TRANS WORLD COMMUNICATIONS, INC. ■ A DATRON COMPANY

AT100
AUTOMATIC ANTENNA TUNER
TECHNICAL MANUAL SUPPLEMENT

TRANSWORLD™
for communications

lanual Part No. AT100-MS
Publication #990438
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Revision C

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WARRANTY

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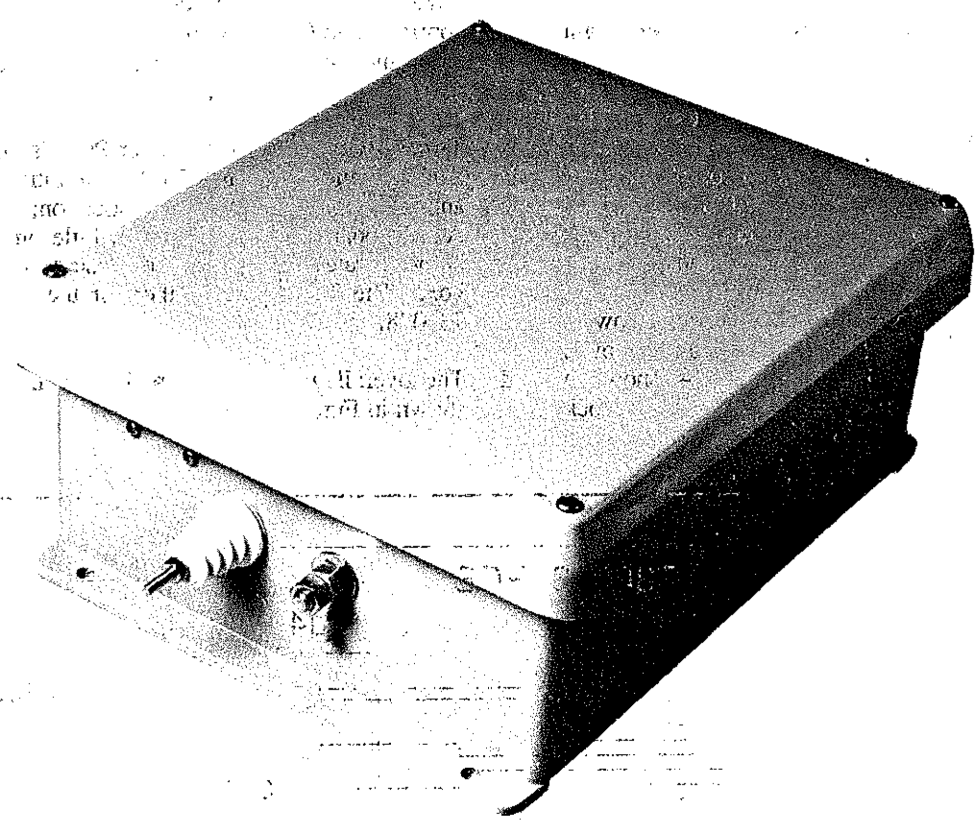


FIGURE 1.
AT100 Automatic Antenna Tuner.

AT100 MANUAL SUPPLEMENT

1.0 GENERAL

The AT100 is the same automatic antenna tuning unit as the RAT100, repackaged in a waterproof fiberglass enclosure. All specifications and electrical operation are identical to the RAT100. Therefore, the RAT100 manual should be consulted for all questions concerning installation, operation, theory, maintenance or alignment.

2.0 DIFFERENCES

The differences between the RAT100 and AT100 are as follows:

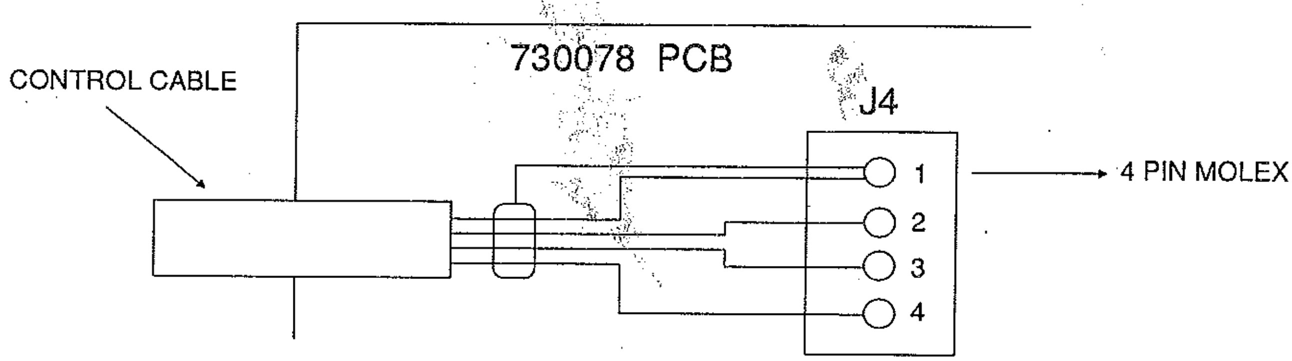
a. **Enclosure.** The AT100 is packaged in a watertight fiberglass box.

b. **Connectors.** The AT100 RF input connector is a UHF type, while the RAT100 uses a type N. The AT100 control cable passes through a waterproof gland in the fiberglass box and connects to the PCB via a 4-pin molex connector; the RAT100 control cable is attached via an 8-pin connector directly to the box.

   AT100 control cable connections are shown below in Figure 2. Figure 3 shows a block diagram of a TW100/AT100 installation and Figure 4 shows a TW2000/AT100 installation. Figure 5 is a block diagram of a TW100F/AT100 installation. The diagrams identify all cables used in the installations and provide appropriate TWC part numbers. Note that the control cable used in the TW100 system can be either the standard 4-wire cable or a special 10-wire cable used when the memory option is installed in the antenna tuner and transceiver. Since the memory option is not available in the TW100F or TW2000 transceivers, no memory-option cable is shown. Table 1 defines the lines in the standard 4-wire control cable; it shows the pins on the TW100, TW100F and the TW2000. Table 2 defines the lines for the memory control cable (detailed information on the memory and auto-tune options can be found in Section 8 of this manual).

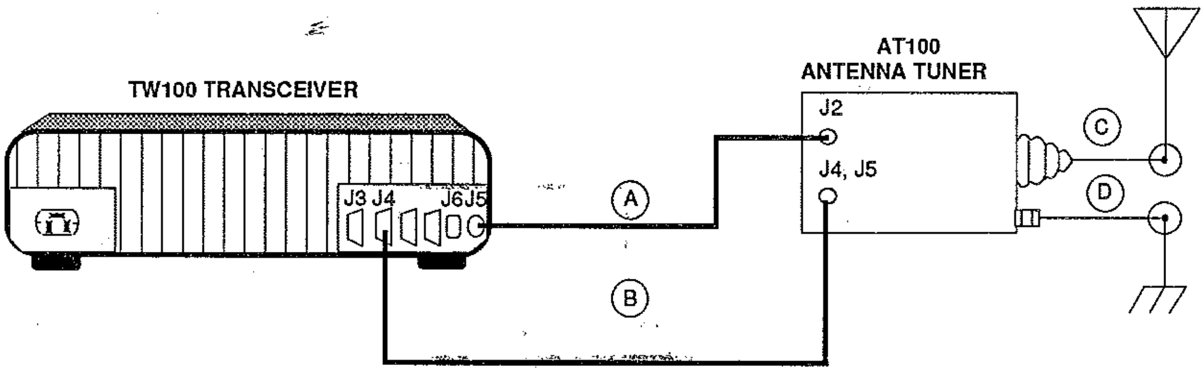
c. **Tuner PCB.** The AT100 tuner PCB is slightly larger than the one in the RAT100. Circuitry is the same, and is in exactly the same location; however, the AT100 board is extended out a little on the edges to allow for the slightly larger enclosure of the fiberglass box. The TWC part number for the AT100 PCB is 730078.

d. The overall wiring diagram for the antenna tuner is shown in Figure 6.



TERMINAL	FUNCTION	WIRE COLOR
1	GROUND	BLACK
2	KEY	WHITE
3	TUNE INITIATE	GREEN
4	+12 VDC	RED

FIGURE 2.
AT100 Control Cable Connections.



CABLES

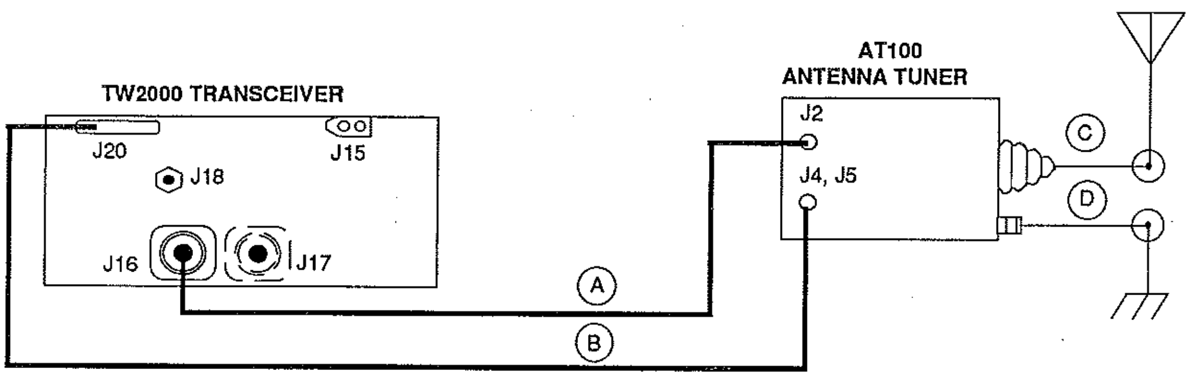
A C991535 RF cable

B Either of the following:
- C991530 standard control cable
- C991547 memory-option control cable

C Either of the following:
- direct connection to long-wire antenna
- antenna lead-in wire to whip antenna

D Ground strap

FIGURE 3.
TW100/AT100 Installation.



CABLES

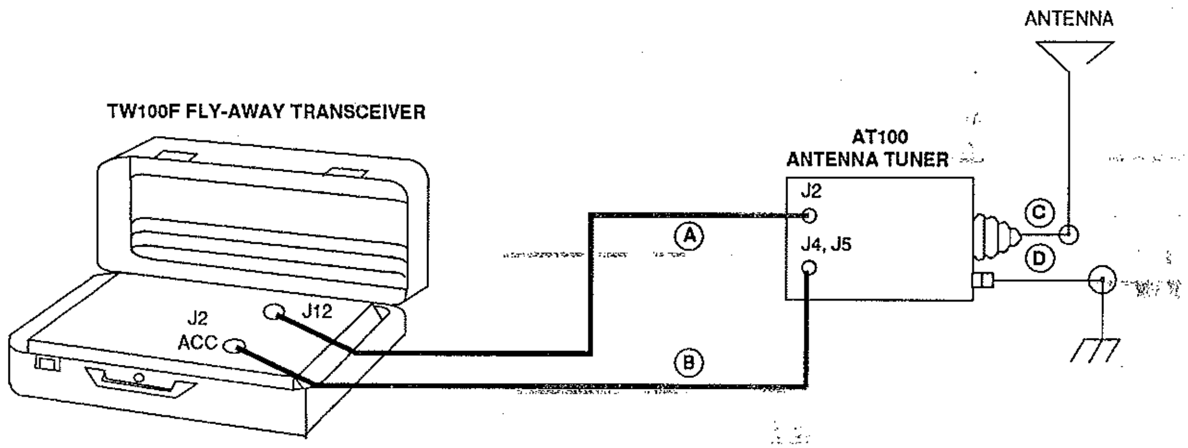
A C991562 RF cable

B C991696 standard control cable

C Either of the following:
- direct connection to long-wire antenna
- antenna lead-in wire to whip antenna

D Ground strap

FIGURE 4.
TW2000/AT100 Installation.



CABLES

A C991535 RF cable

B C991513 standard control cable

C Either of the following;
- direct connection to long-wire antenna
- antenna lead-in wire to whip antenna

D Ground strap

FIGURE 5.
TW100F/AT100 Installation.

TABLE 1
Internal Connections - Standard Control Cable.

Conn. Pin TW2000 J20	Conn. Pin TW100 J4	Conn. Pin TW100F J2	Conn. Pin AT100 J4	Line Description
17	4	A	2	KEY - Keys the transmitter on for low-level carrier tuning. An open-collector NPN transistor capable of sinking 0.5 A to ground when activated.
5	2	F	4	+12 Vdc - Nominal 12 V at 1.5 A, maximum.
18	1	H	1	Ground.
4	5	G	3	Initiate Tune - Starts tune cycle. Line is normally open. Pressing ATU button puts momentary ground on this line, which activates coupler tune cycle.

NOTE: If the AT100 is used with the TW2000, an external tune-initiate wire must be run out of the transceiver. Momentarily grounding this wire will initiate the tune cycle.

TABLE 2.
Internal Connections - Memory Control Cable.

Connector Pin TW100, J4	Connector Pin AT100, J4	Line Description
4	2	KEY - Keys the transmitter on for low-level carrier tuning. An open-collector NPN transistor capable of sinking 0.5 A to ground when activated.
2	4	+12Vdc - Nominal 12 V at 1.5 A, maximum.
1	1	Ground.
5	3	Initiate Tune - Starts tune cycle. Line is normally open. Pressing ATU button puts momentary ground on this line which activates coupler tune cycle.
	J5	
7	4	Data - Serial data from the transceiver providing channel number information.
8	3	Check Tune - Negative-going pulse from transceiver telling the tuner to "read" the channel number and set itself to the setting stored in memory.
6	2	Clock - Toggles to allow data to be shifted and read properly.
3	1	Strobe - A high level on this line allows parallel loading of the BCD channel data into the serial-out shift register.

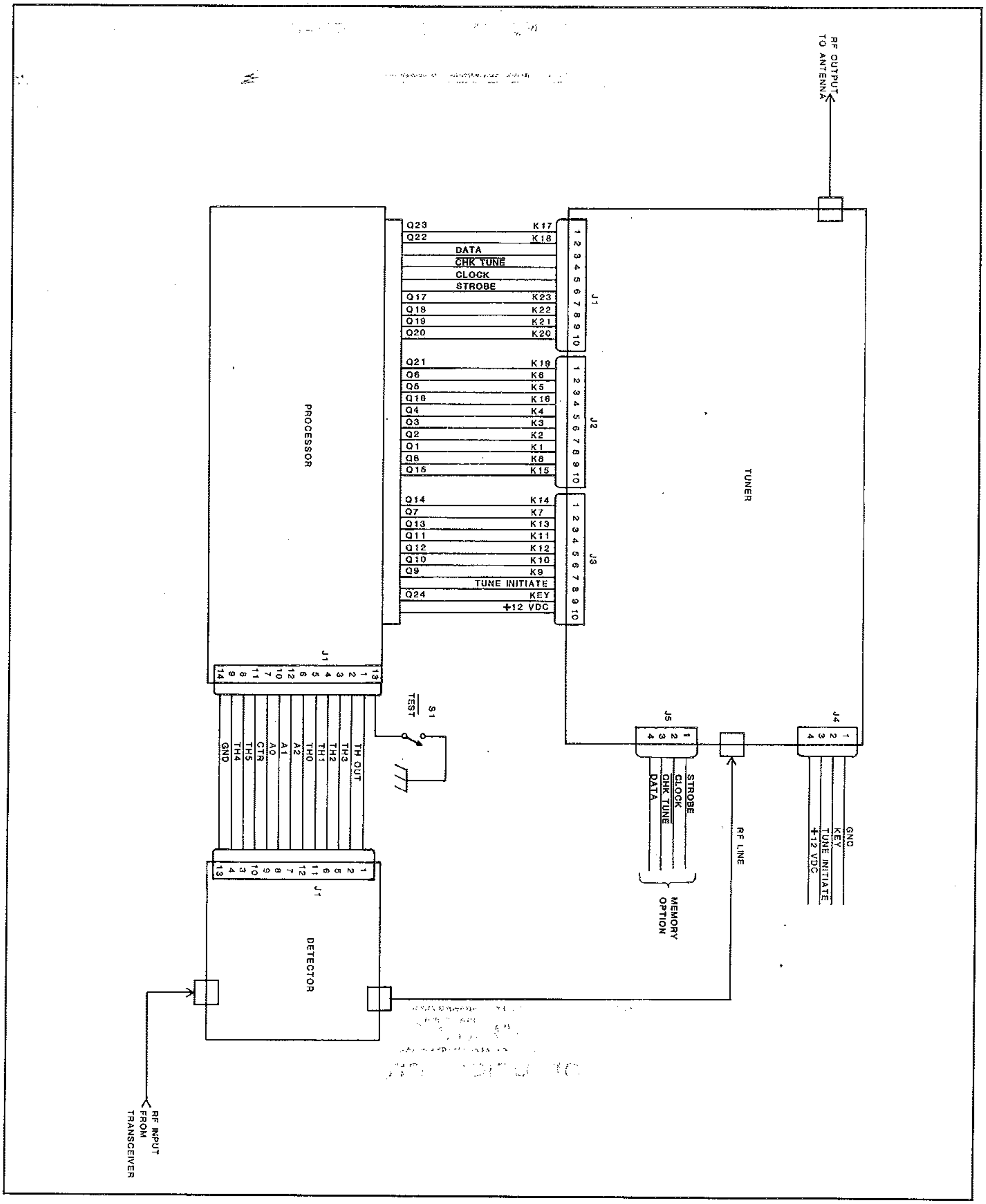


FIGURE 6.
AT100 Wiring Diagram.

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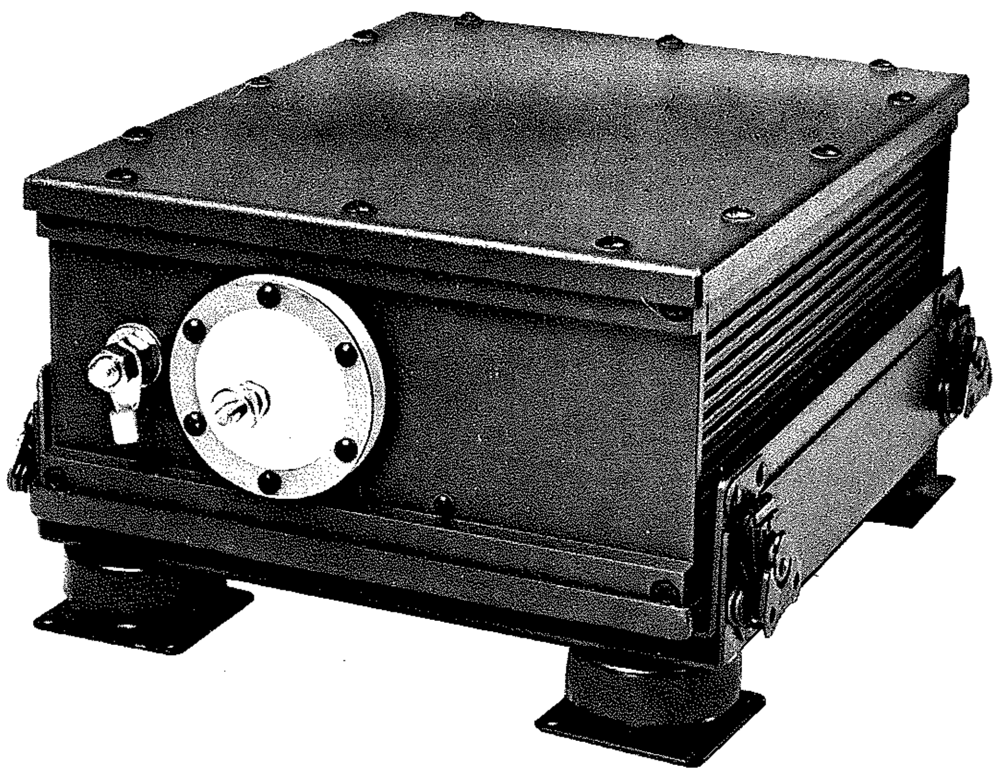


FIGURE 1-1.
RAT100 Automatic Antenna Tuner.

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 RAT100 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 2-30 MHz. All operation, including network tuning and VSWR monitoring, is fully automatic and microprocessor controlled. Tuning time is typically one second.

The 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 should be mounted (in any altitude) as close as possible to the radiating part of the antenna.

1.4 ELECTRICAL DESCRIPTION
The tuner has a reactance-cancelling network consisting of 12 inductors in a binary-coded sequence, two series capacitors and two parallel capacitors. Each inductor and capacitor is inserted into the network by a relay with the inductance variable from 1.0 microhenry to 128 microhenrys in 0.03 microhenry increments. Series capacitors of 35 pF and 100 pF and parallel capacitors of 50 pF and 100 pF may be selected. The antenna is matched to the correct impedance by a broadband RF transformer which provides 11 impedance steps from 3 ohms to 800 ohms.

Tuning is fully automatic. The tuner is connected to the transceiver by a 4-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, an audio signal is also provided which indicates the transceiver is in the tune mode. When RF tune power is received, the tuner automatically matches the antenna to a VSWR of 1.5:1 or less.

When tuning is completed, the coupler releases the KEY signal and turns off the tune tone at the transceiver; normal transmissions from the transmitter are then allowed.

1.5 TECHNICAL SPECIFICATIONS
Table 1-1 lists the technical specifications of the automatic antenna tuner.

1.6 SEMICONDUCTORS
Table 1-2 defines the semiconductors used in the automatic antenna tuner.

1.7 FSK OPERATION (CONTINUOUS TRANSMIT DUTY)

NOTE

The following conditions must be observed when operating in the FSK mode. If these conditions are met, the tuner may be operated continuously in the transmit mode.

1. ANTENNA LENGTHS

The following minimum antenna lengths should be used:

Frequency Range	Antenna Length
2.0 - 30 MHz	27 m (75 ft.)
2.5 - 30 MHz	9.6 m (32 ft.)
3.5 - 30 MHz	6.9 m (23 ft.)
4.0 - 30 MHz	4.8 m (16 ft.)
4.5 - 30 MHz	2.5 m (8 ft.)

2. SUN LOADING

The tuner is rated for operation to 60° C ambient. This temperature can be exceeded if the case is exposed to direct sunlight. For FSK operation it is important that the tuner is installed so that the case is not exposed to direct sunlight.

3. FSK OPERATION - SHORT ANTENNAS

A special version of the RAT100 is available for operation on FSK from 2-30 MHz using a 6.9-m (23-ft.) or longer antenna. This version of the tuner has a restricted frequency range when used with the mobile whip.

1.8 MEMORY OPTION
Memory or **Automatic Tune** Options are available for the RAT100. These options are described in detail in Section 8.1 of this manual.

TABLE 1-1.
Technical Specifications.

Frequency Range:	1.6-30 MHz.
Tuning Capability:	(2-30 MHz).
Whips	2.45-10.7 m (8-35 ft).
Long Wires	23-46 m (75-150 ft).
Doublets	Less than or equal to 3:1 VSWR at operating frequency.
	NOTE: For operation from 1.6-2.0 MHz the minimum antenna length is 5.5 m (16 ft).
Rated RF Input Power:	150 W PEP (See note in Section 1.7 for continuous operation).
Tuning Mode:	Fully automatic.
Tuning Accuracy:	Typically greater than or equal to 1.5:1 VSWR referenced to 50 ohms; maximum VSWR of 2:1.
RF Efficiency:	Typically 50 to 90 % depending on antenna type and frequency.
Tuning Time:	Typically 1 second.
RF Tune Power:	10-W forward power throughout tuning cycle.
Primary Power Requirements:	12 Vdc @ 1.5 A (peak), or 600 mA (average).
Operating Environment:	Waterproof (sealed), designed for exposed installations.
Temperature Range:	-30° C to +60° C.
Weight:	7.3 kg.
Size (WHD):	24.6 cm x 12.7 cm x 29.9 cm.
RF Connections:	
Input	UG-21C type-N.
Output	High voltage teflon insulator.
Input Control Connector:	CA3102R12SA10S.
Control Lines:	
ATU Initiate	Ground-going pulse from radio enables tune cycle.
Key	Ground from tuner during tune cycle.
Ground Connection:	Ground lug.

SECTION 2
ANTENNA TYPES

2.1 GENERAL

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

Broadband resonant antennas (e.g., log periodic) that cover the full range of the system may be used with the tuner if desired. Narrowband resonant antennas, such as dipoles, may only be used if the antenna VSWR (including coaxial feeder) is less 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 m 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 - 4.8 m (16 ft)

This is the minimum length antenna recommended for good communications. Transworld's RA-MAS is a complete mobile antenna system including a 4.8-m, 4-section fiberglass whip antenna, a mobile base and mounting bracket. Shorter antennas may be used for emergency mobile operation, but the performance decreases markedly with length.

2.4 WHIP - 9.6 m (32 ft)

This is the recommended antenna for portable or fixed station operation where space is limited and a long wire or broadband antenna cannot be used. The RA-PAS is a complete portable antenna system, including a 9.6-m, 8-section fiberglass whip antenna and flange mounting base.

2.5 MARINE ANTENNAS

The AW7 (7.0 m) and AW10 (10.0 m) are side-feed whips with flange mounts recommended for marine installation.

2.6 LONG-WIRE ANTENNAS - 23 m (75 ft) & 46 m (150 ft)

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 2-1 through 2-5 show some typical installations for the automatic antenna tuner.

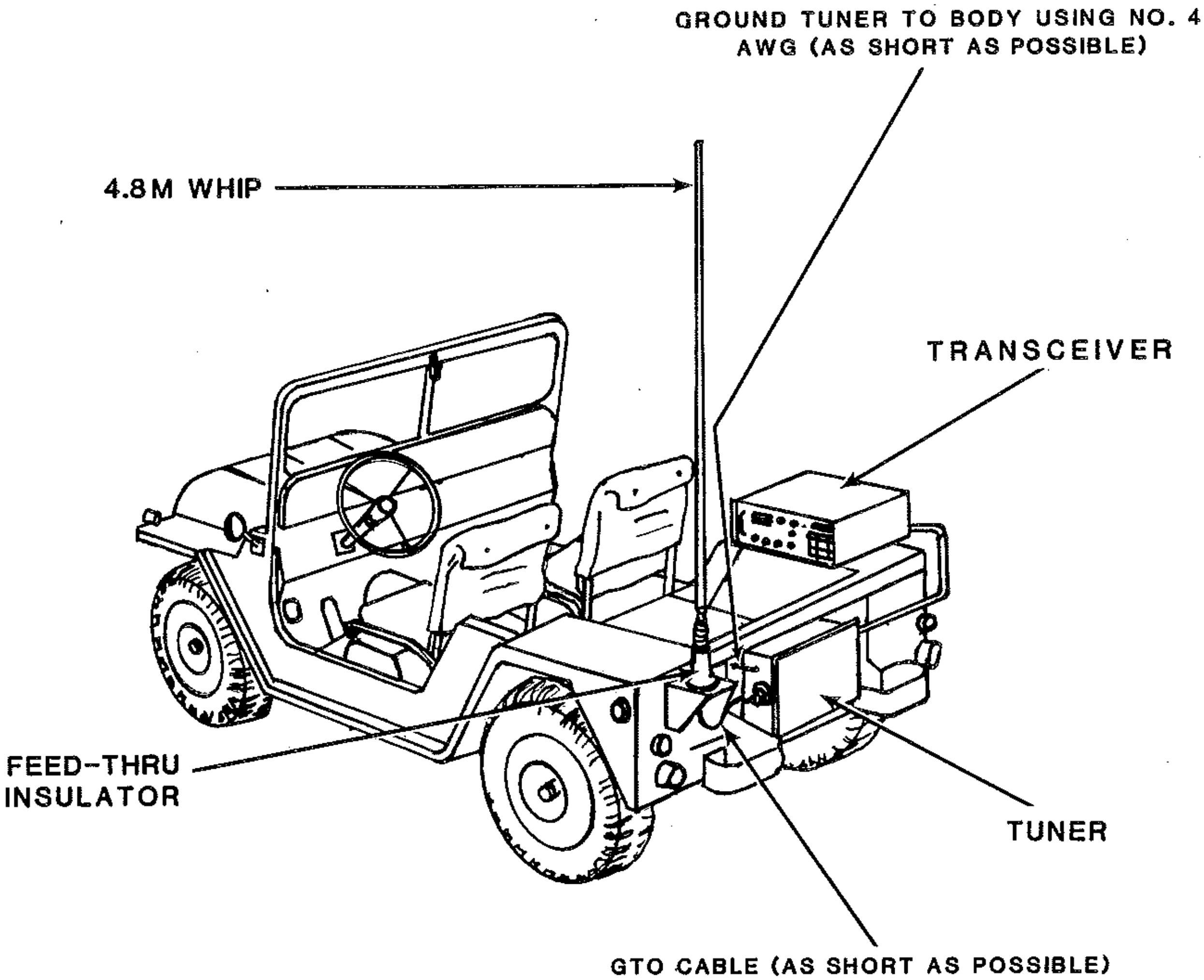


FIGURE 2-1.
Jeep Installation, Whip.

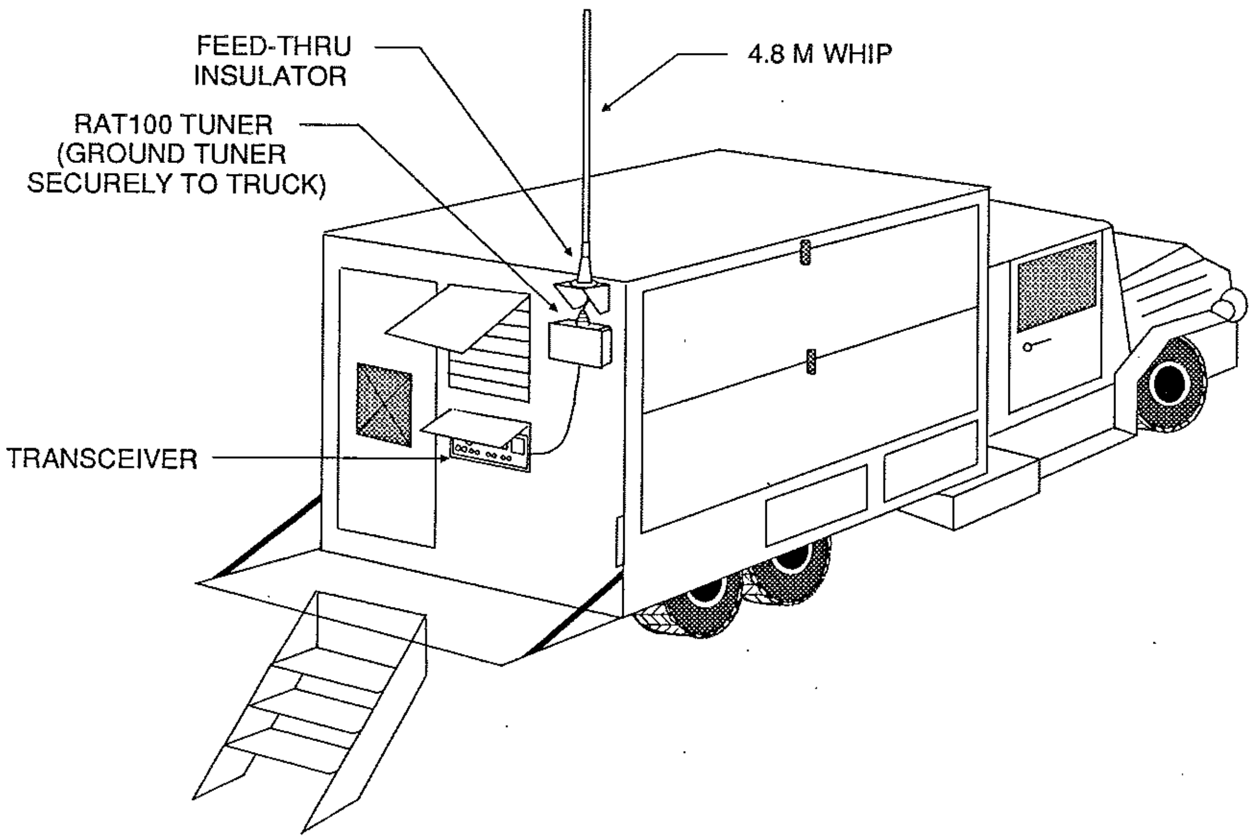


FIGURE 2-2.
Portable Installation.

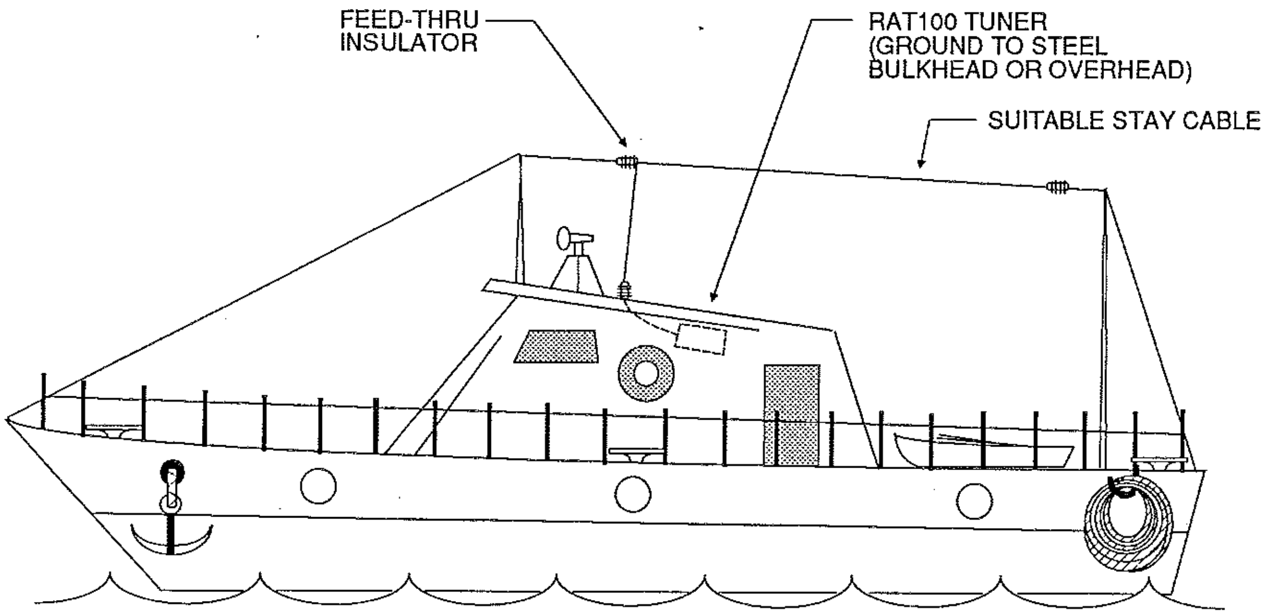


FIGURE 2-3.
Marine Installation, Long Wire, Patrol Vessel.

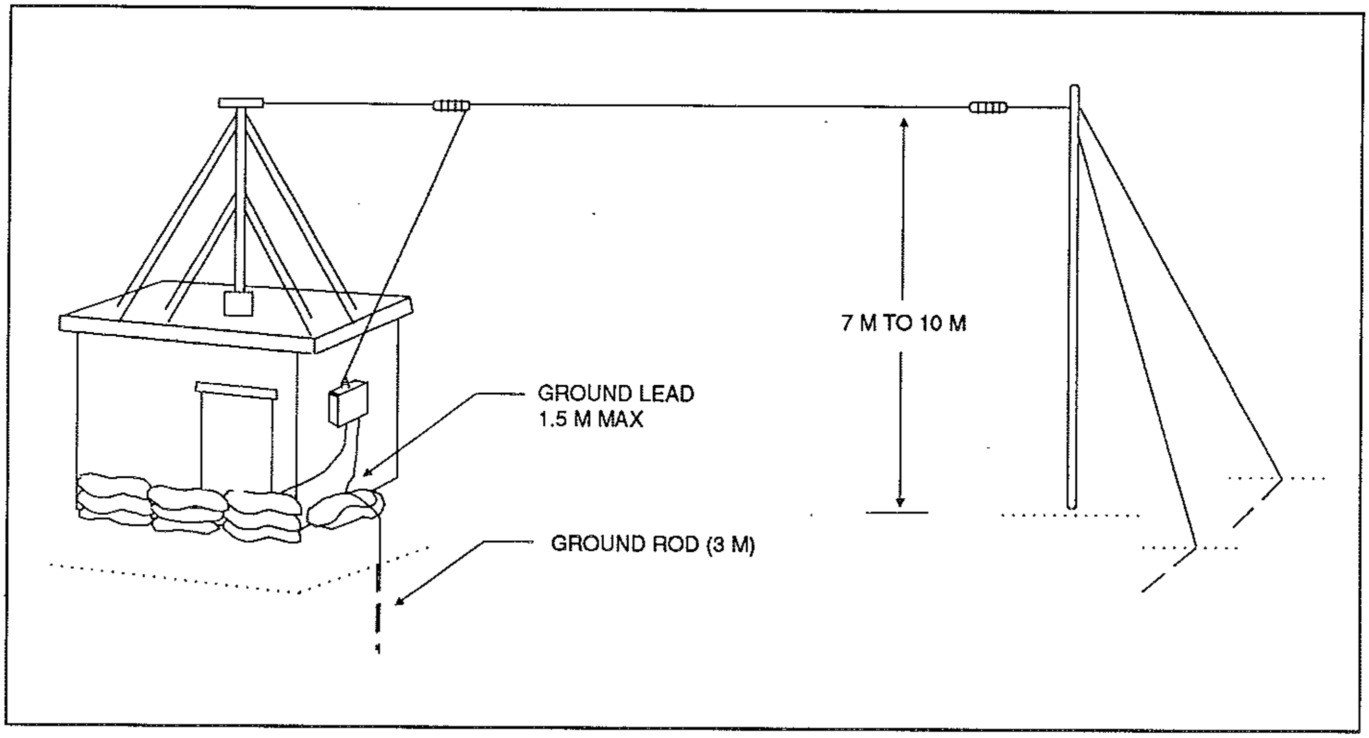


FIGURE 2-4.
Base Station Installation, Horizontal.

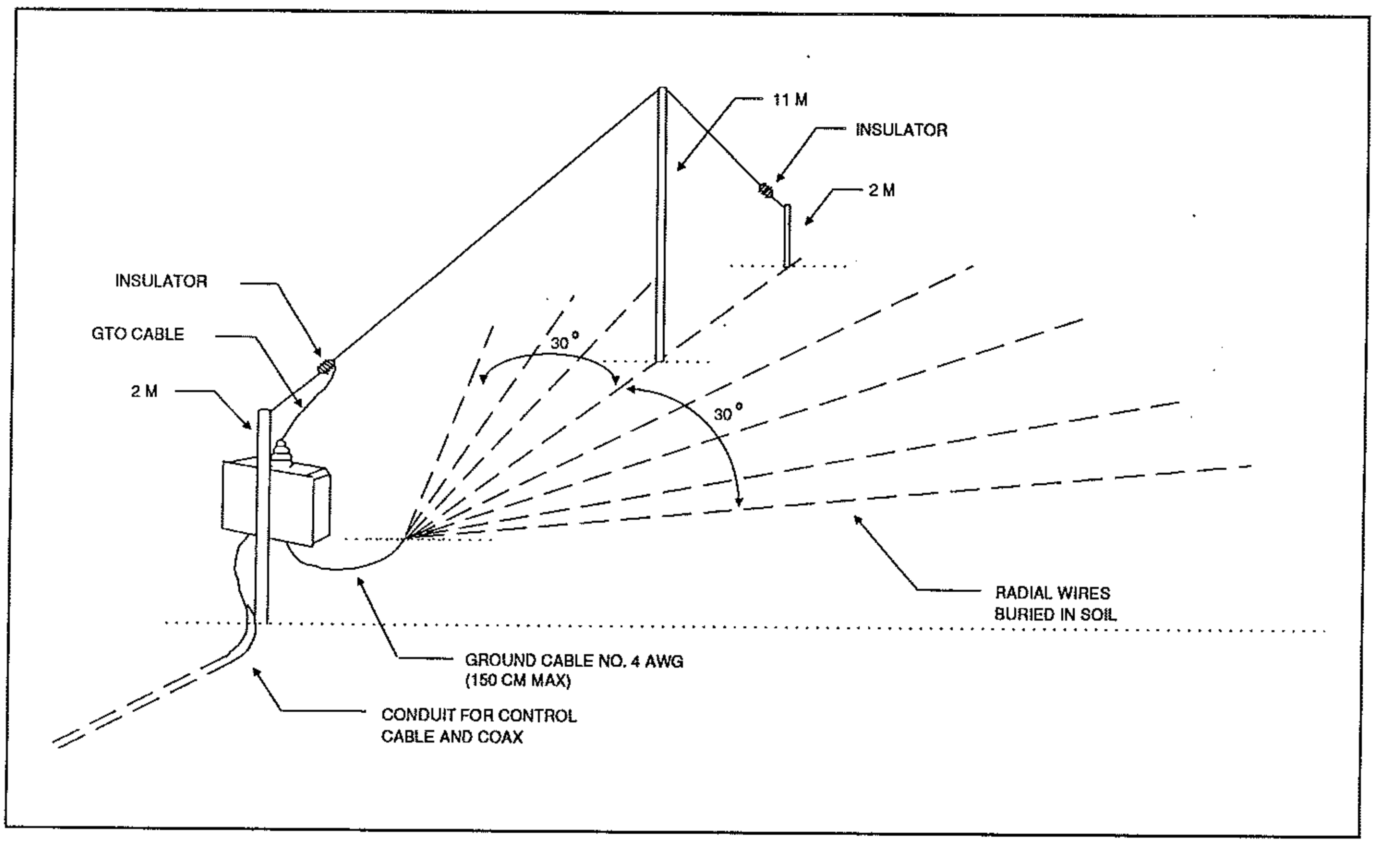


FIGURE 2-5.
Base Station Installation, Inverted "VEE."

SECTION 3
INSTALLATION

3.1 GENERAL

System installation is a three-part process covering the following steps:

a. Installing the antenna.
b. Mounting the antenna tuner.
c. Connecting the appropriate interface cables between the tuner and the transceiver.

This manual section will discuss the above-mentioned three steps in detail. This should provide sufficient information to enable the user to confidently install a complete system in the proper manner.

3.2 ANTENNA INSTALLATION

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.

3.2.1 ANTENNA LOCATIONS

The figures 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 m 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 V) 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 1-1.5 m. 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 m.)

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

3.2.2 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.

3.2.2.1 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 nonmetallic couplings, brushings, fiberglass panels, etc.

3.2.2.2 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. 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.

3.2.2.3 BASE-STATION GROUNDS

In areas of high ground conductivity and effective ground can be made through a grounding rod. The rod should be approximately 3 m 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. If the antenna is at ground level the radials should be buried a few inches below the surface.

3.2.2.4 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.

3.3 ANTENNA-TUNER MOUNTING

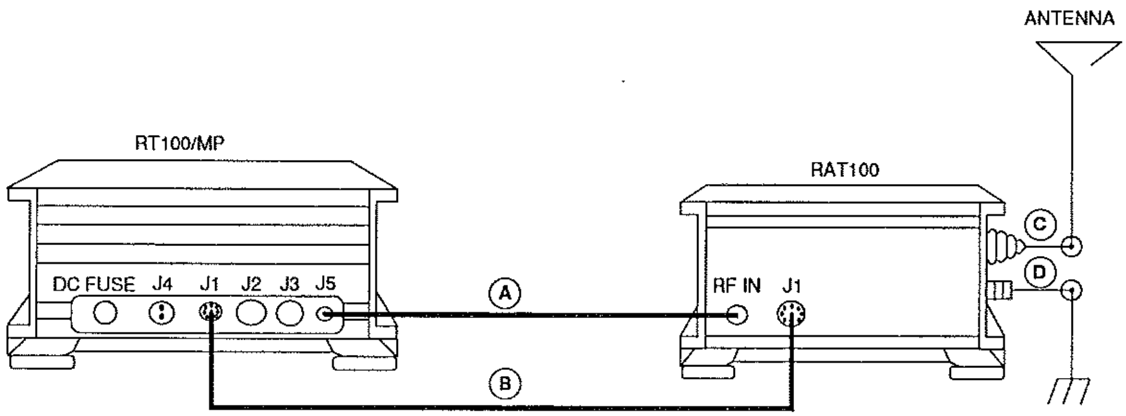
The tuner is mounted using the proper mounting brackets on the case. Choose a location immediately adjacent to the antenna feed point. In trunk-mounted mobile installations it is very important that the tuner is located so that the antenna insulator is within a few centimeters of the antenna exit hole. 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.)

3.3.1 ANTENNA CONNECTION

The antenna lead is connected to the high-voltage insulator. Use two wrenches when tightening the nut to prevent the stud from rotating. 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 that the antenna is spaced at least 3 cm from the conducting surface. Sharp points should be avoided to prevent corona discharges.

3.4 CABLE CONNECTIONS

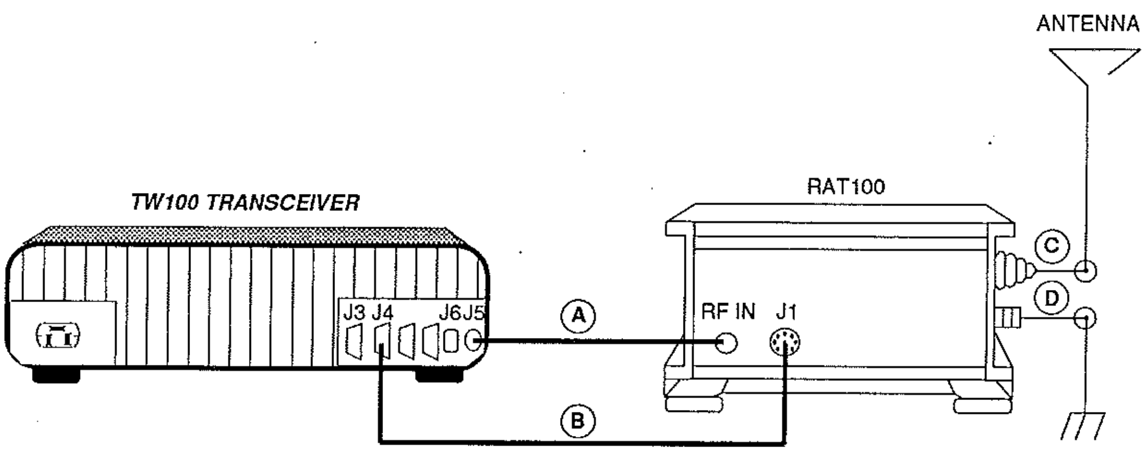
Figure 3-1 shows a block diagram of an RT100/MP/RAT100 installation, and Figure 3-2 shows a TW100/RAT100 installation. The diagrams identify all cables used in the installations and provide appropriate TWC part numbers. Note that the control cable used in each system can be either the standard 4-wire cable, or a special 10-wire cable used when the memory option is installed in the antenna tuner. Figure 3-3 is a block diagram of a TW100F/RAT100 installation. Since the memory option is not available in the TW100F transceiver, no memory-option cable is shown. Table 3-1 defines the lines in the standard 4-wire control cable; it shows the pins on the RT100/MP, the TW100F and the TW100. Table 3-2 defines the lines for the memory control cable (detailed technical information on the memory and auto-tune options can be found in Section 8 of this manual).



CABLES:

A	C991505 RF Cable
B	Either of the following: -C991504 standard control cable -C991542 memory-option control cable
C	Either of the following: -direct connection to long-wire antenna -antenna lead-in wire to whip antenna (Use C991620 for RAT100 to AWM lead-in wire)
D	Ground strap

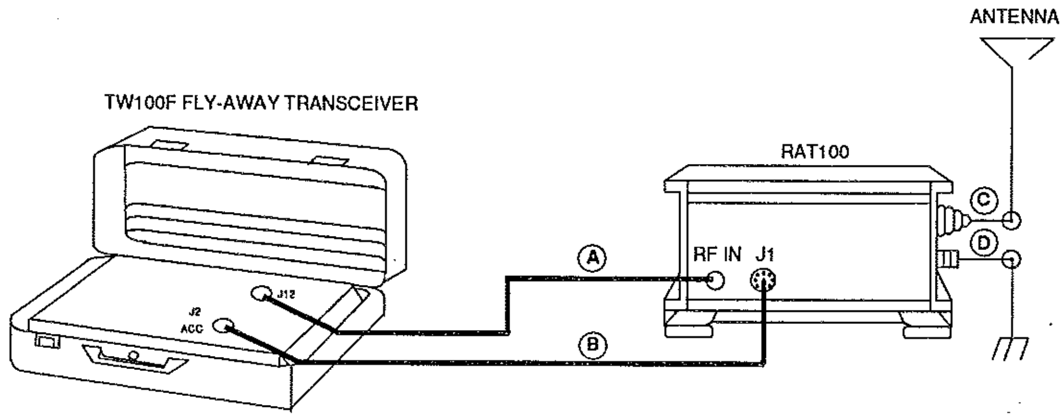
FIGURE 3-1.
RT100/RAT100 Installation.



CABLES:

A	C991526 RF Cable
B	Either of the following: -C991524 standard control cable -C991570 memory-option control cable
C	Either of the following: -direct connection to long-wire antenna -antenna lead-in wire to whip antenna
D	Ground strap

FIGURE 3-2.
TW100/RAT100 Installation.



CABLES:

A	C991526 RF Cable
B	-C991514 standard control cable
C	Either of the following: -direct connection to long-wire antenna -antenna lead-in wire to whip antenna
D	Ground strap

FIGURE 3-3.
TW100F/RAT100 Installation.

TABLE 3-1.
Internal Connections - Standard Control Cable.

Connector Pin (TW100, J4)	Connector Pin (TW100F, J2)	Connector Pin (RAT100 or RT100, J1)	Line Description
4	A	A	KEY -Keys the transmitter on for low-level carrier tuning. An open-collector NPN transistor capable of sinking 0.5 A to ground when activated.
2	F	B	+12 Vdc - Nominal 12 V at 1.5 A, maximum.
1	B	C	Ground.
5	G	D	Initiate Tune - Starts Tune cycle. Line is normally open. Pressing ATU button puts momentary ground on this line which activates coupler tune cycle.

TABLE 3-2.
Internal Connections - Memory Control Cable.

Connector Pin (TW100, J4)	Connector Pin (RAT100 or RT100/MP, J1)	Line Description
4	A	KEY - Keys the transmitter on for low-level carrier tuning. An open-collector NPN transistor capable of sinking 0.5 A to ground when activated.
2	B	+12Vdc - Nominal 12 V at 1.5 A, maximum.
1	C	Ground.
5	D	Initiate Tune - Starts Tune cycle. Line is normally open. Pressing ATU button puts momentary ground on this line which activates coupler tune cycle.
7	E	Data - Serial data from the transceiver providing channel number information.
8	F	Check Tune - Negative going pulse from transceiver telling the tuner to "read" the channel number and set itself to the setting stored in memory.
6	G	Clock - Toggles to allow data to be shifted and read properly.
3	H	Strobe - A high level on this line allows parallel loading of the BCD channel data into the serial-out shift register.

SECTION 4
OPERATION

4.1 GENERAL

The automatic antenna tuner is designed to operate with either the TW100 or RT100/MP series of transceivers.

NOTE

It will also operate with Transworld's PRC1099 manpack transceiver in either a 20-W or 100-W (with RA100 RF amplifier) configuration. Refer to the PRC1099 technical manual for details.

After installing the antenna and the tuner, it is only necessary to connect the tuner to the transceiver using the multiwire control cable and RF coaxial cable described in Section 3.4.

4.2 OPERATION WITH RT100/MP OR TW100 TRANSCEIVERS

The following procedure should be followed when operating the tuner with the RT100/MP or TW100 transceivers.

a. Select the operating mode of the RT100/MP or TW100, i.e., LSB, USB, AM or FSK.

b. Turn on the power using the front-panel switch. Note that there are no operator controls on the tuner.

c. Select the operating frequency or channel.

d. Press and then release the "ATU-initiate" button on the front panel.

After the ATU-initiate button is pressed, the TUNING TONE should come on, which indicates that a tune cycle is in progress (the transceiver internal tune tone is activated). During this period the tuner holds the transceiver key line down (transmit mode) until the tune cycle is completed. Upon completion of the tune cycle the TUNING TONE goes off and the key line is released. The system is ready for use when this occurs.

If the antenna tuner does not achieve a satisfactory match, an interrupted tune tone will be heard at the end of the tuning cycle. The tuner will then be switched out of circuit, which leaves a direct connection between the radio and the antenna. If a match is not achieved, it may be due to a transient happening and the tuning cycle should be repeated.

NOTE

The transceiver should be unkeyed when the ATU-INITIATE button is depressed in order to activate the tune cycle. This ensures that timing is correct for the most accurate match to be achieved.

NOTE

If the transceiver is being operated using the remote control, then antenna tuning is accomplished by pressing the "ATU" key on the remote control (after operating mode and frequency have first been input per the procedure).

SECTION 5
THEORY OF OPERATION

5.1 INTRODUCTION

The automatic antenna tuner matches the 50-ohm output of a 150-W transmitter to a wide variety of whip or long-wire antennas. Since the tuner is completely automatic, all tuning, control and monitoring functions are completely self-contained. Figure 5-1 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 inductor 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 impedance matching transformer. The reflected power detector provides a voltage proportional to reflected RF power and is used to monitor tuning accuracy and to indicate VSWR for comparison with predetermined tuning thresholds. The forward power detector is used to ensure the correct tune power is applied to the tuner.

The basic matching system used in the tuner is shown in Figure 5-2. If the antenna appears capacitive, the series inductance is adjusted until the reactance is cancelled. If the antenna is inductive, series or parallel capacitance is added until the antenna appears capacitive. Series inductance is then added until the reactance is cancelled. At this point the antenna appears resistive and the correct tap is selected on the input matching transformer. This transformer has five impedance ratios and can be reversed to give eleven output impedances from 3 ohms to 800 ohms.

The inductances are selected by relays controlled by the microprocessor. Twelve inductances are used, arranged in a binary sequence from 0.03 microhenry to 64 microhenrys. This means the inductances may be selected to give a total inductance range of 1.0 microhenry to 128 microhenrys in 0.03 microhenry steps. Two values of series capacitance and two values of parallel capacitance are selected by relays. High-voltage relays are used at all points where the voltage exceeds 500 V.

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 5-3 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 1.6-30 MHz. Providing the system is properly installed and good grounding is provided, tuning capability

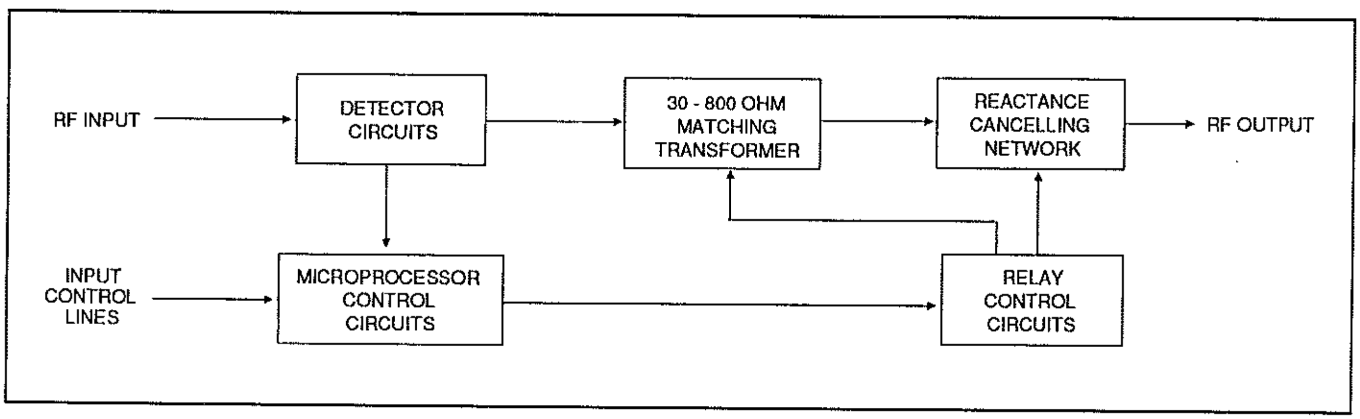


FIGURE 5-1.
Block Diagram.

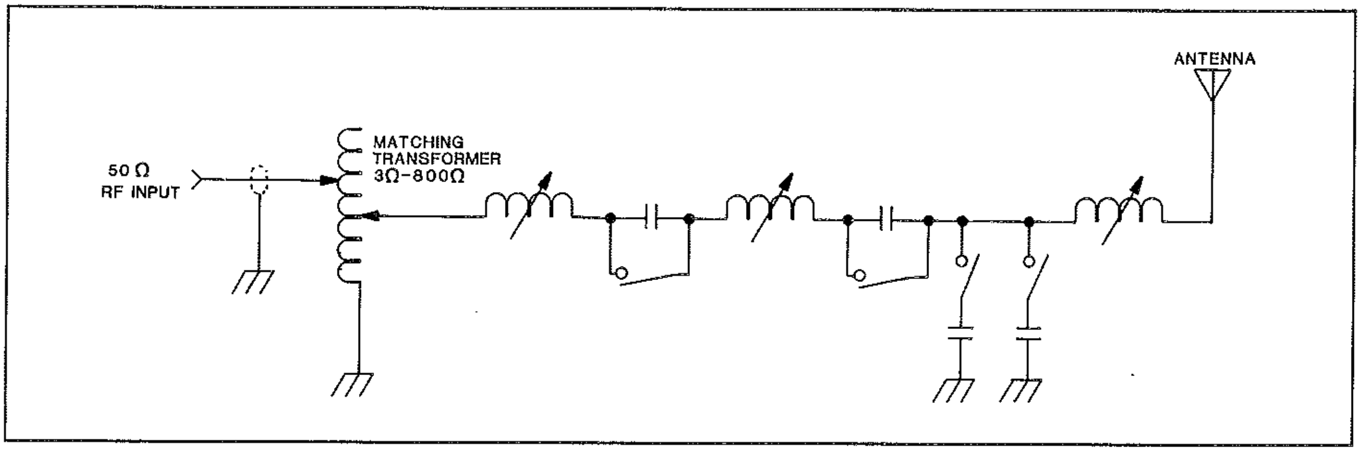


FIGURE 5-2.
RF Tuning Network.

is directly proportional to antenna impedance and operating frequency (for a given set of tuning element values). Figure 5-4 gives an illustration of how the tuning network operates to match a typical antenna impedance. A 16-ft whip antenna has a load impedance (depending on ground conditions) of 10-j1500 ohms at 2 MHz. In order to tune this antenna, the tuner adds inductance until the capacitive reactance is cancelled and the antenna appears resistive (ZT = RT + j0). The correct tap is selected on the input matching transformer so that the antenna resistance is transformed to 50 ohms.

5.3.2 RF TUNE POWER

The tuner operates at a tune power of 10 W. If the power level is insufficient to operate the tune detectors, the tuner will not start the tune cycle. In the TW100 and RT100/MP transceivers, the carrier is used for tuning, which prevents interference during the tune cycle. The power level is automatically controlled to 10 W by the transceiver ALC system.

5.4 DETECTOR MODULE - DETAILED DESCRIPTION

5.4.1 PHASE DETECTOR (refer to Figure 7-4)

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 L2, the output from which causes conduction through D1 and D2 on positive-going peaks. C1 and L1 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 L1. This causes equal conduction through D1 and D2 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 L1 arriving out of phase as compared to the output from L2.

5.4.2 /Z/ DETECTOR (refer to Figure 7-4)

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. L3 senses the current and causes D3 to conduct. C14 and C15 divide the RF voltage to a suitable level and output from this divider is applied to D4. When the load is exactly 50 ohms, the current signal from L3 balances 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 (refer to Figure 7-4)

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 dc output.

L4 provides a current pickup while C20 and C21 deliver a divided sample of the voltage on the line. As long as the two inputs to D6 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 dc output will appear proportional to the VSWR.

5.4.4 FORWARD POWER (refer to Figure 7-4)

The forward-power leg of the VSWR bridge is used to determine the power level. D5 provides a dc voltage proportional to the forward power.

5.4.5 DETECTOR MICROPROCESSOR INTERFACE

The output of the phase and resistance magnitude detector is applied to the output of two operational amplifiers U1A and U1B. The output of the operational amplifiers is 4 V when the detectors are balanced for a 50-ohm resistive load. Small changes in balance cause the operational amplifiers to swing towards rail (8 V) or ground (2 V). The reflected power output from the VSWR detector is amplified by a simple bipolar amplifier with a voltage gain of approximately 10. The forward power output from the

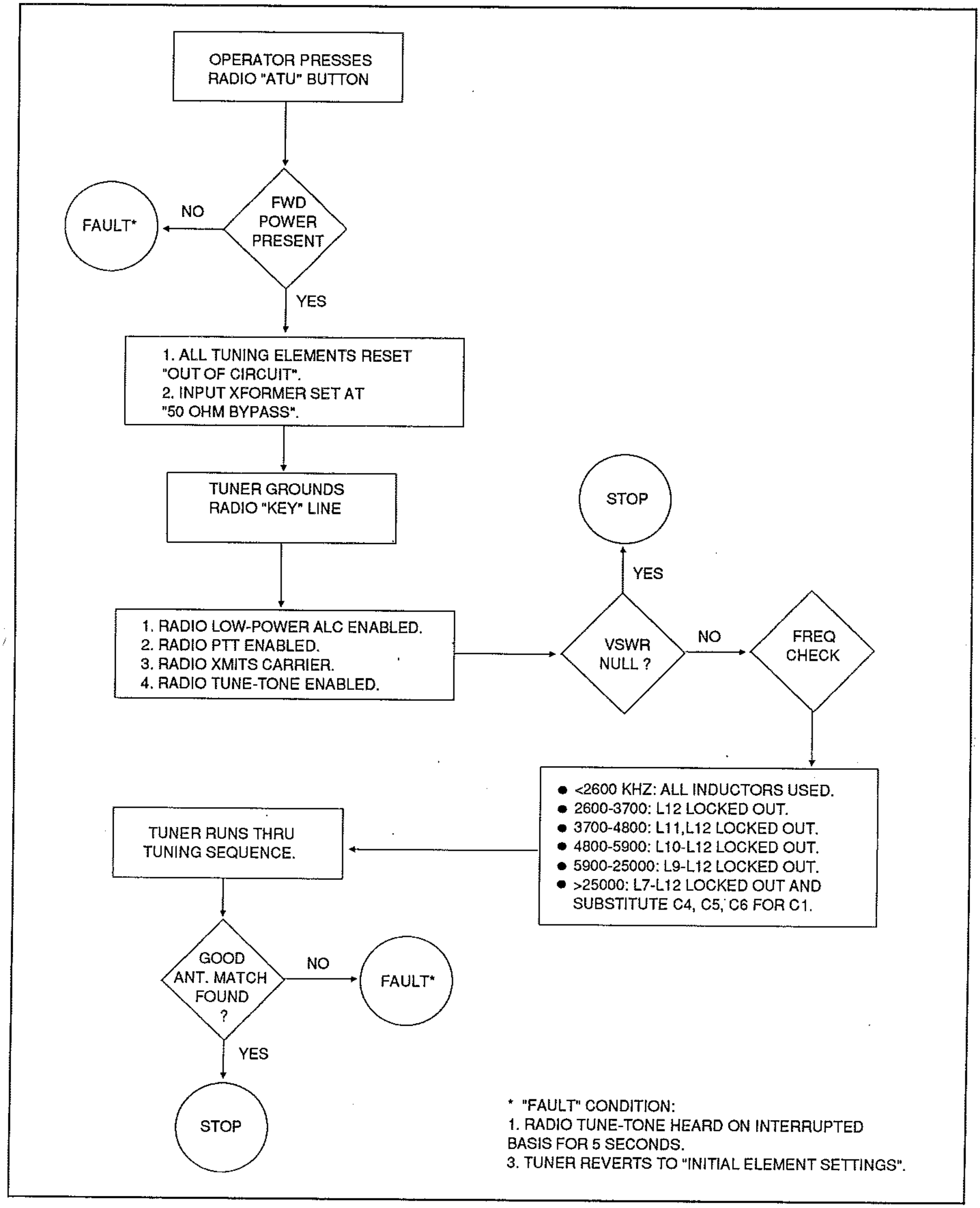


FIGURE 5-3.
Sequence of Events.

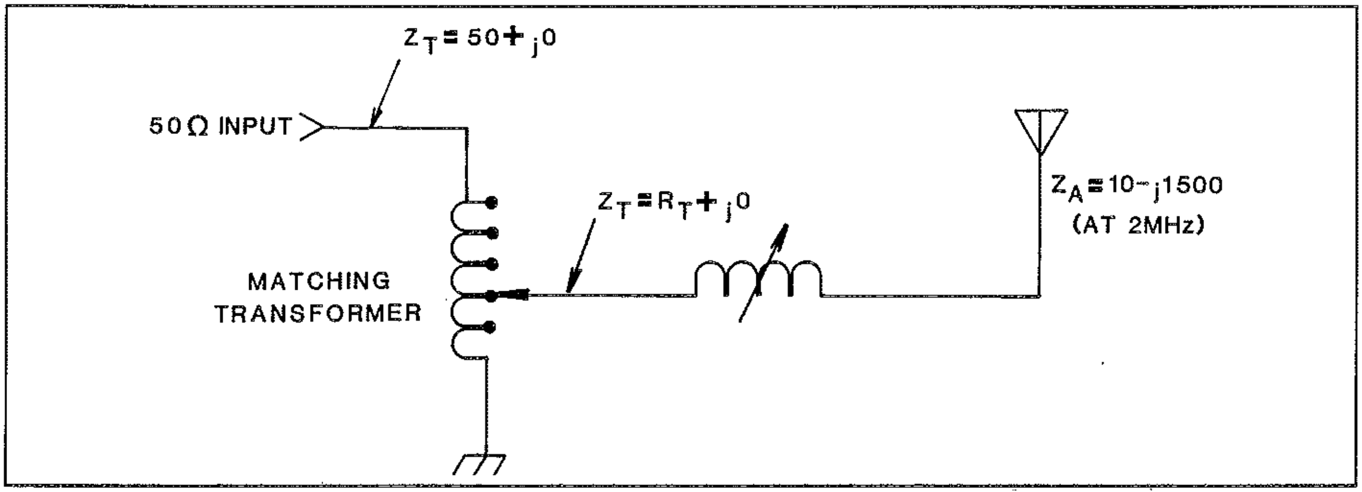


FIGURE 5-4.
Tuning Example.

VSWR detector is at high level and requires no amplification.

All four detector outputs then go to U5, which is an 8-channel multiplexer with three binary inputs. This circuit acts like a digital switch, with the input that is passed on to the output port (pin 3) selected by the processor. For instance, when the processor wants to interrogate the phase detector, it puts all 0's on lines U5-9, 10, and 11; this causes U5-13 to be connected to U5-3 and ultimately to the processor module through D9 and J1-2. The other detector outputs are interrogated in a similar fashion.

U3 is an operational amplifier used to set different thresholds for comparing to the detector outputs. The particular threshold is selected by input lines J-3, 4, 5, 6, 11, and 12 and sets the level at U3-6. This level is then compared to the particular detector output at U3-5.

Q1 and the dividers U6 and U7 are used in conjunction with the microprocessor to form a frequency counter. The frequency information is used to minimize the tuning time by eliminating selection of components not required in specified frequency ranges. U6-11 is the standard output connection to the Processor module via J1-10.

The counter output is routed to the processor module through J1-10. The different elements left out of the tuning program at various frequency ranges are listed in Table 5-1.

5.5 TUNING NETWORK - DETAILED DESCRIPTION

The tuner schematic, Figure 7-2, shows the complete tuning network. T1 is the input matching transformer. This transformer has five impedance taps selected by relays K19-K23. Relays K17 and K18 are used to reverse the inputs and outputs of the transformer to provide step-up or step-down ratios.

L1-L12 are a series of inductors arranged in a binary progression. L1 is 0.03 microhenry and each inductor doubles in size ending with L12 at 64 microhenrys. Relays K1-K12 short out each inductor. By selecting the appropriate relays, it is possible to increment the inductances in 0.03 microhenry steps up to 128 microhenrys.

Two parallel capacitors, C2 and C3, are selected by relays K14 and K15. The series capacitor C1 is selected by K13. At frequencies above 25 MHz the series capacitors C4, C5 and C6 are selected by K16.

A special relay with low capacitance and very good isolation between the contacts and the frame is used for switching functions up to 500 V. Special high voltage reed relays are used for switching the four largest inductors. These relays are rated for 5 kV and are connected in series so that the maximum voltage across any relay cannot exceed 50 % of the maximum potential in the tuner. The series and parallel capacitors are not required when L9-L12 are in circuit, and it is possible to locate them at a lower potential point in the circuit. It should be remembered that when either the series or parallel capacitors are in use, they will be connected directly to the antenna.

Inductors L5-L12 are all toroids which minimize coupling and interaction between the inductors. The inductors are wound with high-voltage, silver-plated, teflon-covered wire. Large cores are used to minimize losses. L11 uses two stacked cores while L12 uses two separate inductors in series, each wound on stacked cores. Special care has been taken to prevent insulation breakdown at the high voltage points in the circuit. Inductors L9-L12 are mounted on an insulated rod completely isolated from the main circuit board. The inductors are wired directly to the contacts at the ends of the glass tubes containing the high-voltage reed switches. This results in complete isolation for all voltages above 500 V. The resistors R1 and R2 prevent the build-up of any static charge on the antenna when the series capacitors are in circuit.

TABLE 5-1.
Element Lock-Out Table.

FREQUENCY	ELEMENTS
Freq. < 2600 kHz	All elements can be used.
2600 kHz ≤ Freq. < 3700 kHz	L12 not used.
3700 kHz ≤ Freq. < 4800 kHz	L11, L12 not used.
4800 kHz ≤ Freq. < 5900 kHz	L10, L11, L12 not used.
5900 kHz ≤ Freq.	L9, L10, L11, L12 not used.
25000 kHz ≤ Freq.	C4, C5, C6 substituted for C1; L7 - L12 not used.

5.6 PROCESSOR CONTROL CIRCUITRY DETAILED DESCRIPTION

The processor module contains the microprocessor and associated components that perform the various control functions within the antenna tuner. This includes interrogating the detectors, locking out frequency-restricted elements, keying the transceiver, and determining which tuning elements are in the circuit at any given time.

5.6.1 CPU PORT FUNCTIONS

The circuit is based on the 80C39 microprocessor (CPU). The CPU has 27 input/output lines (I/O) for communication with the rest of the circuit. These take the form of three 8-bit ports, two 1-bit I/O lines, and an interrupt line. One of the 8-bit ports is called the bus port and performs two functions in this system. First, it acts as the port for transfer of data between the CPU and the other devices on the bus. Second, it is time-multiplexed with the lower 8 bits of the internal address bus such that the external latch, U5, latches those address bits at the proper time in conjunction with the Address Latch Enable (ALE) signal. The data bus port consists of pins 12 through 19 of U1, and ALE is pin 11.

The other ports are split among the various other communications requirements in the system. Some of the port bits are actually performing more than one function. These ports are designated as port 1 and port 2 and are pins 27 through 34, and pins 21 through 24 and pins 35 through 38, respectively.

The lower three bits of port 2 serve as the three most significant address lines. This is their only function. P23 is located at pin 24 of the CPU, and its dedicated function is to input the test program start-up line to the CPU.

The three higher order bits of port 2, pins 36 to 38, form a serial output port which drives the interface to the tuner PCB. Pin 37 or P26 serves only as a clock for the tuner PCB shift registers, U1 through U3.
P25, or pin 36, is the latch strobe signal for the shift registers. When this signal goes to a high level, the data which has been shifted into the interface will appear at the outputs. P27, or pin 38, serves as the data line in the transceiver interface.

The lower six bits of port 1 are used to set thresholds for detector output level comparisons. The top two bits of port 1 and the fifth bit of port 2 (pin 35) are used to address the multiplexer in the detector module in binary fashion.

The two other I/O lines, T0 and T1, at pins 1 and 39 respectively, act as the recipient of the multiplexed detector information and as the input for the frequency counter data.

Pin 6 of the CPU is the "INT" input of the device. It is connected to the external transceiver "ATU" tune line. A momentary ground placed on this line enables the start of the coupler tune cycle.

5.6.2 OPERATIONAL DESCRIPTION

Upon power up, the reset capacitor, C3 is charged from the zero-voltage state, and when the internal threshold is reached, the processor starts executing instructions. The sequence is for the CPU to first fetch the instruction from the program memory, U6, by asserting a low level on the PSEN line. This enables the ROM to write data to the data bus and the CPU can then read the data. Just before this operation the CPU has made sure that the address has been latched by U5 by asserting the ALE line, which pulses high.

NOTE

The socket for the ROM U6 is a 28-pin socket that allows use of either 2716, 2732 or 2764 EPROM's; the 2716 is a 24-pin I.C., while the 2732 and 2764 are 28-pin I.C.'s. Refer to the Processor schematic, Figure 7-6, to locate U6 and the associated jumpers. If the EPROM is a 2716, then jumper A-B should be connected and A-C open; if the EPROM is a 2732 or 2764, then jumper A-C is connected and A-B open.

5.6.3 TUNER PCB INTERFACE

U1, U2, and U3 are 8-stage serial-shift registers having a storage latch associated with each stage for strobing data from the serial input to the parallel buffered 3-state outputs. Each output is connected to a 2N6427 Darlington transistor which acts as the relay driver. There are 23 relays on the tuner PCB, and each is driven by one of the shift-register outputs. The 24th line is used as the transceiver "key" line (Q24, U3-4); this will go to ground immediately on receipt of a "TUNE" pulse on U4-6.

All of the relays on the tuner PCB are activated by turning their respective driver transistor "ON" (ground) except K9, K10, K11, and K12; these four relays are activated by turning their drivers "OFF." Note in the Processor schematic that U2-14 is connected to RP2 so that it drives relay K12. The jumper connection indicated from U3-4 to RP2 is not made in the RAT100.

5.7 TUNING PROCEDURE

The software program controlling the antenna tuner is quite complex, with many procedures designed to minimize the tuning time and to avoid situations where the detectors may not give correct information. The following basic method of tuning is used.

a) Initially, all elements in the tuner are switched out of circuit so that the detectors are connected directly to the antenna.

b) If the output of the phase detector indicates capacitive reactance, inductance is added until the detector indicates zero phase (resistive load).

c) The output of the R detector is then examined. The impedance taps are selected progressively going higher or lower according to whether the detector indicates low or high impedance.

d) If the phase detector indicates inductive reactance, C1, C2, C2 and C3, are selected in turn (C4/C5/C6 above 25 MHz) until the phase changes to indicate capacitive reactance. The tuning procedure used in steps (b) and (c) is then followed.

e) The output of the VSWR detector is monitored continuously and the tuning procedure is stopped immediately when match is achieved (when VSWR is less than 1.2:1). If match cannot be reached, the best match below 1.5:1 is selected. Alternate tuning procedures will be tried if a match of 1.5:1 cannot be found. The program will finally accept a match of less than 2:1 or, if this cannot be achieved, will indicate no match (pulsating tune tone in transceiver for 5 seconds at end of tune cycle).

SECTION 6
ALIGNMENT & TEST

6.1 GENERAL

The automatic antenna tuner has been thoroughly tested and aligned at the factory. Realignment 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

1. 50-ohm dummy load (Bird 8321 or equivalent).

2. Inductance measuring equipment:
   Minimum requirements 0-150 microhenrys in 0.02 microhenry resolution (RLC Meter - MM2).

3. High impedance voltmeter (VTVM or FET).

6.3 DETECTOR ALIGNMENT

1. Connect the antenna coupler to the transceiver using the RF coaxial cable and the control cable.

2. Connect the output of the detector module to the 50-ohm dummy load. (Note: This requires removing the tuner input coaxial cable from the detector first).

3. Set the transceiver frequency to 6.00 MHz.

4. Key the transceiver into the tune mode by placing a short across the "key" line. (Note: This is best accomplished by connecting a clip lead from ground to the "key" pin in the processor module. See Figure 7-5 for location of this pin). Make sure the RF forward power is a minimum of 10 W.

5. Adjust R17 for maximum VSWR sensitivity (fully CCW—see Figure 6-1).

6. Connect the voltmeter to test point 3 on the detector PCB (Figure 6-1). Adjust the voltmeter to read -dc volts at the lowest voltage scale.

7. Adjust C20 for a minimum output on the voltmeter (this "minimum" should be less than 50 mV).

NOTE

If there is a significant "dead zone" around the voltage null, the RF power used during alignment can be increased to the 100-W level. This will eliminate the "dead zone" and allow for more accurate alignment.

8. Connect the voltmeter to test point 2 on the detector PCB (Figure 6-1). Adjust the voltmeter to read +dc volts on a range equal to 10 V.

9. Adjust C14 (using an insulated tuning tool) until the voltage at test point 2 is approximately 4 V.

NOTE

The voltage will "snap" from about 2 volts up to 7.5 volts and vice versa as C14 is adjusted through the optimum alignment point. Setting right at the mid-point (4 volts) is probably impossible without an oscilloscope to monitor the waveform; therefore, when using a voltmeter the best procedure is to turn C14 until the voltage "snaps" from 2 to 7.5 volts, and then give it a slight turn back toward the mid-point (stopping short of making it "snap" back low again).

10. Connect the voltmeter to test point 1 on the detector PCB (Figure 6-1).

11. Adjust R3 until the voltage at test point 1 is approximately 4 V. (See the note under step 9 for the proper alignment procedure.)

12. Using a CW keyer, key the transceiver on high power, and adjust R17 until the voltage at U8 pin 1 indicates 0.900 Vdc.

Again making the adjustment at items (9) and (11) to exactly 4 V may be impossible due to the "snap-action" of the circuit. It is sufficient to adjust the control as closely as possible to the "transition point" between high and low.

6.4 ALIGNMENT OF THE TUNER INDUCTORS

1. The alignment of the inductors is important as it is essential that the inductance can be incremented smoothly over the full inductance range. A wrongly adjusted inductor will cause an incorrect step increment and may prevent the tuner from operating correctly. The inductors have been carefully adjusted in the factory and should not require realignment unless there is physical damage to the inductors. (It is unlikely that an inductor will fail in service.)

2. It is necessary to use an inductance meter that is capable of measuring up to 128 microhenrys with a resolution greater than the smallest increment of 0.03 microhenry. The absolute accuracy of the inductance measurements is not critical, provided the increment steps can be measured.

3. It is necessary to fabricate a test fixture with 12 switches connected to J1, J2 and J3 as shown in Figure 6-2. This fixture is plugged into the tuner (J1, J2 and J3). Power should be applied (12 Vdc) but no RF tuning power is required.

4. Temporarily remove the shelf holding the microprocessor and detector modules. Unsolder the center wire of the input coaxial cable from the main circuit board. Connect the inductance-measuring equipment be-

tween the input on the circuit board and the antenna terminal. It is very important that the connecting leads are kept as short as possible. It should be possible to keep the residual inductance to 1 microhenry.

5. The inductors are adjusted by increasing the spacing of the turns to decrease the inductance, and decreasing the spacing of the turns to increase the inductance. The objective of the alignment procedure is to ensure that if the inductors are stepped in a binary sequence, the inductance will increase in approximately 0.03 microhenry steps. It does not matter if the progression is not exact, provided the maximum step does not exceed 0.04 microhenry and is at least 0.01 microhenry. It is very important that the inductance does not momentarily reverse during the stepping sequence.

a) The residual inductance should be subtracted from the measurements. Start with all switches OFF. The reading here is the residual L.

b) Switch 1 ON. Adjust L1 to 0.03 microhenry (0.03 microhenry greater than the value in step "a").

c) Switch 2 ON and switch 1 OFF. Adjust L2 to 0.06 microhenry.

d) Switches 1 and 2 ON. Measure inductance.

e) Switch 3 ON and switch 1 and 2 OFF. Adjust L3 to 0.03 microhenry increase over step d (0.125 microhenry).

f) Switches 1, 2 and 3 ON. Measure inductance.

g) Switch 4 ON and switches 1, 2 and 3 OFF. Adjust L4 for 0.03 microhenry increase over step f (0.25 microhenry).

h) Switches 1, 2, 3 and 4 ON. Measure inductance.

i) Switch 5 ON and switch 1, 2, 3 and 4 OFF. Adjust L5 for 0.03 microhenry increase over step h (0.5 microhenry).

j) Repeat this procedure up to L12. That is, compare the inductance of all previous inductors with the inductor to be adjusted. The increase in inductance should be 0.03 microhenry.

NOTE

It is difficult to measure the small inductors and it may be necessary to repeat the procedure if it is found that the larger value inductors are varying substantially from the values indicated in Table 6-1.

TABLE 6-1.
Inductor Values.

L1	0.03 μH	L7	2.0 μH
L2	0.06 μH	L8	4.0 μH
L3	0.125 μH	L9	8.0 μH
L4	0.25 μH	L10	16.0 μH
L5	0.50 μH	L11	32.0 μH
L6	1.0 μH	L12	64.0 μH

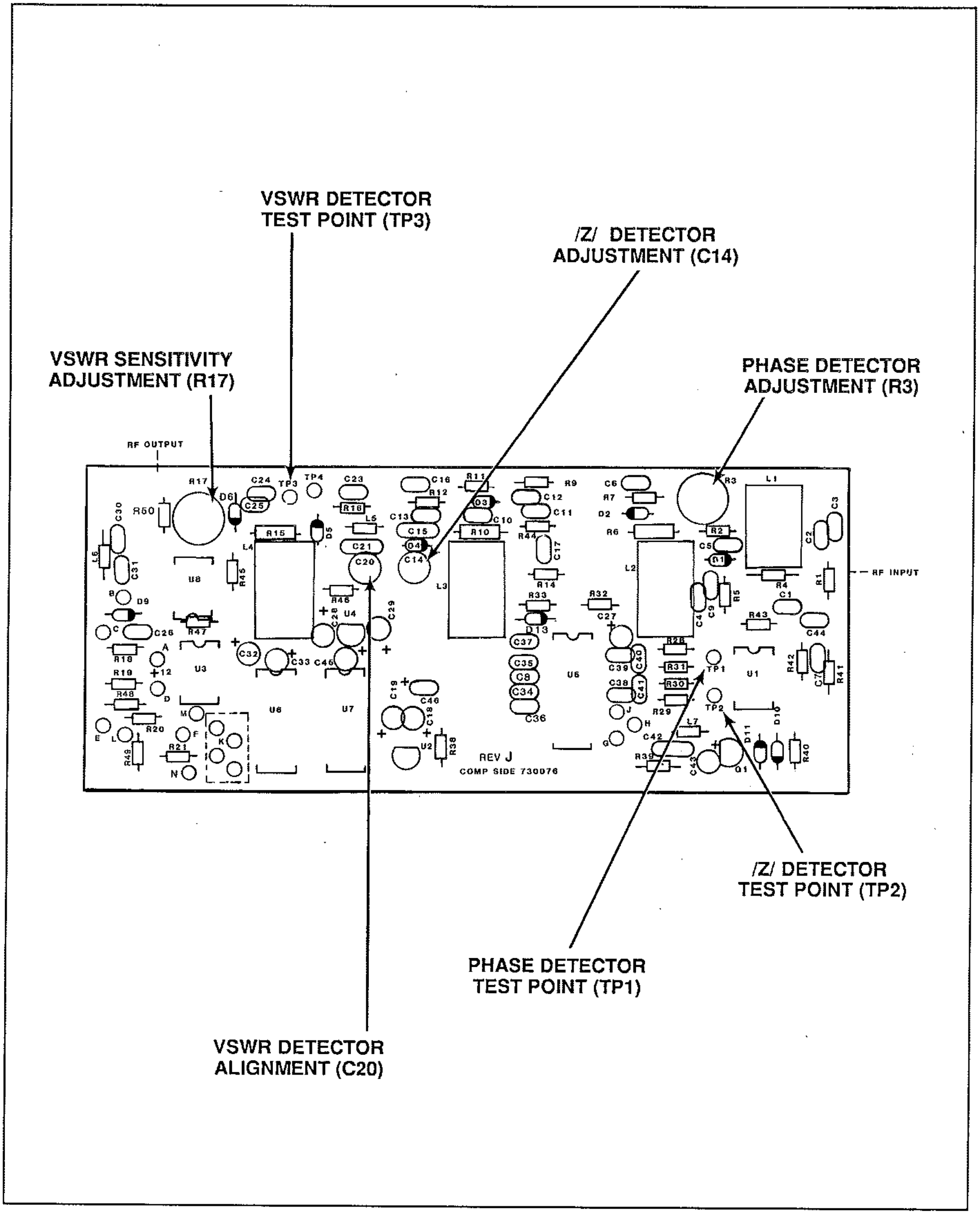


FIGURE 6-1.
Test Points.

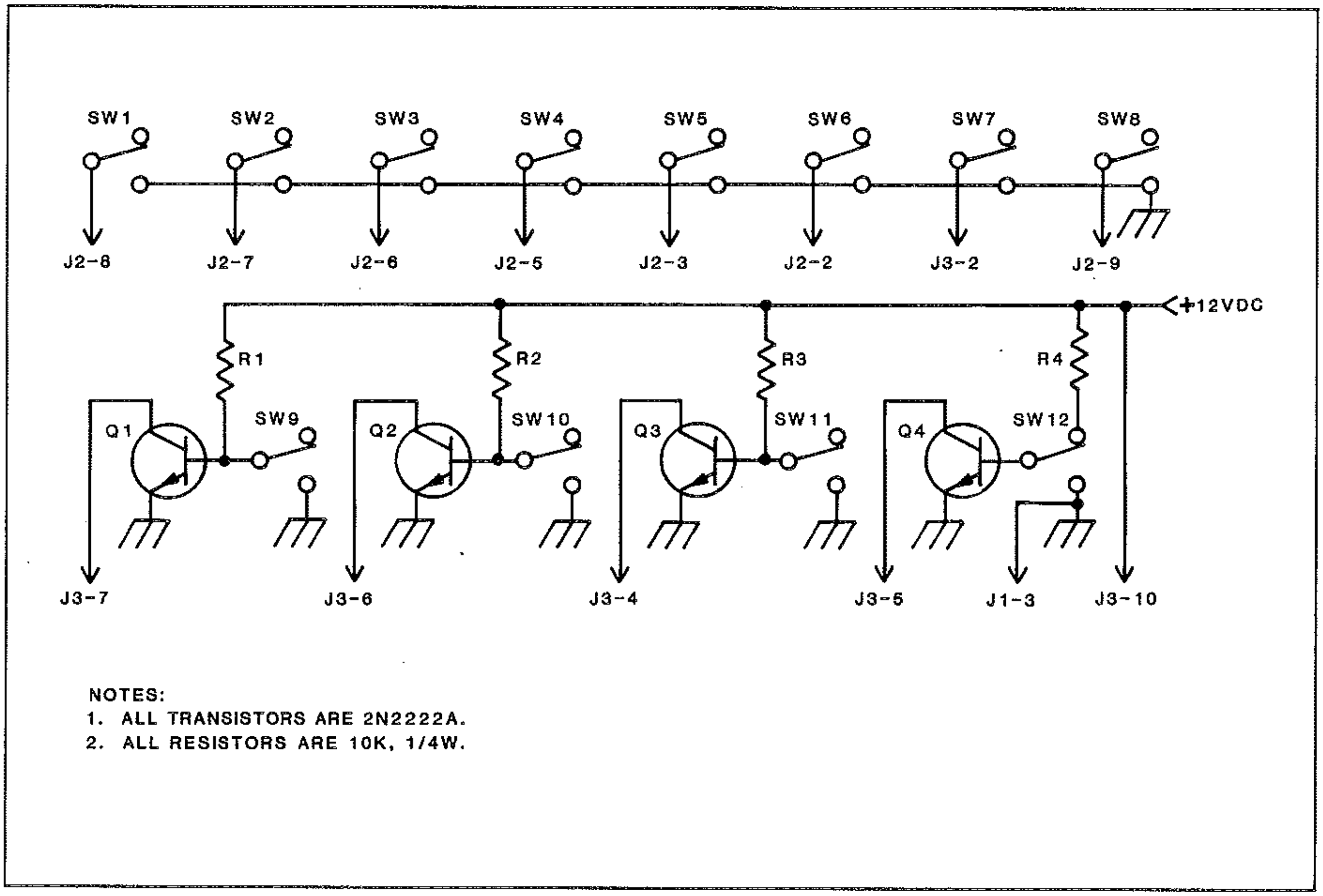


FIGURE 6-2.
Tuner Test Fixture.

SECTION 7
TROUBLESHOOTING

7.1 INSPECTION

Check the interior of the antenna tuner carefully. There should be no signs of heating, arcing or mechanical damage. If there are signs of arcing or heating, it has probably been caused by dirt or moisture. Before making the repair, clean out the case and dry it thoroughly with warm, dry air. Check all of the case seals before reassembly.

7.2 RELAYS

1. Although the relays have an extended life and the calculated MTBF is approximately one million tune cycles, relays are the most likely components to require service. If the tuner does not operate correctly, first check the relays.

2. The first and easiest step is to check the relays for audible operation. Remove the connectors from J1, J2 and J3. Short the pins listed in Table 7-1 to ground, in turn, and listen to the relay action. Note that relays L9-L12 are high-voltage reed relays and will have a different sound from the other relays. It is always possible to detect an open circuit coil, and frequently possible to detect faulty contact action.

3. The contacts on K13 to K23 can be checked for continuity with an ohmmeter.

NOTE

The contact on K14, K15, K19, K20, K21, K22 and K23 are normally open; K13 and K16 are normally closed and K17 and K18 use both the normally closed and normally open contacts.

4. Relays K1 to K12 have the contacts shunted by inductors with low resistance, which means that an ohmmeter cannot be used to check the contacts unless one of the inductor leads is disconnected. It is usually possible to check the relay operation by connecting a signal generator to the input and checking the output with an oscilloscope. A change in amplitude will result as each relay is switched in and out of circuit. Remember the change will be very small with the small value inductors, and will be more readily detected if the signal generator is adjusted to a very high frequency. It is necessary to ground pins 4, 5, 6 and 7 of J3, as relays K9-K12 are normally open and the high inductance of L9-L12 would mask other measurements if left in circuit.

5. If a faulty relay is located, it should be replaced. The adjustment of relays is not recommended.

6. Table 7-2 shows the impedance-transformer tap settings and the relay positions for each setting. An "X" indicates an energized relay.

7.3 DETECTOR MODULE

1. Check that the detectors are correctly aligned (refer to Section 6.3). The basic detector circuitry is passive and faults are unlikely. Check that the diodes are not defective. Note that D5 is a germanium diode and should only be replaced by a similar type. The potentiometers R3 and R4 can be checked with an ohmmeter. Defects in the trimmer capacitors C14 and C20 are usually revealed by erratic mechanical action.

2. Check the voltage at test points 1 and 2 with no RF power applied. If the voltage is not approximately 4 V, U1 should be checked by replacement.

3. **Dc Voltage Checks.** Table 7-3 shows the semiconductor dc voltages in the detector module with no RF power applied. This table can be used to pinpoint a bad IC in some cases.

4. **Dynamic Voltage Checks.** It is difficult to completely check the operation of the detector module by making voltage measurements because of the serial nature of some of the circuitry. This is especially true in the case of U5, the multiplexer. This IC receives the detector data in parallel form and transfers it serially to its output as it is interrogated in binary fashion by the processor module. The binary code on pins 9, 10, and 11 determines which input detector signal is transferred to the output as shown in Table 7-4.

In other words, if the binary code on pins 11, 10, and 9 is 1, 0, 0; the /Z/ detector input on pin 14 is transferred to the output pin 3. It is possible to check this IC by manually applying the different binary inputs; however, IC substitution is probably easier.

U3 is an operational amplifier that takes processor-determined thresholds and compares them to the selected detector output. During a tune cycle, U5-3 should vary between 0.5 and 3.0 volts. The voltage on pins 9, 10, and 11 should vary between 0 and 5 volts. U3-7 should vary between 2 and 8 volts during a tune cycle.

5. **Counter IC.** U6 and U7 form a counter that provides frequency data to the processor module.

An oscilloscope should be used to see if the circuit is working properly (a voltmeter should show a fluctuation at J1-10 of between 0.2 and 0.8 volts).

7.4 PROCESSOR MODULE

Accurate troubleshooting of the processor module requires a good oscilloscope, a test fixture to provide serial data, and a knowledge of the circuitry. It is recommended that the following be done in case of module failure.

TABLE 7-1.
Relay Connections.

Relay	Connector	Pin Number	Contacts
K1	J2	8	N/C
K2	J2	7	N/C
K3	J2	6	N/C
K4	J2	5	N/C
K5	J2	3	N/C
K6	J2	1	N/C
K7	J3	2	N/C
K8	J2	9	N/C
K9	J3	7	N/O
K10	J3	6	N/O
K11	J3	4	N/O
K12	J3	5	N/O
K13	J3	3	N/C
K14	J3	1	N/O
K15	J2	10	N/O
K16	J2	4	N/C
K17	J1	1	DT
K18	J1	2	DT
K19	J2	1	N/O
K20	J1	10	N/O
K21	J1	9	N/O
K22	J1	8	N/O
K23	J1	7	N/O

N/C = Normally Closed N/O = Normally Open DT = Double Throw

TABLE 7-2.
Impedance Matching Transformer.

Relay Ohms	K17	K18	K19	K20	K21	K22	K23
3.0		X					X
7.0		X				X	
12.5		X			X		
19.5		X		X			
28.0		X	X				
50.0							
89.0	X		X				
128.0	X			X			
200.0	X				X		
355.0	X					X	
800.0	X						X

X = Indicates relay activity.

a. Visual inspection of joints, connectors, pins, etc.

b. Check operation of crystal at U4-2, 3.

c. A test program is included in the processor software. This checks operation of all the latches and relay drivers. It needs a test fixture or RLC meter to properly monitor the test sequence, however.

To initiate the test sequence, J1-13 should be grounded (if the "test button" is provided on the module shelf, it should be depressed and held). Grounding U4-6 (or pressing the transceiver "ATU" button) will start the sequence. The sequence can be stopped at any time by releasing the "test" button; depressing it again will resume the sequence.

NOTE

It is recommended that no RF power be applied during the sequence. Once started, the test sequence must run its course ***unless the power to the module is removed.***

d. The best way of troubleshooting the module in the event that adequate test equipment or fixtures are not available, is through part substitution.

TABLE 7-3.
Detector Module - Dc Voltages.

U1	
Pin 1	2.0-7.0 V
Pin 2	4.0 V
Pin 3	4.0 V
Pin 4	Ground
Pin 5	4.0 V
Pin 6	4.0 V
Pin 7	2.0-7.0 V
Pin 8	8.0 V

U5					
Pin 1	5.0 V	Pin 9	0.0 V		
Pin 2	5.0 V	Pin 10	5.0 V		
Pin 3	0.0 V	Pin 11	5.0 V		
Pin 4	0.0 V	Pin 12	0.0 V	0.0 V	
Pin 5	0.0 V	Pin 13	3.0 V	NO 1.0-3.0 V	10 W-
Pin 6	0.0 V	Pin 14	3.0 V	RF 1.0-3.0 V	"Matched
Pin 7	0.0 V	Pin 15	0.0 V	1.5 V	Condition"
Pin 8	0.0 V	Pin 16	5.0 V		

U8		
Pin 1	0.0 V	9.0 V (Open Circuit)
Pin 2	0.0 V	
Pin 3	0.0 V	
Pin 4	Ground	
Pin 5	--	
Pin 6	--	
Pin 7	--	
Pin 8	12.0 V	

U3	
Pin 1	0.0 V
Pin 2	0.0 V
Pin 3	0.0 V
Pin 4	Ground
Pin 5	0.0 V
Pin 6	0.0 V
Pin 7	0.0 V
Pin 8	12.0 V

Q1	
D	5.0 V
S	2.0 V
G	0.0 V

U6			
Pin 1	0.3 V	Pin 8	0.2 V
Pin 2	0.0 V	Pin 9	0.2 V
Pin 3	0.3 V	Pin 10	0.2 V
Pin 4	1.0 V	Pin 11	0.2 V
Pin 5	4.0 V	Pin 12	0.0 V
Pin 6	4.5 V	Pin 13	0.2 V
Pin 7	0.0 V	Pin 14	5.0 V

U7		
Pin 1	1.5 V	Pin 8 0.2 V
Pin 2	0.0 V	Pin 9 0.2 V
Pin 3	0.2 V	Pin 10 0.2 V
Pin 4	4.0 V	Pin 11 0.2 V
Pin 5	0.2 V	Pin 12 0.0 V
Pin 6	0.2 V	Pin 13 0.2 V
Pin 7	0.0 V	Pin 14 5.0 V

TABLE 7-4.
Multiplexer Transfer Chart.

PIN 11	PIN 10	PIN 9		PIN 3	FUNCTION
0	0	0	Selects	13	Phase
1	0	0	Selects	14	/Z/
0	1	0	Selects	15	Forward Power
1	1	0	Selects	12	VSWR

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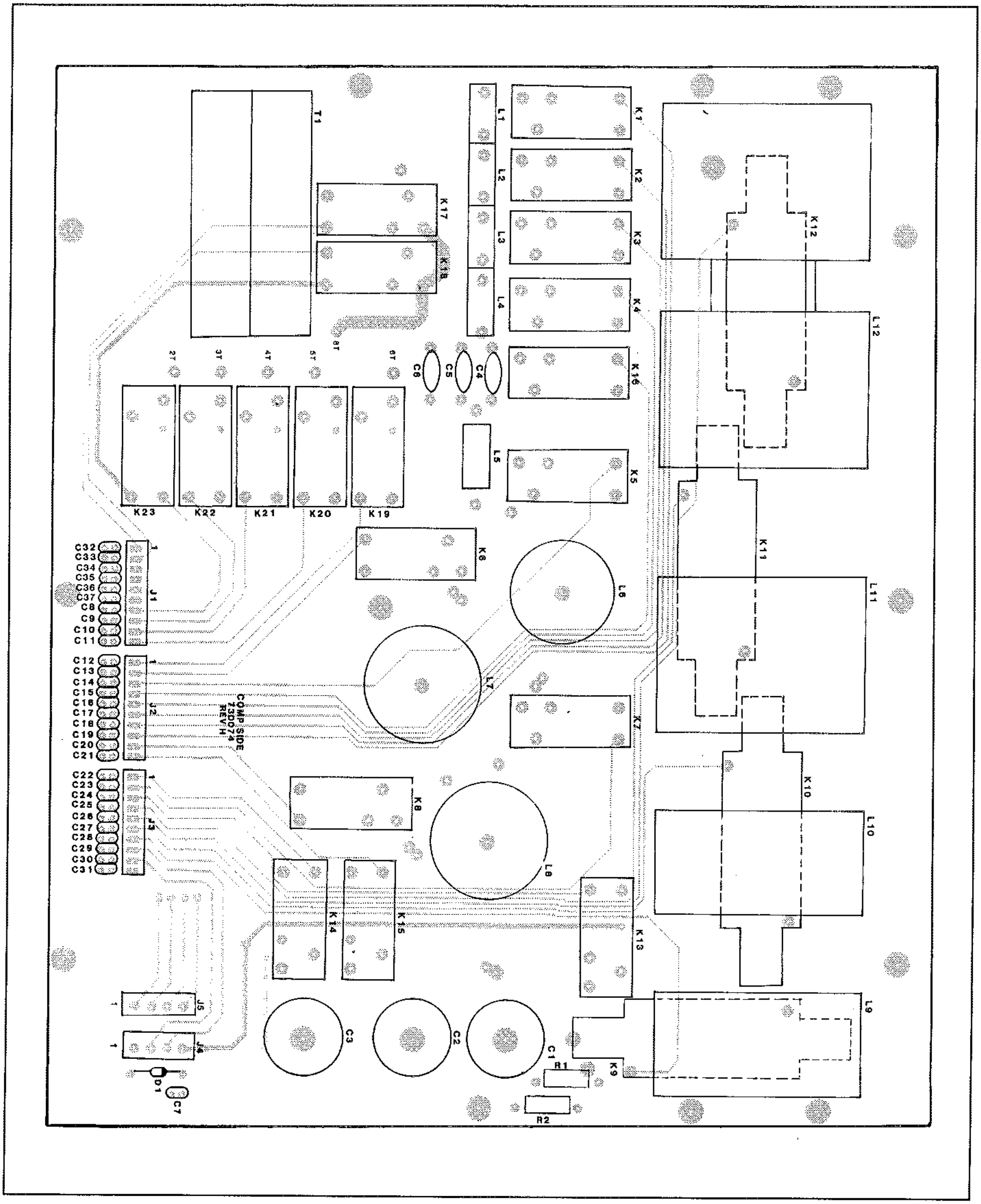
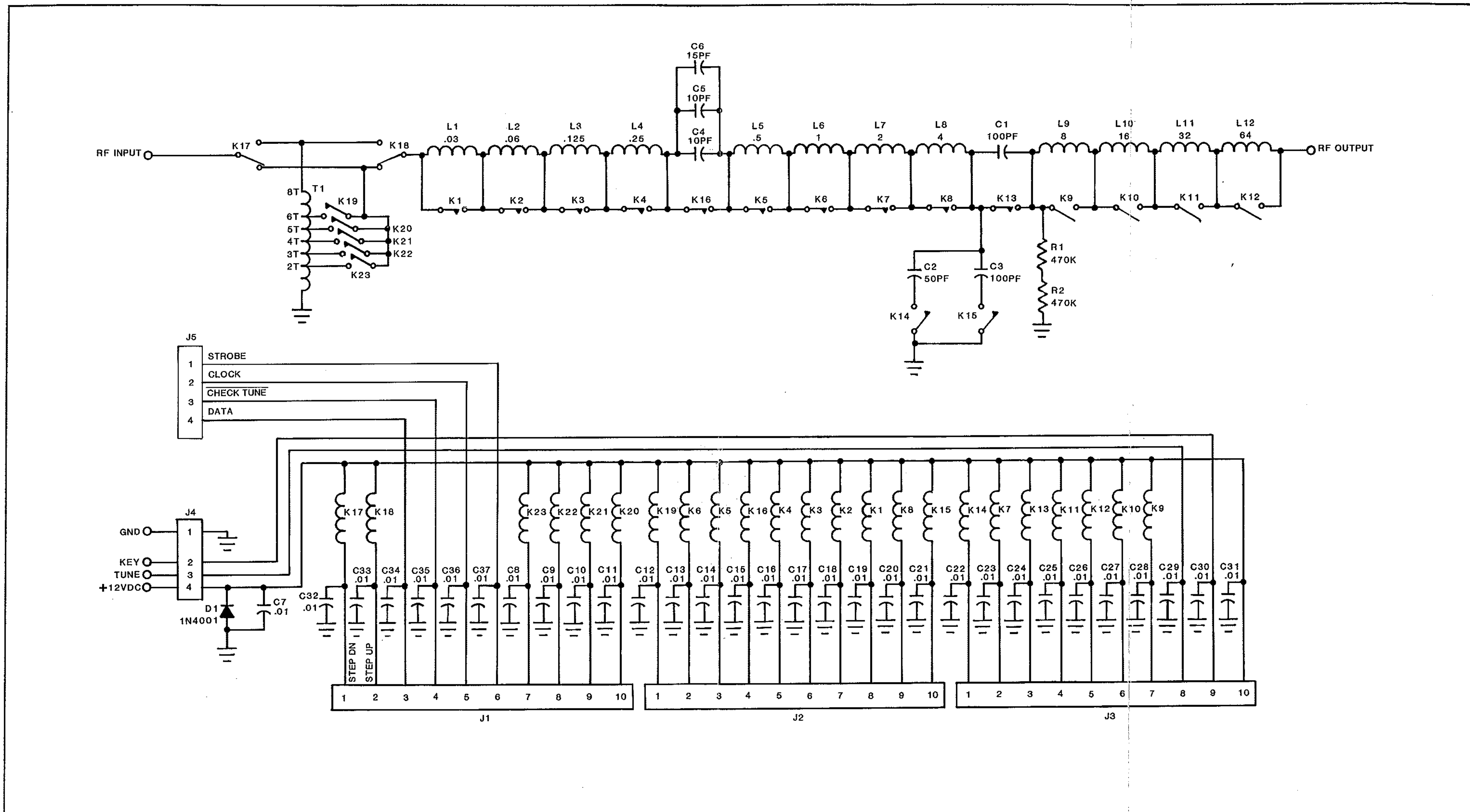


FIGURE 7-1.
Component Locations, Antenna Tuner Board.



NOTES: (UNLESS OTHERWISE SPECIFIED)
1. CAPACITANCE IS IN MICROFARADS.
2. INDUCTANCE IS IN MICROHENRYS.

FIGURE 7-2. Schematic Diagram, Antenna Tuner Board.

TABLE 7-5.
Parts List, Antenna Tuner Board.

C1	216101	Capacitor, Door Knob 100 pF
C2	216500	Capacitor, Door Knob 50 pF
C3	216101	Capacitor, Door Knob 100 pF
C4,C5	211100	Capacitor, Disc 10 pF
C6	211150	Capacitor, Disc 15 pF
C7-C33	214103	Capacitor, Monolithic 50 V 0.01 µF
C34-C37		Not Used.
D1	320102	Diode, 1N4001
K1-K8	540013	Relay, SPDT 12 Vdc 10 A
K9-K12	540021	Relay, Reed 12 Vdc
K13-K23	540013	Relay, SPDT 12 Vdc 10 A
L1	450376	Inductor, RF
L2	450377	Inductor, RF
L3	450378	Inductor, RF
L4	450379	Inductor, RF
L5	450380	Inductor, RF
L6	450381	Inductor, RF
L7	450382	Inductor, RF
L8	450383	Inductor, RF
L9	450384	Inductor, RF
L10	450385	Inductor, RF
L11	450386	Inductor, RF
L12	450387	Inductor, RF
R1,R2	134474	Resistor, Film 1/2 W 5% 470 kΩ
T1	450375	Transformer, RF

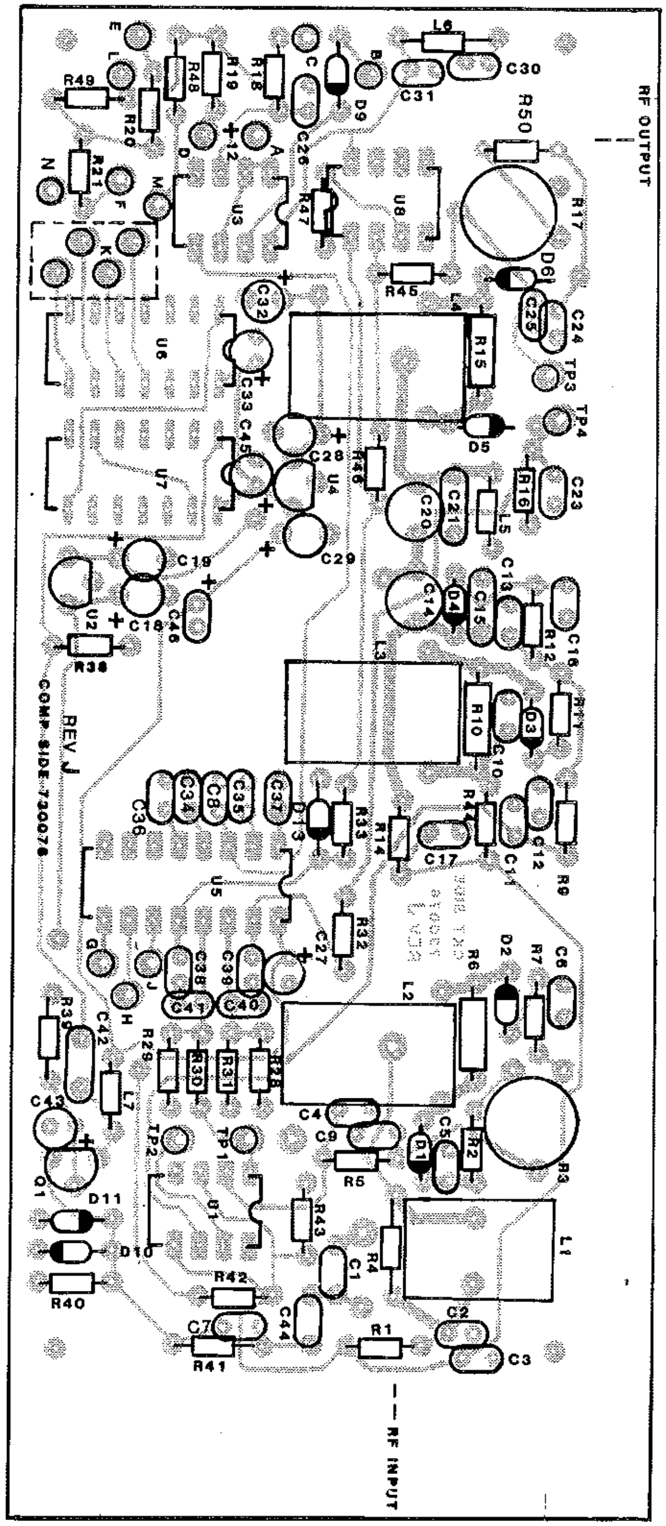
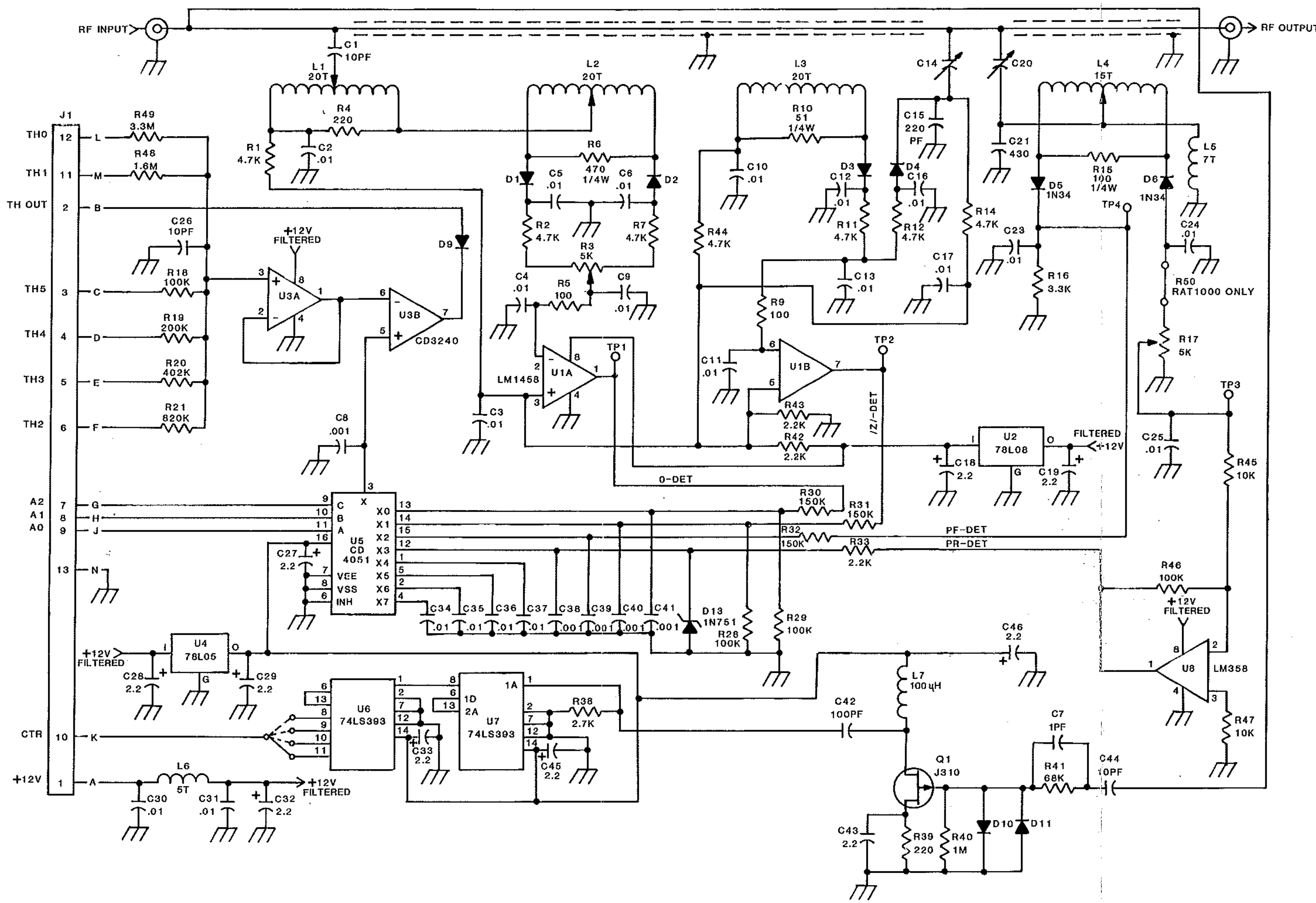


FIGURE 7-3.
Component Locations, Detector Module.



NOTES: (UNLESS OTHERWISE SPECIFIED)
1. RESISTANCE IS IN OHMS.
2. CAPACITANCE IS IN MICROFARADS.
3. DIODES ARE 1N4148.
4. S1 NOT USED.

FIGURE 7-4. Schematic Diagram, Detector Module.

TABLE 7-6.
Parts List, Detector Module.

C1	210100	Capacitor, Disc NPO 10 pF
C2-C6	214103	Capacitor, Monolithic 50 V 0.01 μF
C7	210010	Capacitor, Disc NPO 1 pF
C8	210102	Capacitor, Disc 0.001 μF
C9-C13	214103	Capacitor, Monolithic 50 V 0.01 μF
C14	261250	Capacitor, Trimmer 1-25 pF
C15	220221	Capacitor, Mica DM15 220 pF
C16,C17	214103	Capacitor, Monolithic 50 V 0.01 μF
C18,C19	241020	Capacitor, Tantalum 2.2 μF
C20	261250	Capacitor, Trimmer 1-25 pF
C21	220431	Capacitor, Mica DM15 430 pF
C22		Not Used.
C23-C25	214103	Capacitor, Monolithic 50 V 0.01 μF
C26	210100	Capacitor, Disc NPO 10 pF
C27-C29	241020	Capacitor, Tantalum 2.2 μF
C30,C31	214103	Capacitor, Monolithic 50 V 0.01 μF
C32,C33	241020	Capacitor, Tantalum 2.2 μF
C34-C37	214103	Capacitor, Monolithic 50 V 0.01 μF
C38-C41	210102	Capacitor, Disc 0.001 μF
C42	220101	Capacitor, Mica DM15 100 pF
C43	241020	Capacitor, Tantalum 2.2 μF
C44	210100	Capacitor, Disc NPO 10 pF
C45,C46	241020	Capacitor, Tantalum 2.2 μF
D1-D4	320002	Diode, 1N4148
D5,D6	320003	Diode, 1N34A
D7,D8		Not Used.
D9-D11	320002	Diode, 1N4148
D12		Not Used.
D13	320204	Diode, Zener 1N751
L1,L2	450388	Transformer, 20 turns CT Bifilar
L3	450389	Transformer, 20 turns
L4	450391	Transformer, 15 turns CT Bifilar
L5	450390	Balun Bead, 7 turns
L6	450392	Inductor Detector, 5 turns
L7	430014	Inductor, Molded 100 μH
Q1	310033	Transistor, FET J310
R1,R2	113472	Resistor, Film 1/8 W 5% 4.7 kΩ
R3	170111	Resistor, Trimmer 5 kΩ
R4	124221	Resistor, Film 1/4 W 5% 220 Ω
R5	113101	Resistor, Film 1/8 W 5% 100 Ω
R6	124471	Resistor, Film 1/4 W 5% 470 Ω
R7	113472	Resistor, Film 1/8 W 5% 4.7 kΩ
R8		Not Used.
R9	113101	Resistor, Film 1/8 W 5% 100 Ω
R10	124510	Resistor, Film 1/4 W 5% 51 Ω
R11,R12	113472	Resistor, Film 1/8 W 5% 4.7 kΩ
R13		Not Used.
R14	113472	Resistor, Film 1/8 W 5% 4.7 kΩ
R15	124101	Resistor, Film 1/4 W 5% 100 Ω
R16	113332	Resistor, Film 1/8 W 5% 3.3 kΩ
R17	170111	Resistor, Trimmer 5 kΩ
R18	1111003	Resistor, Film 1/8 W 1% 100 kΩ

TABLE 7-6.
Parts List, Detector Module, Continued.

R19	1112003	Resistor, Film 1/8 W 1% 200 kΩ
R20	1114023	Resistor, Film 1/8 W 1% 402 kΩ
R21	113824	Resistor, Film 1/8 W 5% 820 kΩ
R22-R27		Not Used.
R28,R29	113104	Resistor, Film 1/8 W 5% 100 kΩ
R30-R32	113154	Resistor, Film 1/8 W 5% 150 kΩ
R33	113222	Resistor, Film 1/8 W 5% 2.2 kΩ
R34-R37		Not Used.
R38	113272	Resistor, Film 1/8 W 5% 2.7 kΩ
R39	113221	Resistor, Film 1/8 W 5% 220 Ω
R40	113105	Resistor, Film 1/8 W 5% 1 MΩ
R41	113683	Resistor, Film 1/8 W 5% 68 kΩ
R42,R43	113222	Resistor, Film 1/8 W 5% 2.2 kΩ
R44	113472	Resistor, Film 1/8 W 5% 4.7 kΩ
R45	113103	Resistor, Film 1/8 W 5% 10 kΩ
R46	113104	Resistor, Film 1/8 W 5% 100 kΩ
R47	113103	Resistor, Film 1/8 W 5% 10 kΩ
R48	113165	Resistor, Film 1/8 W 5% 1.6 MΩ
R49	113335	Resistor, Film 1/8 W 5% 3.3 MΩ
U1	330019	IC, RC1458CP-1
U2	330018	IC, 78L08
U3	330211	IC, CD3240
U4	330025	IC, 78L05
U5	330194	IC, CD4051BE
U6,U7	330193	IC, 74LS393
U8	330081	IC, LM358N

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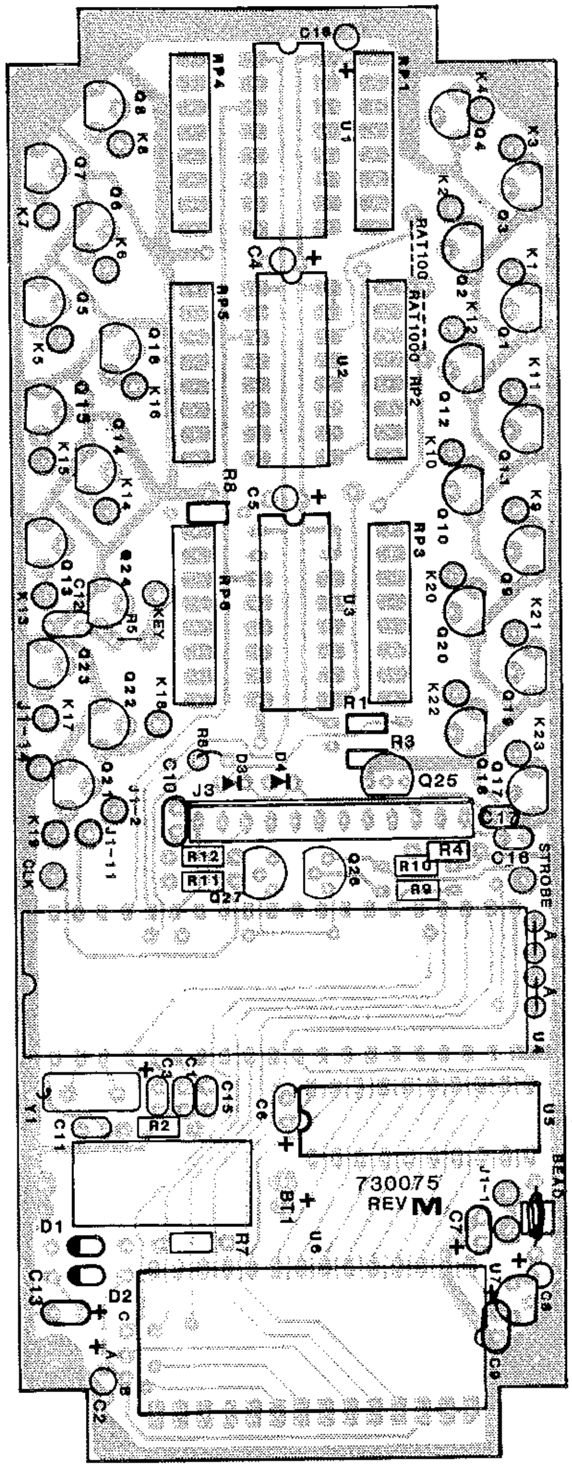
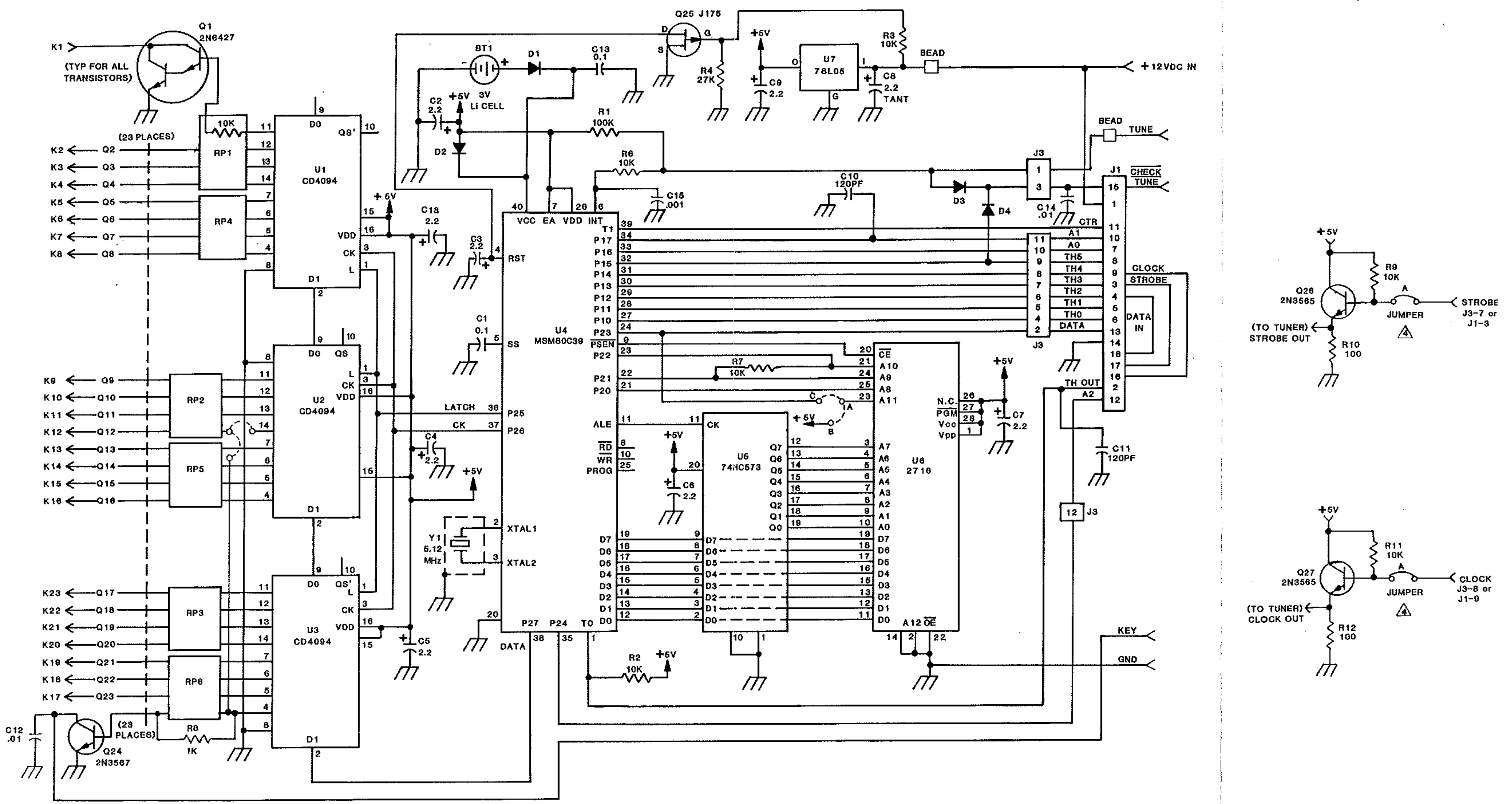


FIGURE 7-5.
Component Locations, Processor Module.



NOTES: (UNLESS OTHERWISE SPECIFIED)
1. RESISTANCE IS IN OHMS.
2. CAPACITANCE IS IN MICROFARADS.
3. DIODES ARE 1N4148
4. INSTALL JUMPERS (2) ACROSS TOP SOLDERABLE PADS FOR MEM-RAT.

FIGURE 7-6. Schematic Diagram, Processor Module.

TABLE 7-7.
Parts List, Processor Module.

BT1*	750025	Battery, Lithium 3 V
C1	275104	Capacitor, Monolithic .1 μF
C2-C9	241020	Capacitor, Tantalum 2.2 μF
C10,C11	210121	Capacitor, Disc NPO 12 pF
C12	214103	Capacitor, Monolithic .01 μF
C13	275104	Capacitor, Monolithic .1 μF
C14	214103	Capacitor, Monolithic .01 μF
C15	210102	Capacitor, Disc 25 V .001 μF
C16,C17		Not Used.
D1-D4	320002	Diode, 1N4148
Q1-Q23	310064	Transistor, Darlington 2N6427
Q24	310003	Transistor, NPN 2N3567
Q25	310072	Transistor, J175
Q26,Q27	310006	Transistor, NPN 2N3565
R1	113104	Resistor, Film 1/8 W 5% 100 kΩ
R2,R3	113103	Resistor, Film 1/8 W 5% 10 kΩ
R4	113273	Resistor, Film 1/8 W 5% 27 kΩ
R5		Not Used.
R6,R7	113103	Resistor, Film 1/8 W 5% 10 kΩ
R8	113102	Resistor, Film 1/8 W 5% 1 kΩ
R9	113103	Resistor, Film 1/8 W 5% 10 kΩ
R10	124101	Resistor, Film 1/4 W 5% 100 Ω
R11	113103	Resistor, Film 1/8 W 5% 10 kΩ
R12	124101	Resistor, Film 1/4 W 5% 100 Ω
RP1-RP6	182009	Resistor Pack, 10 kΩ x 4
U1-U3	330126	IC, CD4094BE/MC14094BCP
U4	330142	IC, 80C39
U5	330141	IC, 74HCT573
U6	330102	IC, UPD2716-6
U7	330025	IC, 78L05
Y1	360018	Crystal, 5,120.000 kHz

*Part used on Memory Option.

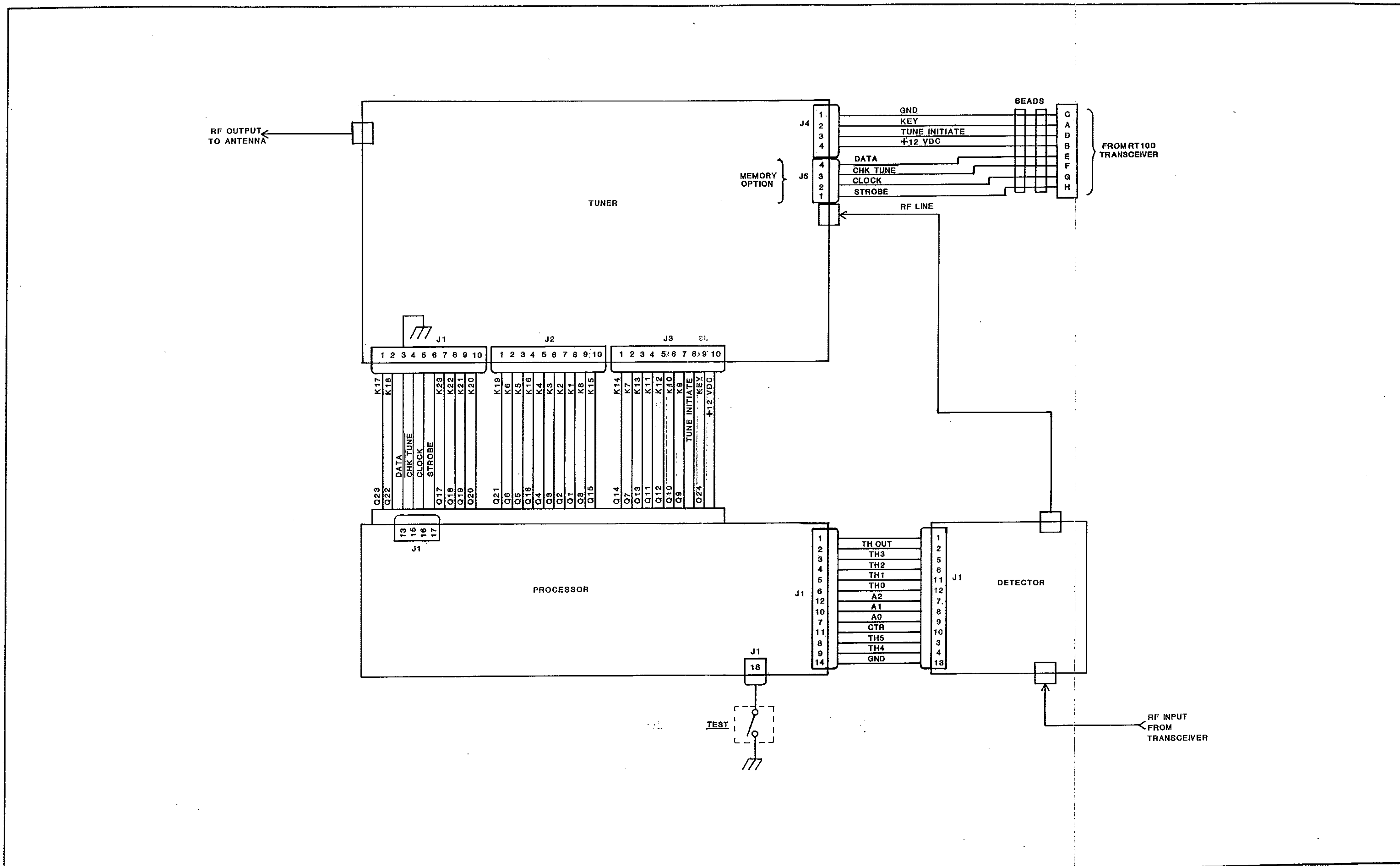


FIGURE 7-7. Schematic Diagram, Mainframe.

SECTION 8
AUTO-TUNE OR MEMORY OPTION

8.1 GENERAL DESCRIPTION

The RT100/MP and TW100 series of transceivers can be configured to interface with the automatic antenna tuner to provide either an auto-tune or memory option. These options utilize the same hardware, but different software and are mutually exclusive. Neither option precludes the use of the transceiver front-panel "tune button" for manual tuning, which can be used anytime the operator desires. The options also affect only the "programmable" channels—channel 00 frequencies must still be tuned manually by depressing the tune button.

8.2 DESCRIPTION

8.2.1 AUTO-TUNE OPTION

The auto-tune option provides for automatic initiation of the coupler tune cycle under one of the following conditions:

1. After the channel has been changed, or
2. After the channel has been changed and the PTT has been engaged. It is possible to configure the option for either of the above conditions. See section 8.4 for instructions.

8.2.2 MEMORY OPTION

The memory-tuner option provides for storage and retention of the antenna-tuner settings on up to ten preprogrammed channels when used with the microprocessor-controlled transceivers. A lithium cell is installed in the tuner's microprocessor module to achieve memory retention. The cell will not reach the end of its useful life in the service life of the tuner and should not require replacement.

8.3 OPERATION

Auto-Tune Option—When configured for condition 1 of paragraph 8.2.1 (automatic initiation of the coupler tune cycle after the channel has been changed), the tune sequence will be initiated whenever a channel number is entered at the transceiver. When configured for condition 2 of paragraph 8.2.1 (automatic initiation of the coupler tune cycle after the channel has been changed and the PTT has been engaged), the channel must be changed and then the PTT must be activated to start the tune cycle. In both cases, the operator must wait for the tune cycle to be completed before beginning the transmission of information. The tune cycle is indicated by the presence of an audible tone.

Memory-Tuner Option—The tune sequence must first be manually initiated on each of the channels 00-10 which are to be memorized. Thereafter, when any of those channels is selected, the tuner will set its network to the memorized setting. The time from the channel change until the tuner is set is approximately 60 milliseconds. This retained setting may be changed at any time by manually initiating the tune sequence on that channel.

8.4 INSTALLATION HARDWARE MODIFICATIONS

When configured for condition 1 of paragraph 8.2.1, install R11 (100 kΩ, P/N 113104) and remove jumper "A-B". When configured for condition 2 of paragraph 8.2.1, remove R11 and install jumper "A-B". For memory-tuner operation, install R11 and remove jumper "A-B".

8.5 TECHNICAL DESCRIPTION

The auto-tune and memory-tuner options utilize the same circuit contained inside the transceiver. It is composed of three subsections—a parity detector, a pulse generator, and a shift register. Refer to the transceiver technical manuals for the schematic diagram of the option circuitry.

The seven BCD channel lines from the frequency-control module, (M9MP), are connected to U1 and U2 in the memory-tuner PCB. U2 is the parity detector whose output, pin 9, changes whenever the channel is changed. This signal in turn triggers the first stage of the dual monostable multi-vibrator ("one-shot"), U3.

When connected for condition 1 of paragraph 8.2.1, the first stage one-shot outputs a pulse on U3 pin 7, the width of which is controlled by R11 and C13. The width of this pulse is not critical and its rising edge triggers the second one-shot. When connected for condition 2 of paragraph 8.2.1, pin 7 will go low, and will not produce a rising edge until the PTT line, and hence pin 3, the reset for the first one-shot, is grounded.

The second one-shot produces a pulse approximately 20 milliseconds in width. In the auto-tune configurations, the second one-shot output, pin 9, is connected to the tune initiate line.

In the memory-tuner configuration, pin 9 is connected to a special input in the antenna tuner's microprocessor module. This is the CHECK TUNE line, and the pulse indicates that the tuner should retrieve the channel number from the transceiver and set itself to the memorized setting, if any.

The antenna tuner then places a high logic level on the STROBE line, in order to parallel load the BCD channel data into the serial-out shift register, U1. The CLOCK line is then toggled high, then low again to accomplish this. Q26 and Q27 in the antenna tuner processor module are current buffers for the STROBE and CLOCK signals respectively. The tuner then toggles the clock line eight times and reads the eight data bits in serial fashion. If the channel number is ten (10) or less, the memorized setting is output and the tuner awaits the next command. If the channel number is higher than ten (10), the tuner will default to the channel (10) setting and await the next command.

8.6 ANTENNA TUNER MODIFICATIONS

Inside the antenna tuner, some of the threshold output lines double in function as STROBE, CLOCK, and CHECK TUNE lines. The serial data is read in on the P23 line. The lithium cell added to the processor module is a 3-Vdc nominal, 0.5-Ah cell which keeps the microprocessor's internal RAM memory at sufficient voltage for data retention when the power is off. The cell current, which remains below 10 microAmps at all times, is fed to pin 40 of the microprocessor through a diode to prevent charging of the cell.

CAUTION

Shorting of the cell because of a diode failure or soldering of the cell with a grounded iron while the tuner is still connected can cause the cell to **out-gas toxic materials** or even ***explode***. Use ***extreme care*** when servicing this portion of the circuit.

The terminal voltage for this type of cell is about 2 Vdc. Whenever necessary, measure the cell voltage with the power to the tuner switched off. Replace the cell if it measures less than the terminal voltage. Remember to ***disconnect the tuner from all cables and grounds*** before soldering in the new cell.

If a problem is encountered with intermittent memory loss, observe the various power supply voltages with an oscilloscope as the transceiver's power is switched on and off. The rise and fall of the regulated +12 V must be smooth and uniform. Any "jagged transitions" can cause memory loss problems. This is most often encountered in mobile installations as the engine is started or stopped. It may be necessary to install transient absorbers in the lines from the battery.

NOTES