be used if the antenna VSWR (including coaxial feeder) is greater than or equal to 3:1 at the operating frequency. In both of these cases connection to the tuner is made through the type-N input connector.

#### 2.2 SELECTION

The Automatic Antenna Tuner will operate into almost any end fed antenna with a length of 2.5 meters or more, provided an effective ground is used. The antenna efficiency will be proportional to length and in most applications will be maximum at a length of 1/4 wavelength. This means that the longest possible antenna should be selected for each installation. Very short antennas are only recommended where there is no other alternative such as in a vehicular mobile installation. The performance of short whip antennas is always very poor, particularly at the lower channel frequencies, and radiation efficiencies will be only a few percent.

#### 2.3 WHIP - 2.5M (8')

This antenna is recommended only for vehicular mobile installations. The short length will result in poor performance compared with the longer antennas.

#### 2.4 WHIP ANTENNA - 7.0M (23')

This antenna is recommended for marine installation in smaller vessels. It may also be used in base stations if there is no way of using a longer antenna.

#### 2.5 WHIP ANTENNA - 10.7M (35')

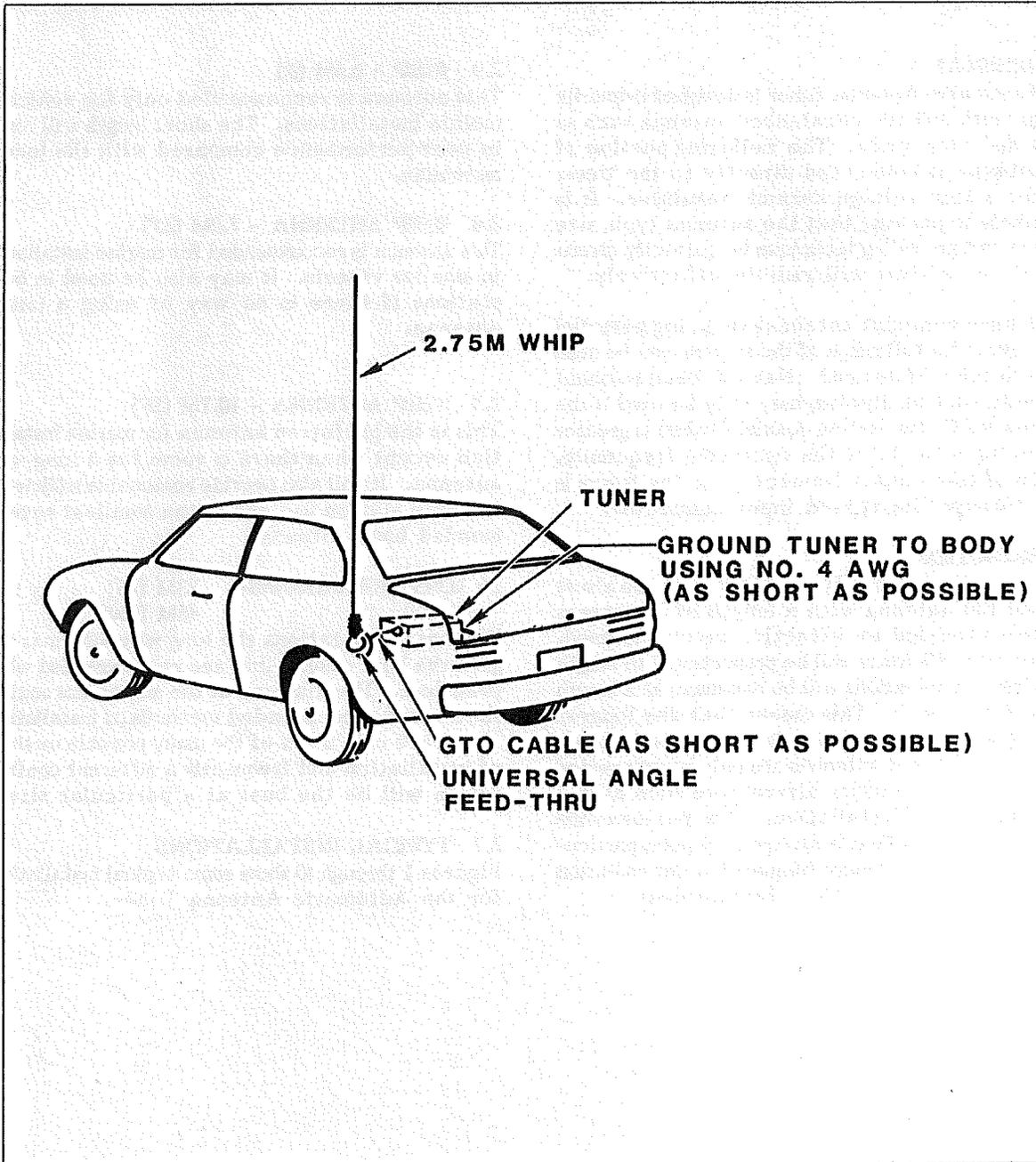
This is the preferred antenna for marine installation except when there is room for a long wire antenna. It will also provide reasonable efficiency for base station use and is the smallest recommended base antenna.

#### 2.6 LONG WIRE ANTENNAS- 23M (75') 46M (150')

For most applications the long wire antennas will give the best results and are recommended when practical. The diagrams at the end of this section show some recommended methods of installation. These are only a few of the many possible methods of installation and frequently a different configuration will be the best at a particular site.

#### 2.7 TYPICAL INSTALLATIONS

Figures 1 through 10 show some typical installations for the Automatic Antenna Tuner.



**Figure 1. Automobile Installations, Whip.**

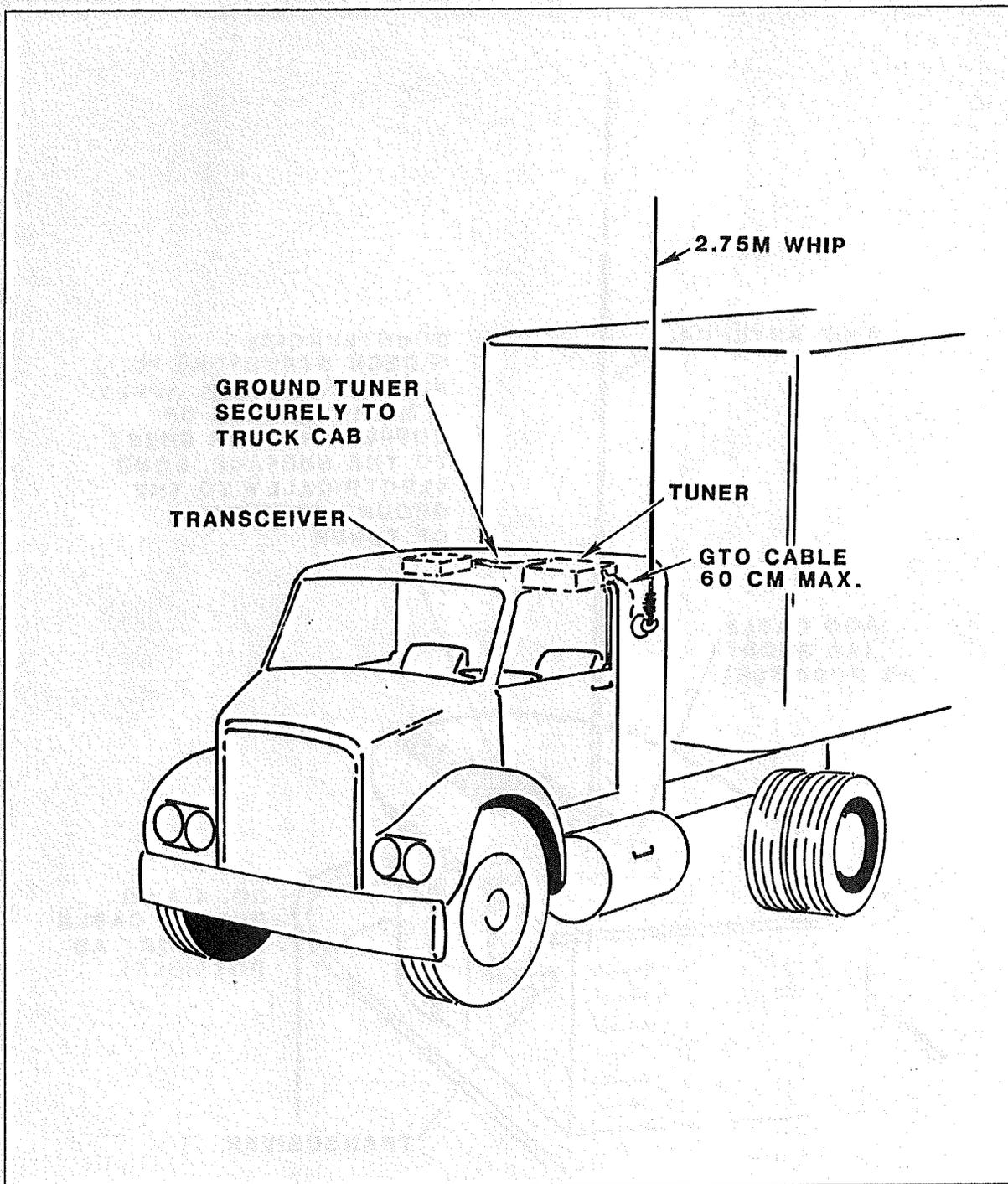


Figure 2. Truck Installation.

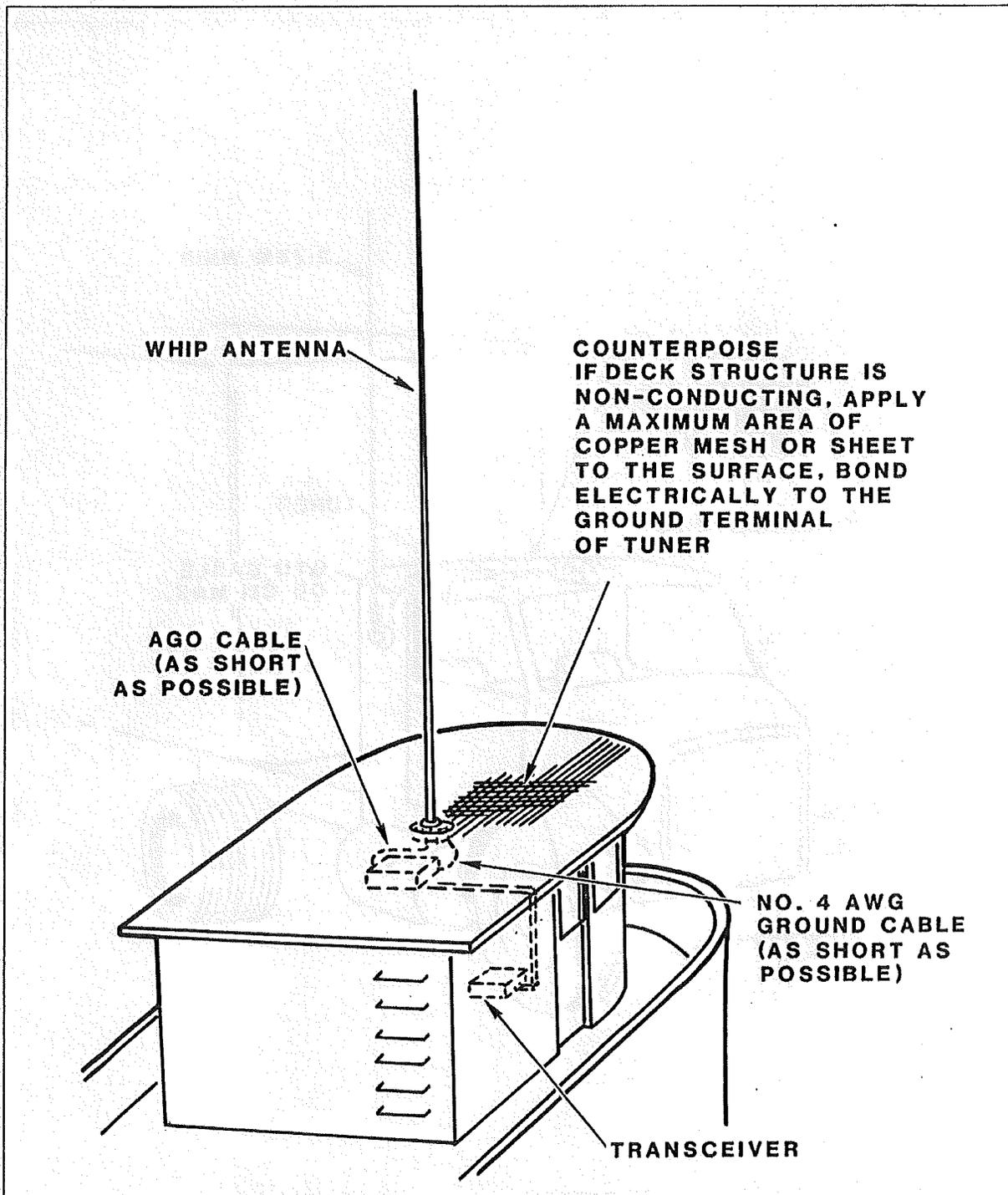


Figure 3. Marine Installation, Whip.

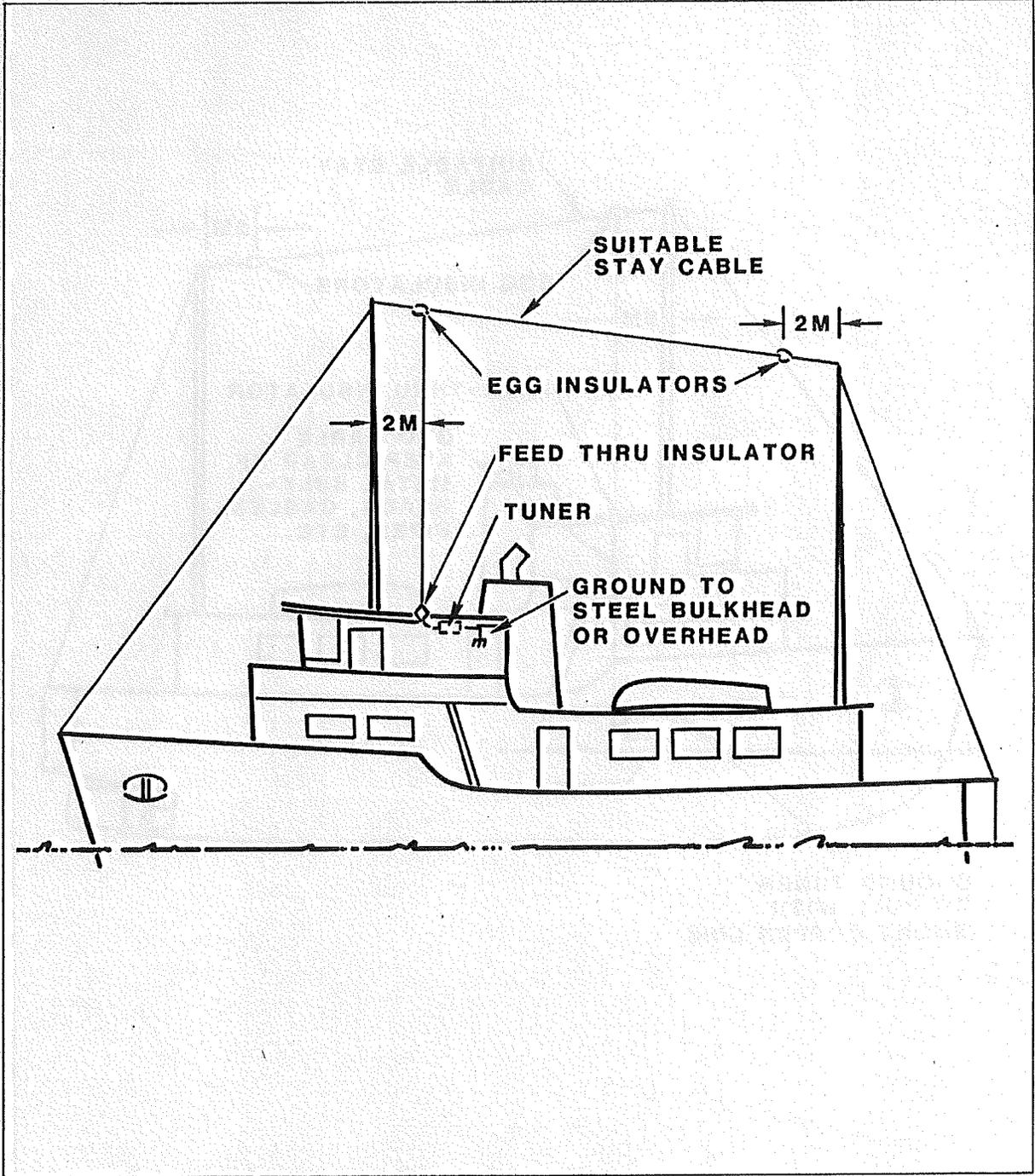


Figure 4. Marine Installation, Long Wire, Steel Vessel.

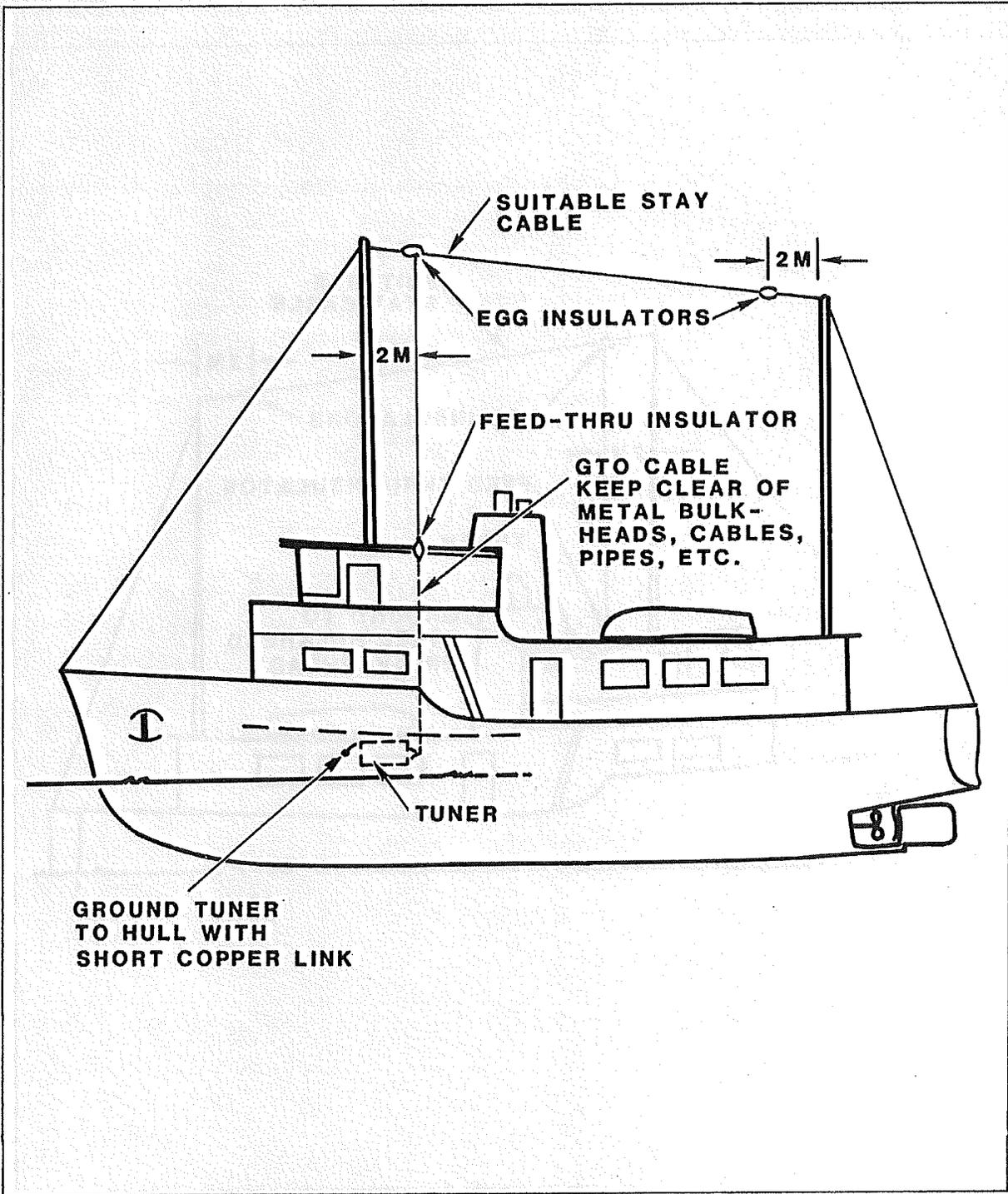


Figure 5. Marine Installation, Long Wire, Steel Hull, Timber Superstructure.

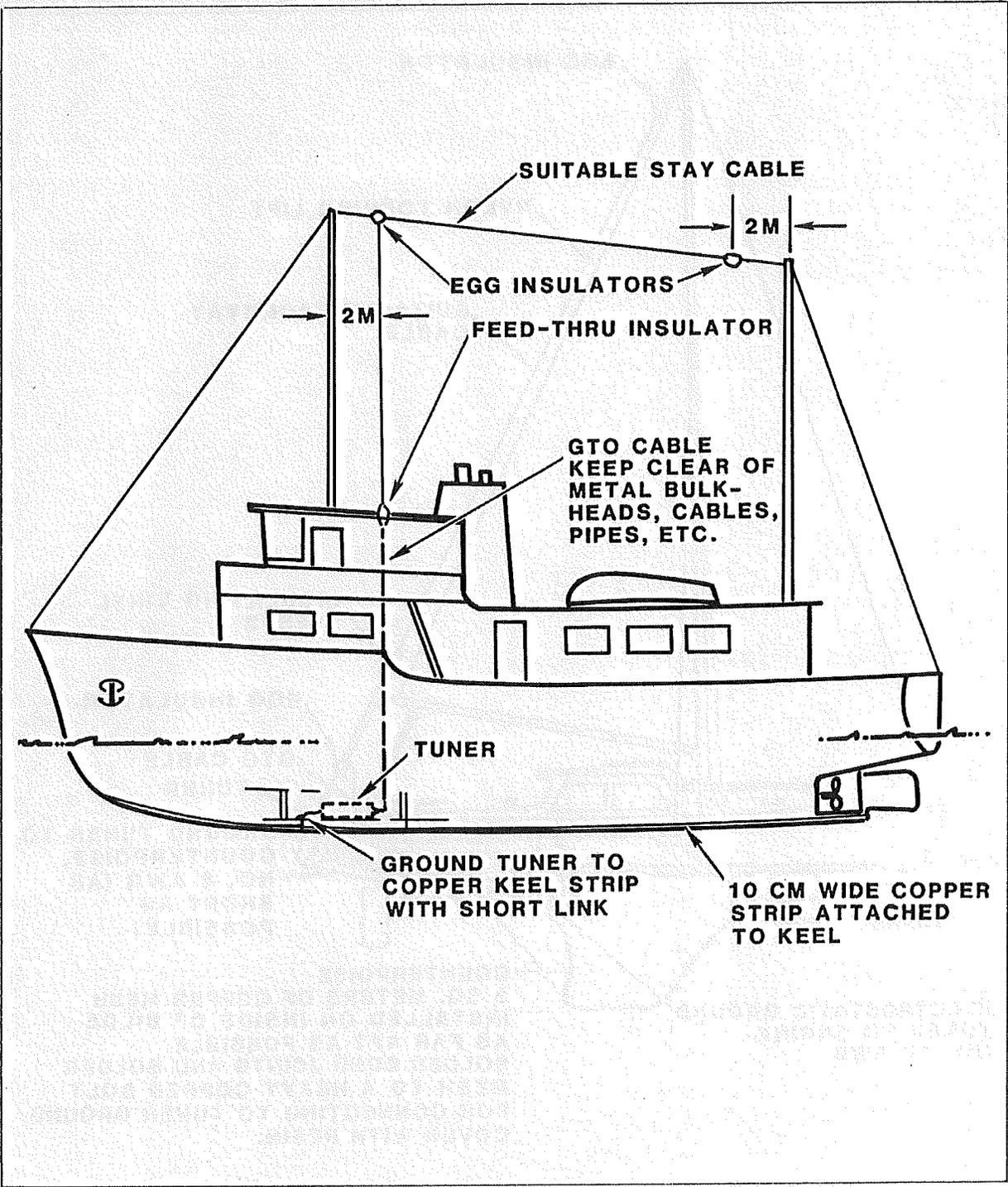
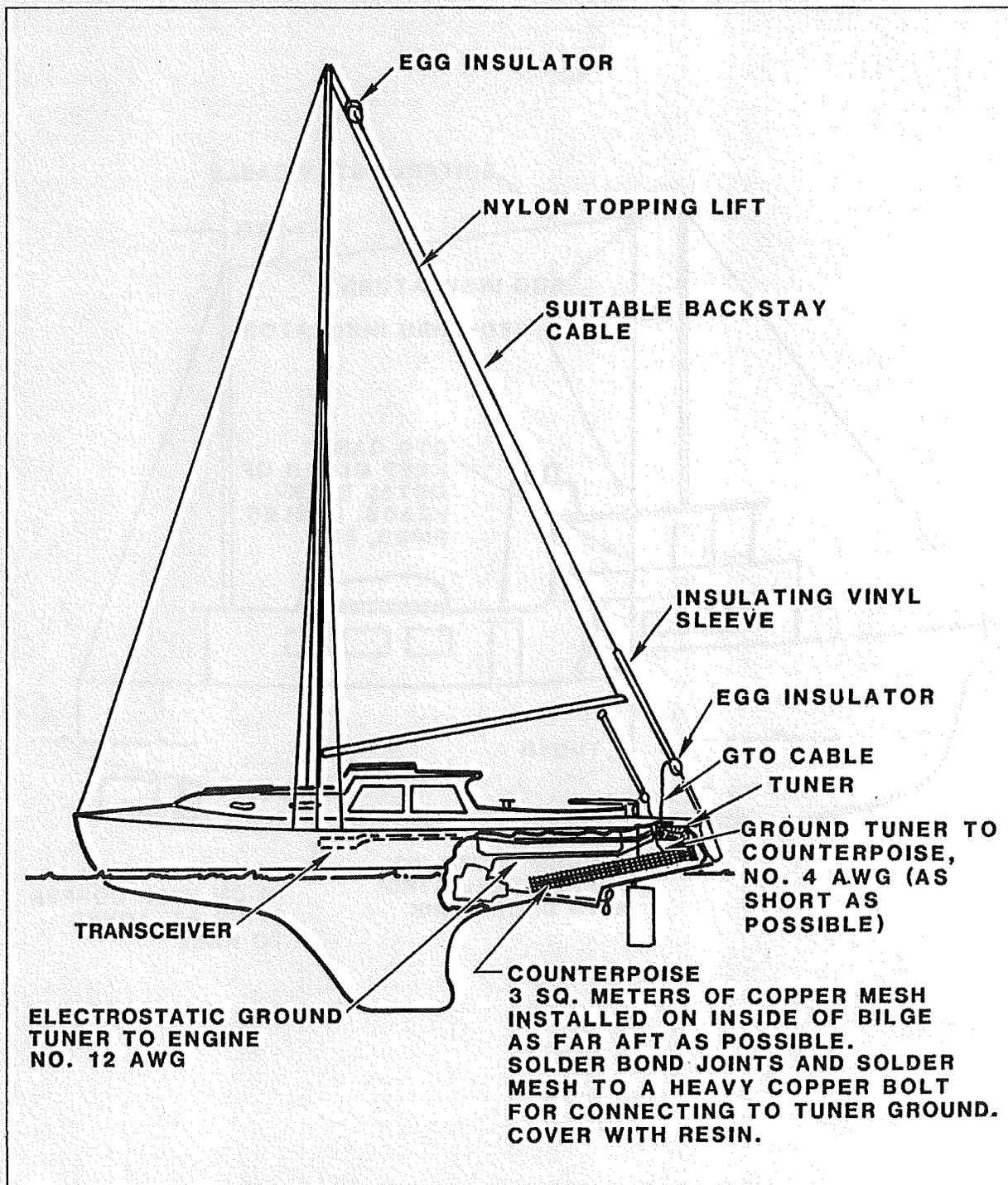


Figure 6. Marine Installation, Long Wire, Timber Vessel.



**Figure 7. Marine Installation, Sailboat, Timber or Fiberglass Hull.**

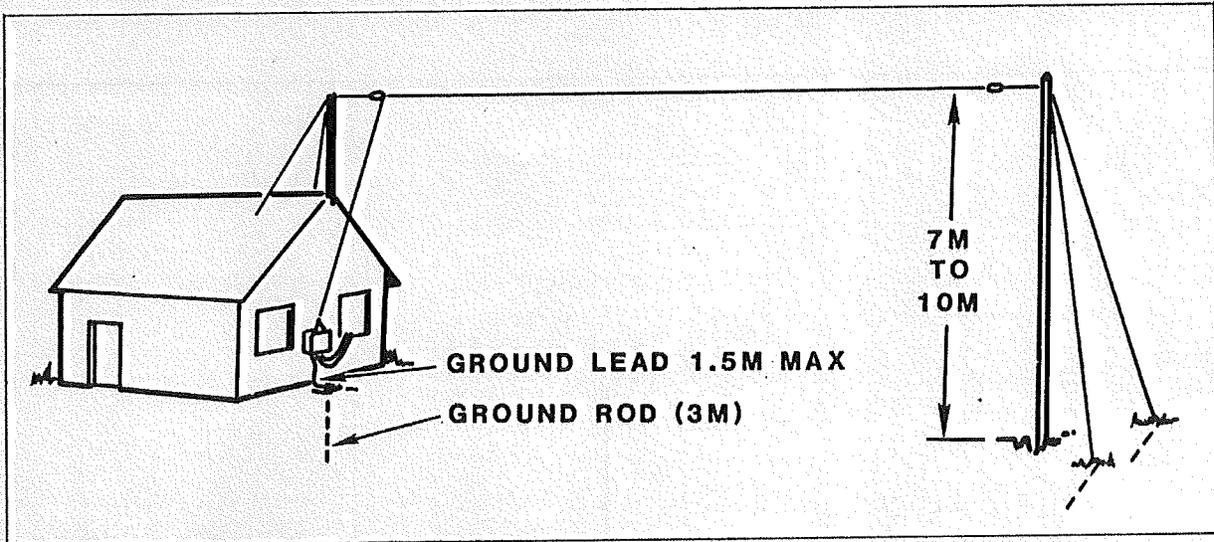


Figure 8. Base Station Installation, Horizontal.

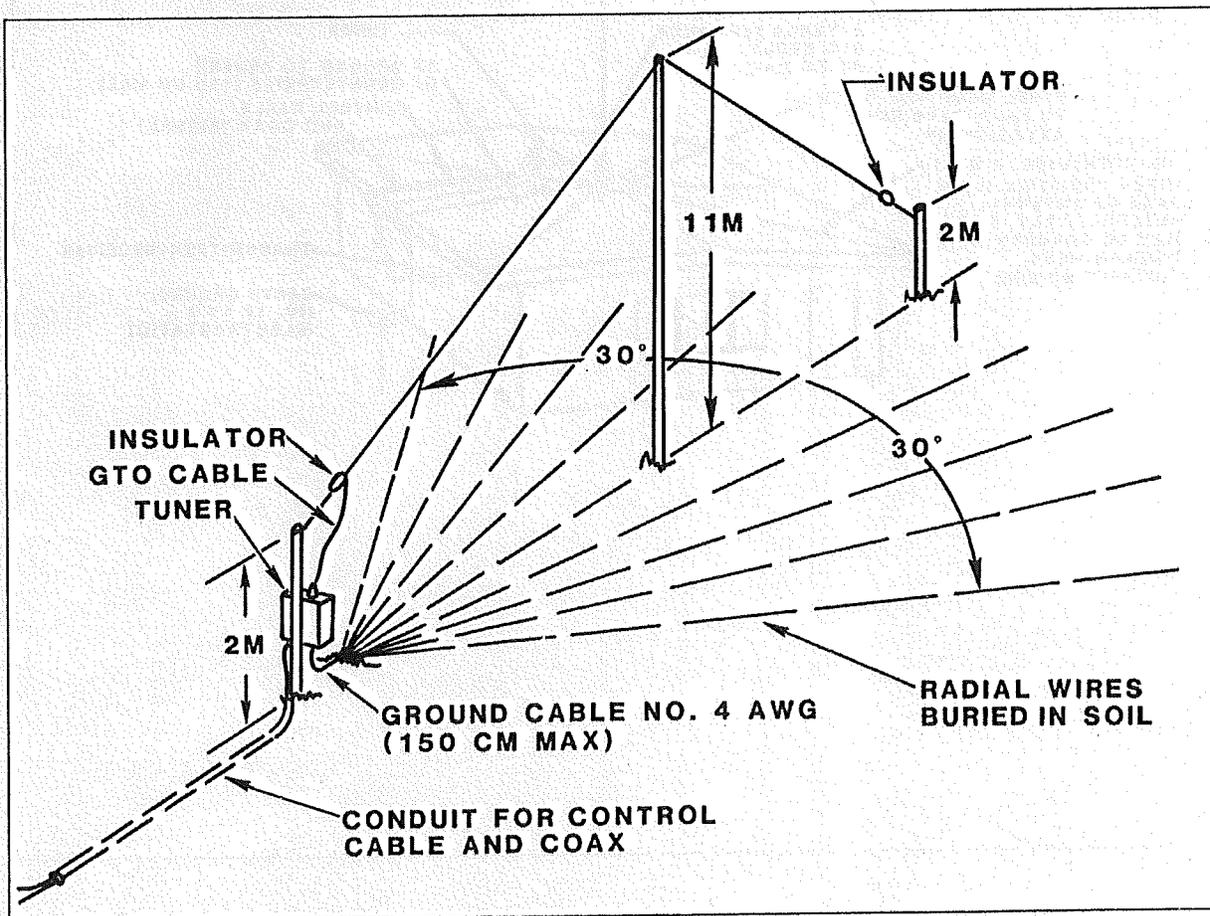


Figure 9. Base Station Installation, Inverted "VEE".

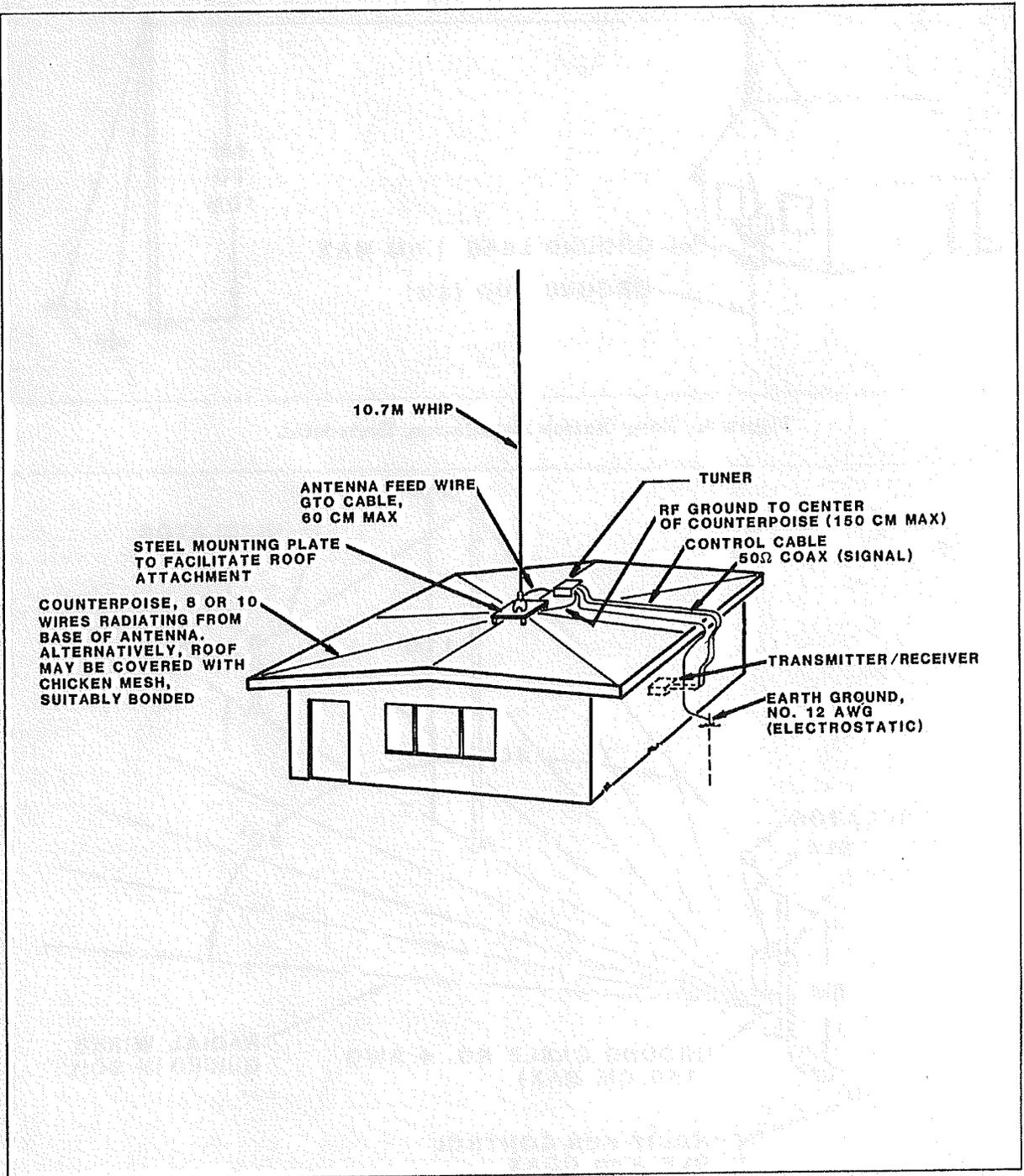


Figure 10. Base Station Installation, Rooftop, Vertical.

## SECTION 3

### ANTENNA INSTALLATION

#### 3.1 GENERAL

The antenna system is a key part of the communication system and for satisfactory operation the system must be installed correctly. The unbalanced antennas used with the Automatic Antenna Tuner use the ground as half of the antenna system. The ground forms an "image" antenna and is a critical part of the system. This makes it essential to consider both the ground and the antenna when designing the system.

#### 3.2 ANTENNA LOCATION

The diagrams in Section 2 illustrate several different antenna installations. The following points should be carefully considered when designing the antenna system.

a. The antenna should be located in a position free of obstructions, particularly in the desired direction of communication.

b. The antenna should be kept as far away as possible from buildings, trees and vegetation. If metallic masts or supports are used, arrange the insulators so that the antenna is spaced at least 2 meters from the mast.

c. Remember that the radiating part of the antenna starts at the tuner.

The location of the bottom portion of the antenna is important.

d. Vertical antennas have an omni-directional radiation pattern and will provide equal performance in all directions.

e. Horizontal wire antennas have maximum radiation broadside to the antenna when the frequency is less than  $1/4$  wavelength. As the frequency increases beyond  $1/4$  wavelength lobes will appear in the radiation pattern with the principal lobes becoming closer to the plane of the antenna as the length increases. At all times, radiation will be minimum at the end of the antenna and it should be located so that the ends point in directions where communications are not required.

f. The "VEE" construction minimizes the directivity of the horizontal antenna and is recommended for

all around coverage. In addition the "VEE" antenna is a compromise between vertical and horizontal polarization and will give good results for communications with land or marine mobiles using vertical whip antennas.

g. High voltages (sometimes exceeding 5000 volts) are present on the antenna. All parts of the antenna and tuner must be located or protected so that there is no possibility of accidental contact.

h. Do not locate the antenna close to other antenna systems.

i. Make sure the antenna is rigidly supported. The antenna will detune if it sags or sways.

j. The connection from the tuner to the ground must be a small percentage of the total length of the antenna. Do not let the length of the ground strap exceed 1 to 1.5 meters. Use heavy gauge wire or strap for the ground connection.

k. Whip antennas should be connected with the minimum length of wire. (Do not exceed 0.6 meters).

l. Do not locate the tuner further from the transceiver than necessary. If the distance exceeds 35 meters it is recommended that low loss coaxial cable is used.

#### 3.3 GROUND SYSTEM

The ground system is a key part of the overall antenna system and is the primary cause of poor performance and difficulty of adjusting the tuner. There is no point in installing the antenna unless a good ground can be provided.

##### 3.3.1 VEHICLE GROUNDS

Connect the tuner directly to the frame of the vehicle. Ensure that a heavy strap is used from the tuner ground lug and the connections are cleared of all paint and dirt so that the shiny metal is exposed. Make sure that the grounding point is not insulated from other parts of the vehicle by non-metallic couplings, brushings, fiberglass panels, etc.

### 3.3.2 MARINE GROUNDS

A metal hulled vessel in salt water provides an almost ideal ground. The tuner should be connected directly to the hull using the shortest possible ground strap. Make sure that the contact point is free from paint and dirt. Ensure a good contact area for minimum resistance.

Wooden hulled vessels present more of a grounding problem. It is normally necessary to bond all large metallic parts such as the engine, propeller shaft, etc. and sometimes an external grounding plate should be connected to the hull. The bonding and grounding plate should take into consideration the problems of electrolysis. Severe damage may result if dissimilar metals are connected together and expert advice should be obtained.

### 3.3.3 BASE STATION GROUNDS

In areas of high ground conductivity an effective ground can be made through a grounding rod. The rod should be approximately 3 meters in length and should be installed as close as possible to the tuner. It may be necessary to use several ground rods bonded together to improve the ground contact.

Water pipes are sometimes recommended as grounds and may be used provided the following conditions are met.

- a. The water pipe is close to the tuner.
- b. The water pipe enters the ground very close to the tuner bonding point.
- c. There are no joints or couplings in the pipe that will increase the resistance path to ground.
- d. The water pipe enters soil with good conductivity.
- e. A low resistance contact is made to the water pipe.

Frequently the ground conductivity will not be sufficient to provide satisfactory operation of the tuner. This is almost certainly the case with well drained sandy, rocky or loamy soils, and a counterpoise must be used as the ground system. This is also very important in a roof-top installation where there is no existing ground plate. The ideal ground would be a conducting surface extending several wavelengths in all directions around the antenna.

On a rooftop this situation may be approximated by placing a screen of chicken mesh or similar material over the roof of the building. More frequently, a counterpoise system of radial wires must be used. We recommend the use of at least 8-10 radials bonded together as shown in Section 2. If the antenna is at ground level the radials should be buried a few inches below the surface.

### 3.3.4 CORROSION

The ground connections are subject to corrosion and oxidation. All joints must be clean and the hardware adequately tightened. The joints may be protected by an application of silicon grease and under severe conditions covered with electrical tape and waterproof varnish.

### 3.4 ANTENNA TUNER MOUNTING

The tuner is mounted using the proper mounting brackets on the case. Choose a location immediately adjacent to the antenna feed point. In trunk mounted mobile installations it is very important that the tuner is located so the antenna insulator is within a few centimeters of antenna exit hole. Note also that the antenna lead must pass through an insulated bushing. High voltage connecting cable must be used. (RG8U cable with solid insulation may be used if the outer shielding is removed).

### 3.5 ANTENNA CONNECTION

The antenna lead is connected to the high voltage insulator. Use two wrenches when tightening the nut to prevent the stud rotating and possibly cracking the insulator. Potentials of several thousand volts may be present at the antenna terminal and adequate protection must be made against accidental contact. It is also necessary to ensure the antenna is spaced at least 3 cm from the conducting surface. Sharp points should be avoided to prevent corona discharges.

### 3.6 CABLE CONNECTIONS

#### 3.6.1 CONTROL CABLE

The Tuner uses a MS3106F-8-27P control connector. Internal connections are as defined in Table 3.

The mating cable connector is a MS3106F-8-27S and is supplied with the Tuner. Instructions for cable fabrication are given in Figure 11.

### **3.6.2 COAXIAL CABLE**

The RF connection between the transceiver and the tuner should be made with a good grade of RG8/U type 50 Ohm coaxial cable. The tuner end of the cable should be terminated with a UG-21C Type N connector. Fabrication instructions for this cable are given in Figure 12.

### **3.6.3 TRANSCEIVER INTERFACING**

The ATA will interface directly with either the TW100 or RT100 transceivers. When used with the

RT100, the Control Cable has an identical MS3106F-8-27S connector on the transceiver end. Pin connections are also the same. When used with the TW100, the control cable has a Molex 1625-15P connector on the radio end. Pin connections are as shown in Table 4.

The RF coaxial cable should be terminated on the transceiver with a UG-21C type-N connector (RT100) or a PL259 UHF Connector (TW100).

**Table 3. Internal Connections**

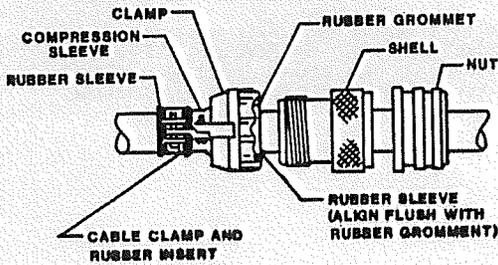
Connector Pin	Line Description
A	<u>KEY</u> -keys the transmitter on for low-level carrier tuning. An open-collector NPN transistor capable of sinking 0.5A to ground when activated.
C	<u>+12VDC</u> -Nominal 12 volts at 1.5A, max.
F	<u>Ground</u> .
H	<u>Initiate Tune</u> -Starts Tune cycle. A pulse greater than 200us, starting at a level less than 3.0 volts, rising to 6.5 volts or higher, then dropping to less than 3.0 volts.

**Table 4. Accessory Connector**

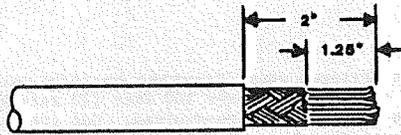
Connector Accessory 1	Line
6	KEY
5	ATU INITIATE TUNE
3	+12 VDC
1	GROUND

**Table 5. Interface Cables**

Use	Mating Connector	Cable Type	Mating Connector
Control Multiconductor	MS3106F-8-27P	18AWG Wire (10 conductor) purchased separately	MS3106F-8-27S
RF Coaxial	UG-21C	RG-213/U purchased separately	UG021C



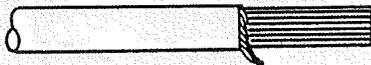
Install cable clamp and rubber insert, rubber sleeve clamp, compressing sleeve, rubber grommet, shell, and nut over cable. Assemble as shown. Leave cable clamp loose. Align rubber sleeve flush with rubber grommet inside clamp. Push assembly back out of way to perform the steps shown below.



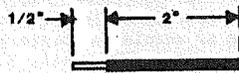
Remove 2" (5.08 cm) of vinyl jacket from cable as shown. Do not cut into shielding. Remove 1.25" (3.18 cm) of shielding as shown. Take care not to damage insulation on wires in cable bundle.



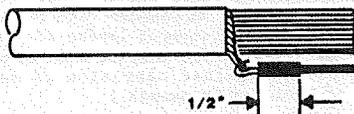
Carefully comb out shield wires as shown.



Make a part in the combed shield wires opposite the black wire in the cable. Pull the shield wires around both sides of the cable and twist together to make a pigtail as shown.

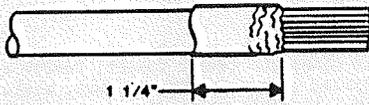


Remove 1/2" (1.27 cm) of insulation from a 2-1/2" (6.35 cm) length of No. 22 black stranded wire.

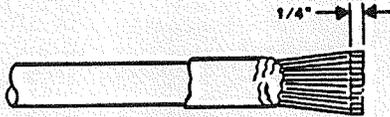


Twist the stripped end of black wire with the pigtail and solder. Cut 1/2" (1.27 cm) black shrink sleeving and install over soldered connection. Use a heat gun (an alternative is an open flame) to shrink sleeving exercising caution to avoid getting heat onto the cable jacket.

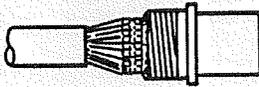
Figure 11. Control Cable Fabrication



Install shrink sleeving over cable as shown. Apply heat and "shrink" in place. Use heat gun. If no heat gun is available, use open flame. Avoid getting heat on cable jacket. Rotate cable for an even shrinkage.



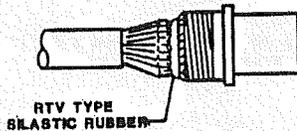
Remove 1/4" (.635 cm) insulation from wires to be used.



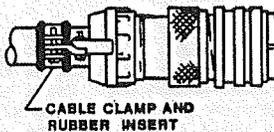
Twist and tin stripped wires together to form pairs as shown for cable lengths over 100 feet (30 meters). Twist and tin remaining stripped wires. Cut sleeving supplied in connector kits in 1/2 inch (1.27 cm) lengths and slide over each wire. Keep wires parallel as they come out of the cable bundle to the connector pins. Ensure the black wire installed in step 6 and the black wire in the cable are lined up with and soldered to pin D. Solder wires to the solder cups. Slide sleeving over solder cups. Write down wire colors assigned to each pin number for reference when assembling the connector on the other end of the cable.

Repeat assembly and soldering procedures for the other end of the cable.

Check both ends of the cable for continuity, shorts between wires and shorts to the connector shell.



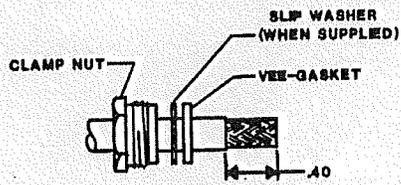
Apply RTV type silastic rubber (supplied in SC400 Accessory Kit) to a thickness of approximately 1/8 inch (.32 cm). Use small opening of nozzle to insure getting rubber between all solder cups. Use small, slender object such as a piece of wire or toothpick to insure a smooth, continuous waterseal.



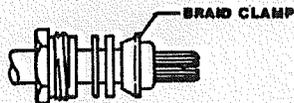
Assemble the plug as shown. Assemble clamp as tightly as possible onto the shell to assure a watertight connection around the cable. Repeat watersealing and assembling of connector on other end of cable. After connector has been threaded on Coupler case connector J2, wrap both connectors with several layers of plastic electrical tape as close to the Coupler case as possible. (For protection against corrosion of mating threads in wet or humid environments.)

Figure 11. Control Cable Fabrication, Continued.

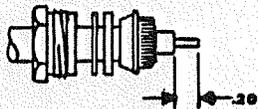
### UG-21C Connector Assembly



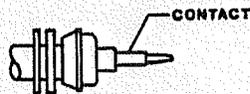
Cut cable end square, place clamp-nut, slip washer (when supplied), and gasket over jacket. Remove .40" (1.02 cm) of vinyl jacket.



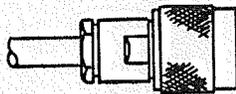
Place braid clamp over braid against jacket cut. Comb out copper braid as shown.



Fold braid back over braid clamp and trim as shown. Cut off dielectric .20 (.51 cm) from end. Tin center conductor.

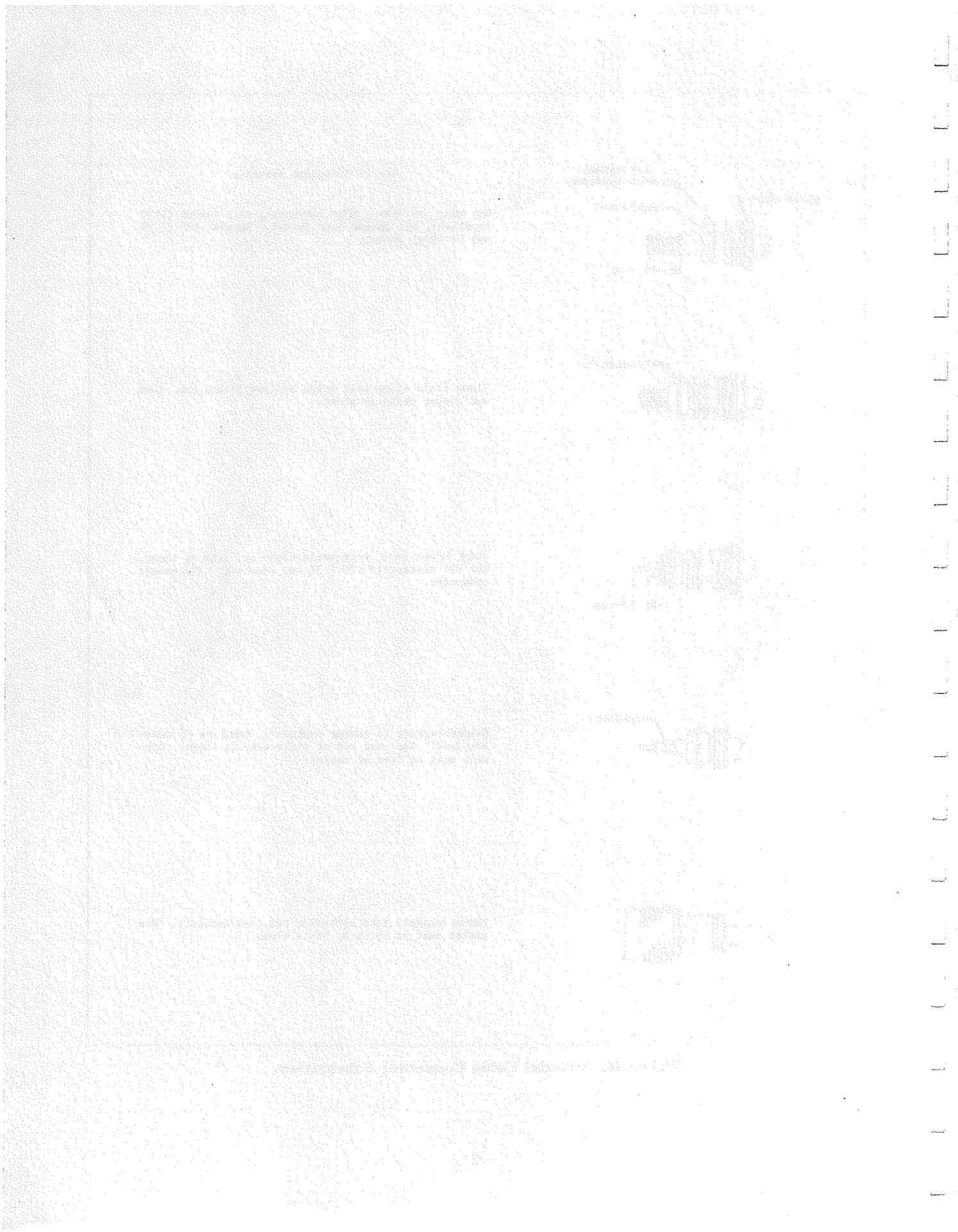


Solder contact to center conductor. Avoid use of excessive heat. See that end of dielectric is clean. Contact must be free of solder.



Thread assembly into connector and lock securely. Vee gasket must be split by braid clamp.

Figure 12. Coaxial Cable Connector Fabrication.



## SECTION 4

### OPERATION

#### 4.1 GENERAL

The Automatic Antenna Tuner is designed to operate with either the TW100 or RT100 series of transceivers. After installing the antenna and the tuner, it is only necessary to connect the tuner to the transceiver using the multi-wire Control Cable and RF coaxial cable described in Section 3.6.

#### 4.2 OPERATION WITH RT100 TRANSCEIVER

The following procedure should be followed when operating the ATA with the RT100.

- a. Select the operating mode of the RT100, i.e., LSB, USB, AM, or REM.
- b. Turn on the power using the RT100 Front Panel switch. Note that there are no operator controls on the ATA.
- c. Select the operating frequency using the six rotary switches on the RT100 front panel.
- d. Press and then release the "ATU Initiate" button on the RT100 front panel.

After the ATU INITIATE button is released the TUNING light on the RT100 front panel should come on indicating that an ATA tune cycle is in progress (or the transceiver internal tune tone is activated). During this period the ATA holds the transceiver key line down (transmit mode) until the tune cycle is completed. Upon completion of the tune cycle

the TUNING light goes out (or the tone goes off) and the key line is released. The system is ready for use when this occurs.

#### NOTE

The Transceiver must be unkeyed when the ATU INITIATE button is depressed in order to activate the ATA tune cycle. The ATA will not start a tune cycle if transmit power is present before the button is pressed.

#### NOTE

If the Transceiver is being operated using the TW5200 Remote Control, then antenna tuning is accomplished by pressing the "opt" key on the Remote Control console (after operating mode and frequency have first been inputted per the TW5200 procedure).

#### 4.3 OPERATION WITH TW100 TRANSCEIVER

The ATA is designed to work with the TW100 (Continuous Coverage Simplex Transceiver) in the same fashion as with the RT100. The same tuning procedure outlined in Section 4.2 applies in this case.

The ATA will also work with the TW100 in semi-duplex mode. However the Tuner will be matched to the antenna only for the Transmit frequencies and not for the Receive frequencies.

The ATA can also be used with the channelized models of the TW100 if it is so desired. However, in most cases, the system will be better configured by using a channelized Antenna Tuner like the AT20.



## SECTION 5

### THEORY OF OPERATION

#### 5.1 INTRODUCTION

The Automatic Antenna Tuner matches the 50 Ohm output of a 150 watt transmitter to a wide variety of whip or long wire antennas. Since the tuner is completely automatic, all network tuning, control and monitoring functions are completely self-contained. Figure 13 is a simplified block diagram of the tuner showing the major system assemblies.

The RF input is routed directly to the detector circuits. There are four detector circuits which sense the condition of the input impedance of the tuning network:

1. A phase detector;
2. Impedance magnitude detector;
3. Forward power detector;
4. A reflected power detector.

All detector functions have a characteristic impedance of 50 Ohms. The detectors provide all sense information used for tuning and monitoring. The phase detector output is an indication of the phase angle of the tuner input impedance (referenced to zero degrees), and is used to control the operation of the relays in the tuning network.

The impedance detector output indicates the real part of the tuner input impedance (referenced to 50 Ohms). When the tuner input impedance is purely resistive, this detector also controls operation of the tuning network relays. The forward power detector provides a voltage proportional to the amount of forward RF power into the coupler; it is used to indicate the presence of RF power for tuning. The reflected power detector provides a voltage proportional to reflected RF power and is used to monitor tuning accuracy and also (in conjunction with the forward power detector) to indicate VSWR for comparison with predetermined tuning thresholds.

The tuner is designed for use with transmitters that have a standard 50 Ohm output impedance. There are advantages, however, in operating automatic antenna coupler systems at a characteristic impedance lower than 50 Ohms. This system uses an  $R_0$  or operating impedance of 12.5 Ohms. Transformer T1 has a turns ratio of 2:1 or an impedance ratio of

4:1, and thus serves to match the optimum 12.5 Ohm antenna system to the standard 50 Ohm transmitter output.

The basic RF tuning network of the tuner is shown in Figure 14. The capacitance and inductance values of the L-network are automatically adjusted to provide a match between the antenna and the 12.5 Ohm tap on the 4:1 Transformer. The "C" and "L" required in the network consist of banks of discrete capacitors and inductors; each discrete inductor or capacitor can be switched in or out of the network as needed. This switching is done with high-voltage relays controlled by the microprocessor control circuit.

All of the interface and control information from both the associated transceiver and the detector circuits is routed to and processed by the microprocessor circuit. The circuitry in this section is used to monitor input control lines, RF power level, and antenna load condition; it then makes the appropriate sequence of responses required to provide automatic operation.

#### 5.2 SYSTEM OPERATION

Figure 15 shows the sequence of events in the tuner from initial application of primary power through completion of the tune cycle.

#### 5.3 TUNING

##### 5.3.1 TUNING CHARACTERISTICS

The tuner has been designed to have the capability to tune short whip and long wire antennas over the frequency range of 2-30MHz. Providing the system is properly installed and good grounding is provided, tuning capability is directly proportional to antenna impedance and operating frequency (for a given set of tuning element values). Figure 16 gives an illustration of how the tuning network operates to match a typical antenna impedance. A 15 foot whip antenna has a load impedance (depending on ground conditions) of 10-1500 Ohms at 2MHz. In order to tune this antenna, the tuner uses its inductive bank to shunt the antenna impedance in a circular fashion to  $Z_B = 12.5 + jX_B$ . The capacitive bank then resonates  $Z_B$  to  $R_0 = 12.5 + j0$ . Transformer T1 then transforms  $R_0$  to 50 + j0 ohms.

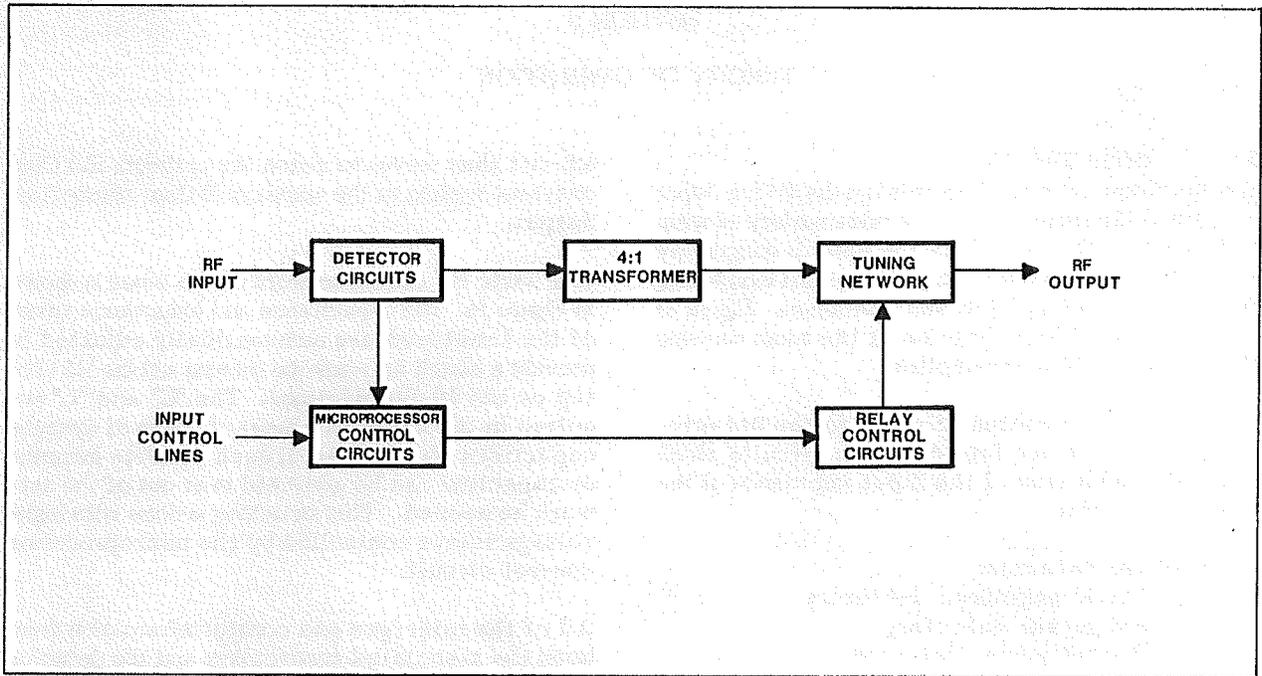


Figure 13. Block Diagram.

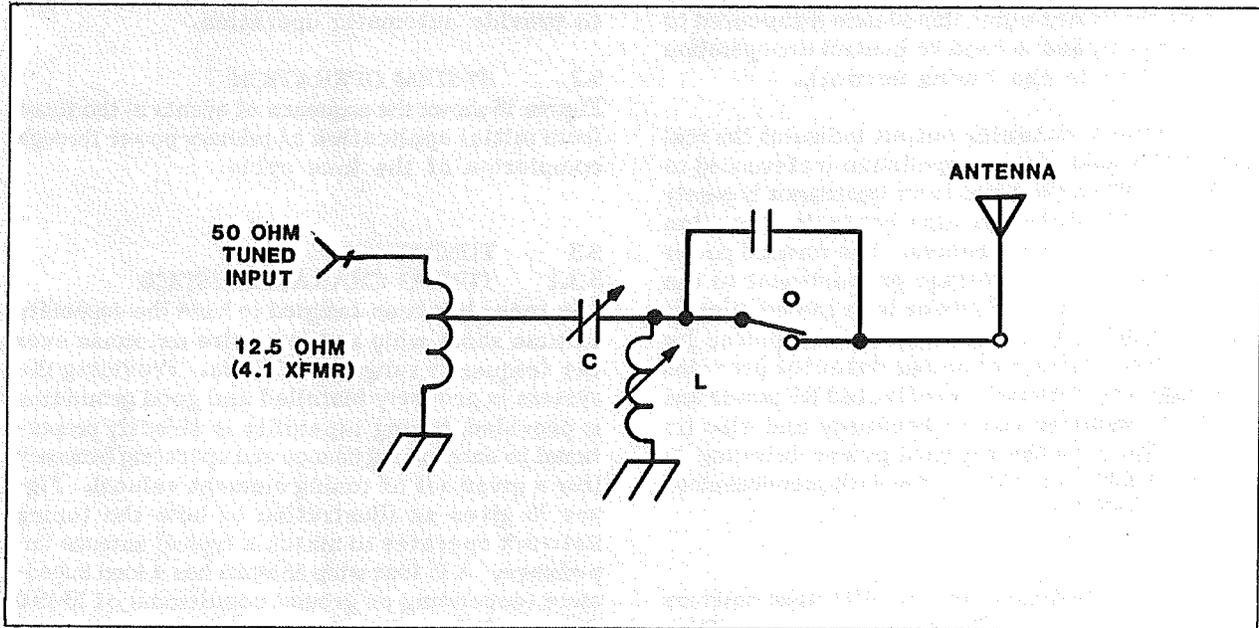


Figure 14. RF Tuning Network.

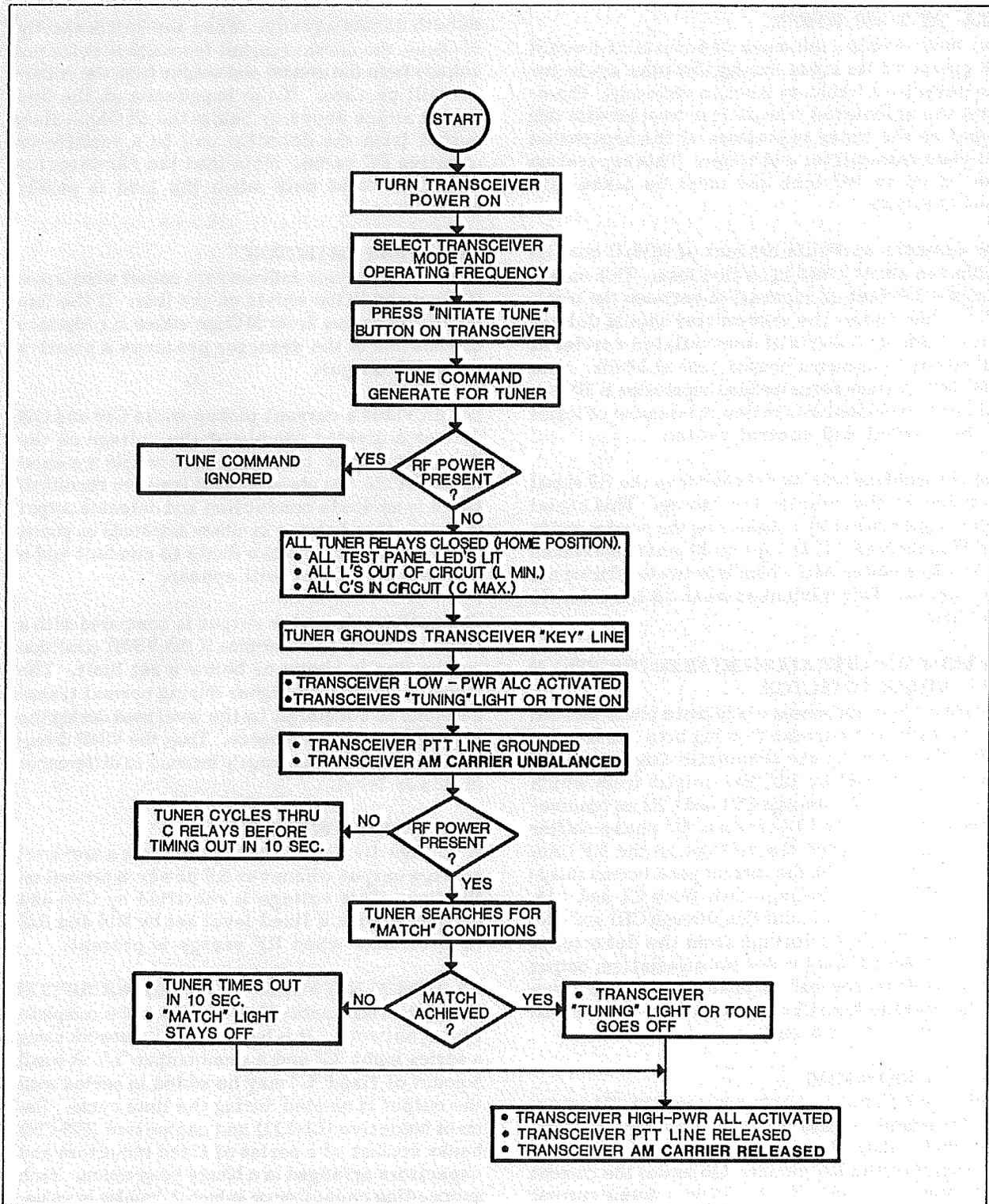


Figure 15. Sequence of Events.

### 5.3.2 RF TUNE POWER

The tuner needs a minimum of 6 watts of forward RF power at its input during the tune cycle for the detector circuits to function correctly. Therefore, the associated transmitter must provide this power to the tuner regardless of the separation between transmitter and tuner. This separation can be up to 100 feet and must be taken into consideration.

For example, at 30MHz 100 feet of RG8/U coaxial cable has about 1.5dB insertion loss. This means that for 100 feet of separation between the transmitter and tuner, the transmitter should deliver a minimum of 12 watts of unmodulated carrier at its output to assure a proper tune at 30MHz. Note that the maximum recommended separation is 100 feet. This recommended limitation is because of losses in the coaxial and control cables.

The transceiver uses its AM carrier as the RF signal provided to the coupler for tuning. This signal level is generated by unbalancing the carrier inside the transceiver. It is kept to 10 watts maximum by the low power ALC which is activated during the tune cycle. This minimizes wear on the relays in the tuner.

## 5.4 DETECTOR OPERATION-DETAILED DESCRIPTION

### 5.4.1 PHASE DETECTOR

The phase detector senses the relative phase between the voltage and current flowing into the RF circuit. Referring to the schematic diagram, the RF current is sensed by L15, the output from which causes conduction through CR1 and CR2 on positive-going peaks. C1 and L14 form a 90° phase-shifter circuit which senses the voltage on the RF line. Into a resistive load, the current peak occurs simultaneously with a voltage null from C1 and L14. This causes equal conduction through CR1 and CR2 and the net output voltage from the detector is zero. If the RF load is not pure resistive, output from the detector will be positive or negative due to the voltage from C1 and L14 arriving out of phase as compared to the output from L15.

### 5.4.2 /Z/ DETECTOR

When the RF load is purely resistive, the /Z/ detector determines if the resistance is above or below 50 Ohms by comparing the ratio of voltage and current flowing into the RF circuit. L16 senses the current and causes CR3 and CR4 to conduct during current peaks. C13 and C14 divide the RF voltage to a suitable level and output from this divider is applied

to both diodes equally. When the load is exactly 50 Ohms, the current signal from L16 is twice the voltage from the divider and output from the detector will be zero. If the impedance on the line varies either above or below the 50 Ohm value, output from the detector will be a positive or negative DC value. Note that the /Z/ detector output is valid only when the load is purely resistive.

### 5.4.3 VSWR DETECTOR

The VSWR detector delivers zero output when a pure 50 Ohm condition exists on the line. If the line condition varies from 50 Ohms either in resistance or reactance, the detector produces a positive going DC output.

L17 provides a current pickup while C18 and C19 deliver a divided sample of the voltage on the line. As long as the two inputs to CR5 are equal in amplitude and phase (50 Ohm resistive condition) there is no diode conduction and detector output is zero. An unbalance in either amplitude or phase, however, will cause the diode to conduct and a positive DC output will appear.

The positive detector output is compared with a fixed DC level to determine if the VSWR condition on the line is above or below a set limit. The fixed DC is shifted higher during normal transmissions as compared to the level used during the low-power tune up sequence. Thus, the VSWR detection process becomes largely immune to differences in power level.

### 5.4.4 POWER DETECTOR

A voltage divider, R12 and R19, delivers a low-level voltage output whenever RF power is present on the line. This voltage is rectified by CR6 and compared with a fixed level set by R18 and R22 to determine when RF energy is present.

## 5.5 TUNING NETWORK - DETAILED DESCRIPTION

The system schematic, Figure 17 shows the complete tuning network. It is basically an L-network using a series input "C" and a shunt output "L". A small amount of fixed "C" may be added in series with the output if needed during the tune cycle. The main inductive (L1-L11) and capacitive (C29-C55) banks consist of a series of fixed inductors and capacitors arranged in a binary progression. Each succeeding capacitor or inductor doubles in value. Eleven inductors are used ranging from .04uH to 25uH and 9 capacitors ranging from 2.3pF to 400pF.

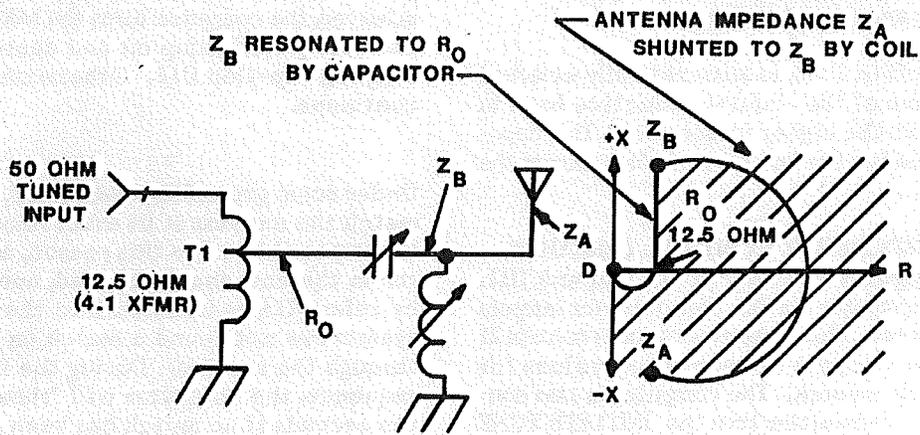


Figure 16. Tuning Example.

Each capacitor and inductor can be switched in and out of the circuit by a relay. By selecting the appropriate relays it is possible to cover .04uH to 50uH in .04uH increments and 2.3pF to 800pF in 2.3pF increments.

A special relay with low capacitance and very good isolation between the contacts and frame is used for the low voltage switching functions. Special high voltage reed relays are used for switching the four largest inductors and the fixed capacitors. These special relays are essential because of the extremely high voltages that may be present at the tuner output and across the large inductors.

The larger inductors are all toroids which minimize coupling and interaction between the elements in the tuner. The toroids are wound with insulated wire and use larger toroid volumes to minimize core heating. High voltage silver mica capacitors are used in the capacitor bank.

A small capacitor, C102, is automatically switched into the bottom of the shunt-L inductive bank to aid in tuning at the higher frequencies. This capacitor compensates for the stray inductance in the "L" bank.

#### 5.6 MICROPROCESSOR CONTROL CIRCUITS

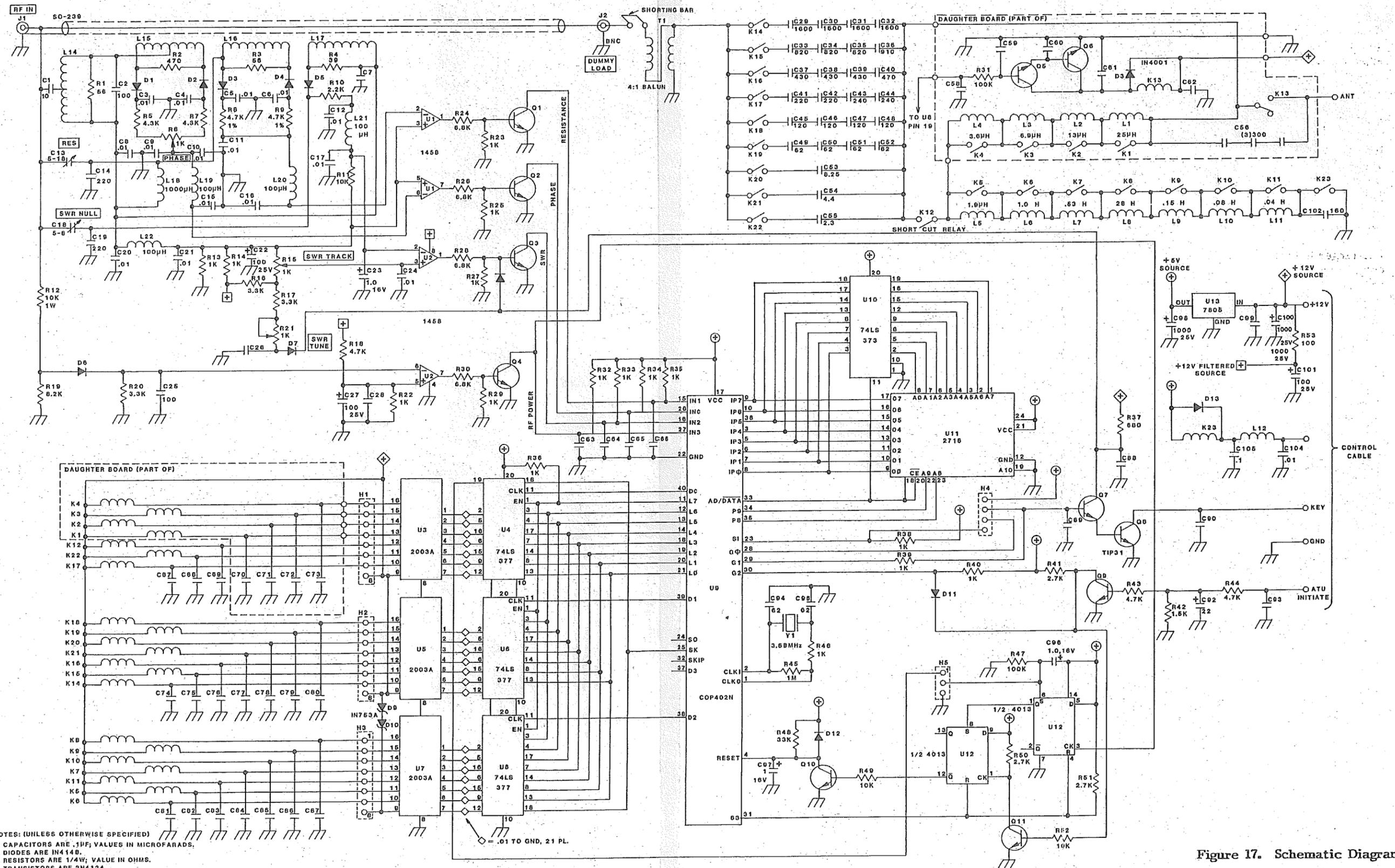
The microcomputer consists of U9, U10 and U11. Inputs to the computer are the four detector outputs described above. The computer outputs control 21 relays that, in turn, set the necessary values for the RF matching network. The computer is also connected to the transmitter thru the INITIATE TUNE and KEY lines which control the tuning sequence to be described.

Normally the computer is held in the standby mode by flip-flop U12 until it is time to "wake up" the system.

If a signal is present on the INITIATE TUNE line from the transmitter, indicating that a tune cycle is requested, the computer will wake up and begin a full tune-up sequence. In this mode the transmitter is keyed on by the computer and a low-level carrier is provided to supply tune-up energy.

During the tuning sequence, the computer makes a series of instructions to the relays. Each time the relay data is changed, the new information is latched into U4, U6, and U8. These latches, in turn, are connected to the relay drivers U3, U5, and U7. After the new relay data is set, the computer waits about 10ms and then samples the detector outputs. If a proper match has been achieved, the computer turns the MATCH FOUND (on the test panel) lamp on and shuts itself off by toggling flip-flop U12. Otherwise the sequence continues.

Under some grounding conditions, attempting to match the antenna at its exact resonant frequency is not possible. For this reason, a series capacitor in the antenna input lead, normally shorted by relay K13, is inserted into the circuit if the system has not found a match on the first pass through the routine. During the initial tune-up sequence, the computer will "time out" in about ten seconds if no match has been found. In this case, the computer shuts itself off without lighting the MATCH FOUND lamp.



NOTES: (UNLESS OTHERWISE SPECIFIED)  
 1. CAPACITORS ARE .1µF; VALUES IN MICROFARADS.  
 2. DIODES ARE IN4148.  
 3. RESISTORS ARE 1/4W; VALUE IN OHMS.  
 4. TRANSISTORS ARE 2N4124.  
 5. C63-C65 ARE ETCHED ON PC BOARD.  
 6. INDUCTANCE IS IN MICROHENRYS.

Figure 17. Schematic Diagram.



## SECTION 6

### ALIGNMENT AND TEST

#### 6.1 GENERAL

The Automatic Antenna Tuner has been thoroughly tested and aligned at the factory and re-alignment in the field should not be attempted unless good quality test equipment is available and all other possible causes of malfunctioning have been investigated.

#### 6.2 EQUIPMENT REQUIRED

- 50 OHM Dummy Load with Connecting Cable
- Oscilloscope
- High Impedance DC Voltmeter

#### 6.3 ALIGNMENT PROCEDURE

1. Connect the coupler to the Transceiver. Disconnect the jumper strap located adjacent the BNC connector on the coupler. Connect the dummy load to the BNC connector. Select a frequency of 6MHz on the transceiver.

2. Connect a two-tone audio generator to the Transceiver Audio Input. Adjust the drive for an RF output of 100 watts, PEP.

3. Connect the scope to the PHASE test point (see Figure 19). Key the Transceiver. Adjust the PHASE potentiometer until the scope baseline is alternating between zero and +5 volts with about equal time in each position. This adjustment assures that the phase-amplifier output is swinging from zero to +5 volts output when RF energy is present.

4. Connect the scope to the R test point. Again key the Transceiver. Adjust the RES trimmer until the scope baseline is alternating between zero and +5 volts with about equal time in each position.

5. Connect the scope ground to the "+6V" test point and the scope probe to the NULL test point. Push the TEST button on the transmitter and adjust the SWR NULL trimmer for zero voltage level as shown on the scope.

#### NOTE

This adjustment may also be made with a high-impedance voltmeter.

#### 6.4 TEST PANEL

A test and status panel is provided to permit local operation and testing of the coupler and to observe the data delivered to the various relay.

If the RELAY SEQUENCE TEST button is pressed, a test program is initiated that energizes each relay in turn. If each relay status lamp lights in turn and each relay is heard to operate, the entire computer circuitry, the latches, the relay drivers, and the relays are proven to be operating correctly. The sequence may be stopped at any relay by pressing the RELAY SEQUENCE TEST button a second time. Pressing the button a third time will complete the sequence.

Pressing the BEGIN TUNE CYCLE pushbutton causes the coupler to perform a complete tune-up sequence, provided a valid channel has been selected at the transmitter.

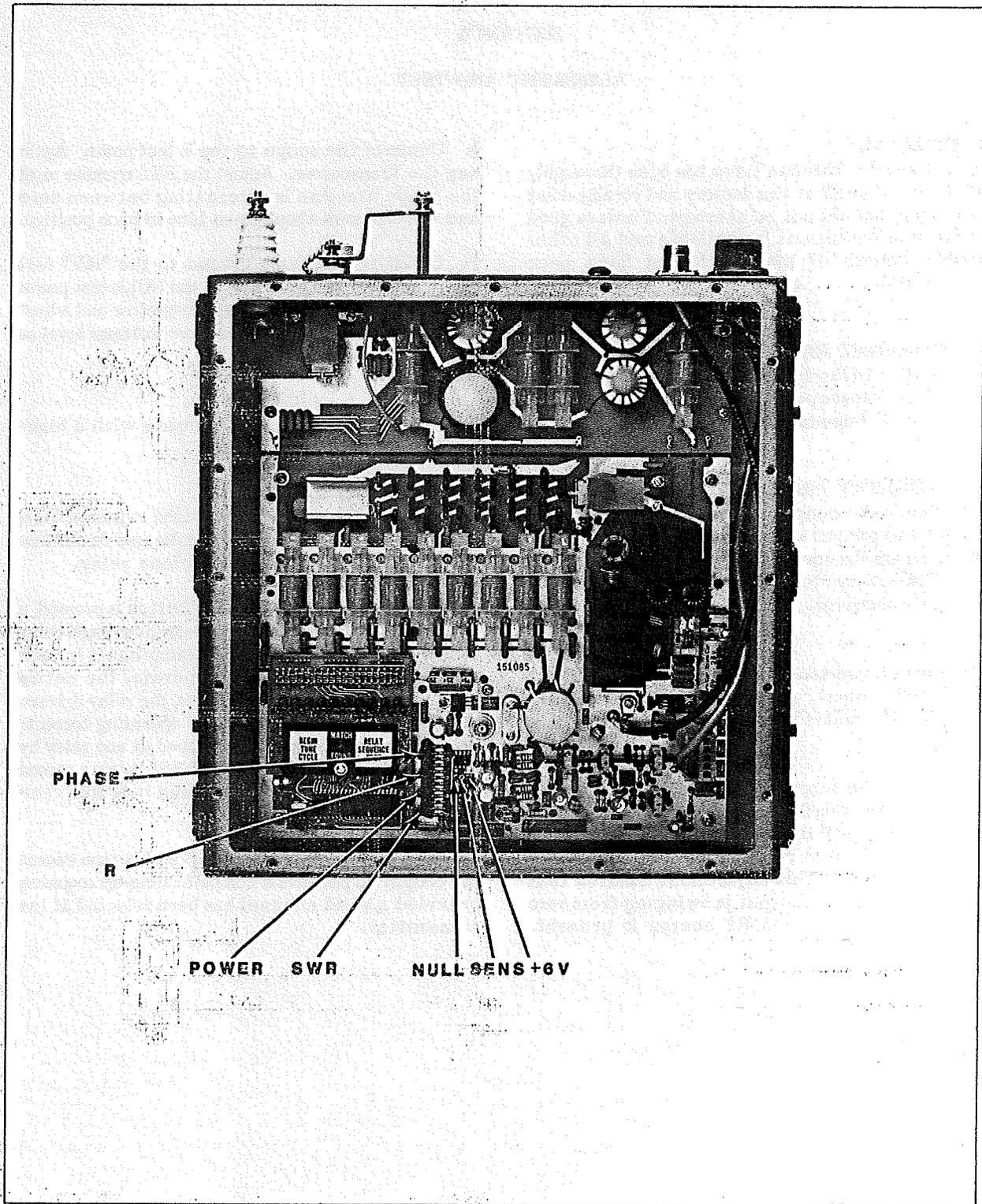


Figure 18. Test Points.

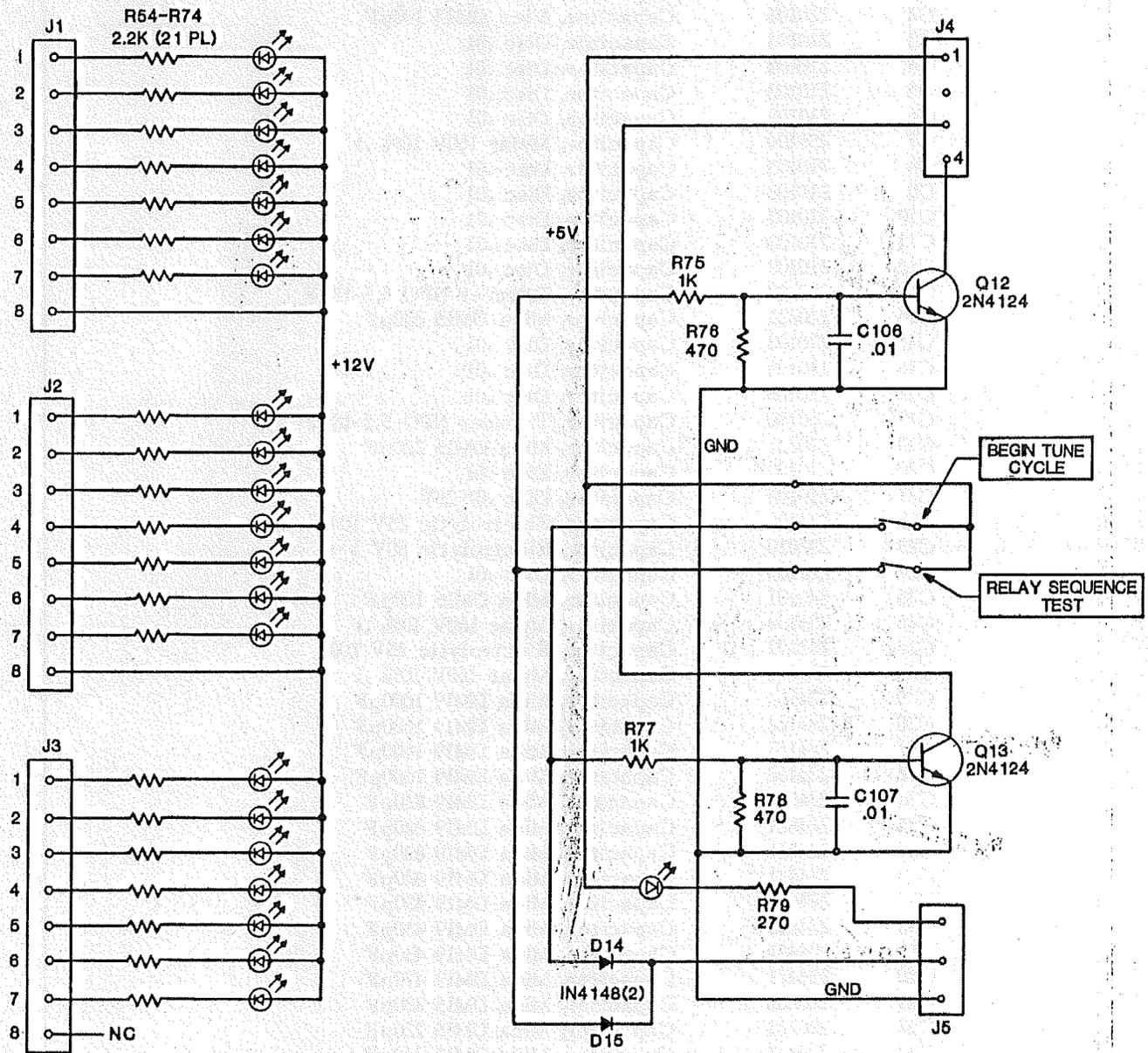


FIGURE 19. Automatic Antenna Tuner Test Panel.

Table 6. Parts List, Automatic Antenna Tuner.

C1	220100	Capacitor, Mica DM15 10pF
C2	220101	Capacitor, Mica DM15 100pF
C3	210103	Capacitor, Disc .01
C4	210103	Capacitor, Disc .01
C5	210103	Capacitor, Disc .01
C6	210103	Capacitor, Disc .01
C7	255104	Capacitor, Mylar 160V 10% .1
C8	210103	Capacitor, Disc .01
C9	210103	Capacitor, Disc .01
C10	210103	Capacitor, Disc .01
C11	210103	Capacitor, Disc .01
C12	210103	Capacitor, Disc .01
C13	260180	Capacitor, Trimmer NPO 5.5-18pF
C14	220221	Capacitor, Mica DM15 220pF
C15	210103	Capacitor, Disc .01
C16	210103	Capacitor, Disc .01
C17	210103	Capacitor, Disc .01
C18	260180	Capacitor, Trimmer NPO 5.5-18pF
C19	220221	Capacitor, Mica DM15 220pF
C20	210103	Capacitor, Disc .01
C21	210103	Capacitor, Disc .01 25V
C22	232101	Capacitor, Electrolytic 25V 100
C23	232010	Capacitor, Electrolytic 50V 1
C24	210103	Capacitor, Disc .01
C25	220101	Capacitor, Mica DM15 100pF
C26	255104	Capacitor, Mylar 160V 10% .1
C27	232101	Capacitor, Electrolytic 25V 100
C28	255104	Capacitor, Mylar 160V 10% .1
C29	224162	Capacitor, Mica DM19 1600pF
C30	224162	Capacitor, Mica DM19 1600pF
C31	224162	Capacitor, Mica DM19 1600pF
C32	224162	Capacitor, Mica DM19 1600pF
C33	224821	Capacitor, Mica DM19 820pF
C34	224821	Capacitor, Mica DM19 820pF
C35	224821	Capacitor, Mica DM19 820pF
C36	224821	Capacitor, Mica DM19 820pF
C37	224431	Capacitor, Mica DM19 430pF
C38	224431	Capacitor, Mica DM19 430pF
C39	224431	Capacitor, Mica DM19 430pF
C40	224471	Capacitor, Mica DM19 470pF
C41	220221	Capacitor, Mica DM15 220pF
C42	220221	Capacitor, Mica DM15 220pF
C43	220241	Capacitor, Mica DM15 240pF
C44	220241	Capacitor, Mica DM15 240pF
C45	220121	Capacitor, Mica DM15 120pF
C46	220121	Capacitor, Mica DM15 120pF
C47	220121	Capacitor, Mica DM15 120pF
C48	220121	Capacitor, Mica DM15 120pF

Table 6. Parts List, Automatic Antenna Tuner Continued.

C49	220620	Capacitor, Mica DM15 62pF
C50	220620	Capacitor, Mica DM15 62pF
C51	220620	Capacitor, Mica DM15 62pF
C52	220620	Capacitor, Mica DM15 62pF
C53		Capacitor, P/O PCB 8.25pF
C54		Capacitor, P/O PCB 4.4pF
C55		Capacitor, P/O PCB 2.3pF
C56A	224301	Capacitor, Mica DM19 300pF
C56B	224301	Capacitor, Mica DM19 300pF
C56C	224301	Capacitor, Mica DM19 300pF
C57	255104	Capacitor, Mylar 160V 10% .1
C58	255104	Capacitor, Mylar 160V 10% .1
C59	255104	Capacitor, Mylar 160V 10% .1
C60	255104	Capacitor, Mylar 160V 10% .1
C61	255104	Capacitor, Mylar 160V 10% .1
C62	255104	Capacitor, Mylar 160V 10% .1
C63	255104	Capacitor, Mylar 160V 10% .1
C64	255104	Capacitor, Mylar 160V 10% .1
C65	255104	Capacitor, Mylar 160V 10% .1
C66	255104	Capacitor, Mylar 160V 10% .1
C67	255104	Capacitor, Mylar 160V 10% .1
C68	255104	Capacitor, Mylar 160V 10% .1
C69	255104	Capacitor, Mylar 160V 10% .1
C70	255104	Capacitor, Mylar 160V 10% .1
C71	255104	Capacitor, Mylar 160V 10% .1
C72	255104	Capacitor, Mylar 160V 10% .1
C73	255104	Capacitor, Mylar 160V 10% .1
C74	255104	Capacitor, Mylar 160V 10% .1
C75	255104	Capacitor, Mylar 160V 10% .1
C76	255104	Capacitor, Mylar 160V 10% .1
C77	255104	Capacitor, Mylar 160V 10% .1
C78	255104	Capacitor, Mylar 160V 10% .1
C79	255104	Capacitor, Mylar 160V 10% .1
C80	255104	Capacitor, Mylar 160V 10% .1
C81	255104	Capacitor, Mylar 160V 10% .1
C82	255104	Capacitor, Mylar 160V 10% .1
C83	255104	Capacitor, Mylar 160V 10% .1
C84	255104	Capacitor, Mylar 160V 10% .1
C85	255104	Capacitor, Mylar 160V 10% .1
C86	255104	Capacitor, Mylar 160V 10% .1
C87	255104	Capacitor, Mylar 160V 10% .1
C88	255104	Capacitor, Mylar 160V 10% .1
C89	255104	Capacitor, Mylar 160V 10% .1
C90	255104	Capacitor, Mylar 160V 10% .1
C91	255104	Capacitor, Mylar 160V 10% .1
C92	255104	Capacitor, Electrolytic Vert 22
C93	255104	Capacitor, Mylar 160V 10% .1
C94	220620	Capacitor, Mica DM15 62pF

Table 6. Parts List, Automatic Antenna Tuner Continued.

C95	220620	Capacitor, Mica DM15 62pF
C96	232010	Capacitor, Electrolytic 50V 1
C97	232010	Capacitor, Electrolytic 50V 1
C98	230102	Capacitor, Electrolytic 25V 1000
C99	255104	Capacitor, Mylar .1
C100	230102	Capacitor, Electrolytic 25V 1000
C101	232101	Capacitor, Electrolytic 25V 100
C102	224161	Capacitor, Mica DM19 160pF
C104		Not Used
C105		Not Used
C106	210103	Capacitor, Disc .01
C107	210103	Capacitor, Disc .01
D1	320002	Diode, 1N4148
D2	320002	Diode, 1N4148
D3	320002	Diode, 1N4148
D4	320002	Diode, 1N4148
D5	320002	Diode, 1N4148
D6	320002	Diode, 1N4148
D7	320002	Diode, 1N4148
D8	320002	Diode, 1N4148
D9	320002	Diode, 1N4148
D10	320002	Diode, 1N4148
D11	320002	Diode, 1N4148
D12	320002	Diode, 1N4148
D13		Not Used
D14	320002	Diode, 1N4148
D15	320002	Diode, 1N4148
D16	320403	Indicator LED
D17	320403	Indicator LED
D18	320403	Indicator LED
D19	320403	Indicator LED
D20	320403	Indicator LED
D21	320403	Indicator LED
D22	320403	Indicator LED
D23	320403	Indicator LED
D24	320403	Indicator LED
D25	320403	Indicator LED
D26	320403	Indicator LED
D27	320403	Indicator LED
D28	320403	Indicator LED
D29	320403	Indicator LED
D30	320403	Indicator LED
D31	320403	Indicator LED
D32	320403	Indicator LED
D33	320403	Indicator LED
D34	320403	Indicator LED
D35	320403	Indicator LED

Table 6. Parts List, Automatic Antenna Tuner Continued.

D36	320403	Indicator LED
D37	320403	Indicator LED
K1	540015	Relay HV 12VDC 5AMP
K2	540015	Relay HV 12VDC 5AMP
K3	540015	Relay HV 12VDC 5AMP
K4	540015	Relay HV 12VDC 5AMP
K5	540017	Relay DPDT 12VDC PC Mount
K6	540017	Relay DPDT 12VDC PC Mount
K7	540017	Relay DPDT 12VDC PC Mount
K8	540017	Relay DPDT 12VDC PC Mount
K9	540017	Relay DPDT 12VDC PC Mount
K10	540017	Relay DPDT 12VDC PC Mount
K11	540017	Relay DPDT 12VDC PC Mount
K12	540015	Relay HV 12VDC 5AMP
K13	540018	Relay HV 12VDC 5AMP
K14	540015	Relay HV 12VDC 5AMP
K15	540015	Relay HV 12VDC 5AMP
K16	540015	Relay HV 12VDC 5AMP
K17	540015	Relay HV 12VDC 5AMP
K18	540015	Relay HV 12VDC 5AMP
K19	540015	Relay HV 12VDC 5AMP
K20	540015	Relay HV 12VDC 5AMP
K21	540015	Relay HV 12VDC 5AMP
K22	540015	Relay HV 12VDC 5AMP
K23	540017	Relay DPDT 12VDC PC Mount
L1	460001	Inductor, Toroid 25uH
L2	460002	Inductor, Toroid 13uH
L3	460003	Inductor, Toroid 6.9uH
L4	460004	Inductor, Toroid 3.6uH
L5	460005	Inductor, Toroid 1.9uH
L6	460006	Inductor, Toroid 1uH
L7	460007	Inductor, Toroid .53uH
L8		Inductor, Airwound .28uH
L9		Inductor, Airwound .15uH
L10		Inductor, Airwound 0.8uH
L11		Inductor, Airwound 0.4uH
L12		Not Used
L13		Not Used
L14	460008	Inductor, Toroid
L15	460009	Inductor, Toroid
L16	460010	Inductor, Toroid
L17	460011	Inductor, Toroid
L18	430025	Inductor, Fixed RFC 1000uH
L19	430026	Inductor, Fixed RFC 100uH
L20	430026	Inductor, Fixed RFC 100uH
L21	430026	Inductor, Fixed RFC 100uH
L22	430026	Inductor, Fixed RFC 100uH

Table 6. Parts List, Automatic Antenna Tuner Continued.

Q1	310069	Transistor, 2N4124	
Q2	310069	Transistor, 2N4124	
Q3	310069	Transistor, 2N4124	
Q4	310069	Transistor, 2N4124	
Q5	310069	Transistor, 2N4124	
Q6	310069	Transistor, 2N4124	
Q7	310069	Transistor, 2N4124	
Q8	310023	Transistor, TIP31	
Q9	310069	Transistor, 2N4124	
Q10	310069	Transistor, 2N4124	
Q11	310069	Transistor, 2N4124	
Q12	310069	Transistor, 2N4124	
Q13	310069	Transistor, 2N4124	
R1	124560	Resistor, Film 1/4W 5% 56	
R2	124471	Resistor, Film 1/4W 5% 470	
R3	124560	Resistor, Film 1/4W 5% 56	
R4	124390	Resistor, Film 1/4W 5% 39	
R5	124432	Resistor, Film 1/4W 5% 4.3K	
R6	170211	Resistor, Trimmer 1K	
R7	124432	Resistor, Film 1/4W 5% 4.3K	
R8	124472	Resistor, Film 1/4W 5% 4.7K	
R9	124472	Resistor, Film 1/4W 5% 4.7K	
R10	124222	Resistor, Film 1/4W 5% 2.2K	
R11	124103	Resistor, Film 1/4W 5% 10K	
R12	144103	Resistor, Film 1W 5% 10K	
R13	124102	Resistor, Film 1/4W 5% 1K	
R14	124102	Resistor, Film 1/4W 5% 1K	
R15	170211	Resistor, Trimmer 1K	
R16	124332	Resistor, Film 1/4W 5% 3.3K	
R17	124332	Resistor, Film 1/4W 5% 3.3K	
R18	124472	Resistor, Film 1/4W 5% 4.7K	
R19	124822	Resistor, Film 1/4W 5% 8.2K	
R20	124332	Resistor, Film 1/4W 5% 3.3K	
R21	170211	Resistor, Trimmer 1K	
R22	124102	Resistor, Film 1/4W 5% 1K	
R23	124102	Resistor, Film 1/4W 5% 1K	
R24	124682	Resistor, Film 1/4W 5% 6.8K	
R25	124102	Resistor, Film 1/4W 5% 1K	
R26	124682	Resistor, Film 1/4W 5% 6.8K	
R27	124102	Resistor, Film 1/4W 5% 1K	
R28	124682	Resistor, Film 1/4W 5% 6.8K	
R29	124102	Resistor, Film 1/4W 5% 1K	
R30	124682	Resistor, Film 1/4W 5% 6.8K	
R31	124104	Resistor, Film 1/4W 5% 100K	
R32	124102	Resistor, Film 1/4W 5% 1K	
R33	124102	Resistor, Film 1/4W 5% 1K	
R34	124102	Resistor, Film 1/4W 5% 1K	
R35	124102	Resistor, Film 1/4W 5% 1K	

Table 6. Parts List, Automatic Antenna Tuner Continued.

R36	124102	Resistor, Film 1/4W 5% 1K	
R37	124681	Resistor, Film 1/4W 5% 680	
R38	124102	Resistor, Film 1/4W 5% 1K	
R39	124102	Resistor, Film 1/4W 5% 1K	
R40	124102	Resistor, Film 1/4W 5% 1K	
R41	124272	Resistor, Film 1/4W 5% 2.7K	
R42	124152	Resistor, Film 1/4W 5% 1.5K	
R43	124472	Resistor, Film 1/4W 5% 4.7K	
R44	124472	Resistor, Film 1/4W 5% 4.7K	
R45	124105	Resistor, Film 1/4W 5% 1M	
R46	124102	Resistor, Film 1/4W 5% 1K	
R47	124104	Resistor, Film 1/4W 5% 100K	
R48	124333	Resistor, Film 1/4W 5% 33K	
R49	124103	Resistor, Film 1/4W 5% 10K	
R50	124272	Resistor, Film 1/4W 5% 2.7K	
R51	124272	Resistor, Film 1/4W 5% 2.7K	
R52	124103	Resistor, Film 1/4W 5% 10K	
R53	124101	Resistor, Film 1/4W 5% 100	
R54	124222	Resistor, Film 1/4W 5% 2.2K	
R55	124222	Resistor, Film 1/4W 5% 2.2K	
R56	124222	Resistor, Film 1/4W 5% 2.2K	
R57	124222	Resistor, Film 1/4W 5% 2.2K	
R58	124222	Resistor, Film 1/4W 5% 2.2K	
R59	124222	Resistor, Film 1/4W 5% 2.2K	
R60	124222	Resistor, Film 1/4W 5% 2.2K	
R61	124222	Resistor, Film 1/4W 5% 2.2K	
R62	124222	Resistor, Film 1/4W 5% 2.2K	
R63	124222	Resistor, Film 1/4W 5% 2.2K	
R64	124222	Resistor, Film 1/4W 5% 2.2K	
R65	124222	Resistor, Film 1/4W 5% 2.2K	
R66	124222	Resistor, Film 1/4W 5% 2.2K	
R67	124222	Resistor, Film 1/4W 5% 2.2K	
R68	124222	Resistor, Film 1/4W 5% 2.2K	
R69	124222	Resistor, Film 1/4W 5% 2.2K	
R70	124222	Resistor, Film 1/4W 5% 2.2K	
R71	124222	Resistor, Film 1/4W 5% 2.2K	
R72	124222	Resistor, Film 1/4W 5% 2.2K	
R73	124222	Resistor, Film 1/4W 5% 2.2K	
R74	124222	Resistor, Film 1/4W 5% 2.2K	
R75	124102	Resistor, Film 1/4W 5% 1K	
R76	124471	Resistor, Film 1/4W 5% 470	
R77	124102	Resistor, Film 1/4W 5% 1K	
R78	124471	Resistor, Film 1/4W 5% 470	
R79	124271	Resistor, Film 1/4W 5% 270	
T1		Not Used	
T2	460012	Toroidal Balun	

Table 6. Parts List, Automatic Antenna Tuner Continued.

U1	330019	IC, MC1458
U2	330019	IC, MC1458
U3	330135	IC, ULN2003A
U4	330136	IC, 74LS377
U5	330135	IC, ULN2003A
U6	330136	IC, 74LS377
U7	330135	IC, ULN2003A
U8	330136	IC, 74LS377
U9	330137	IC, Microprocessor
U10	330136	IC, 74LS377
U11	330138	IC, 2716
U12	330127	IC, 4013 BCP
U13	330015	IC, 7805
Y1	360024	Crystal, 3.580MHz

Note: Unless otherwise specified, capacitance is in microfarads and resistance is in ohms.