CHAPTER 5—THEORY OF OPERATION

For the following discussion, see Figure 5-1, the radio's block diagram at the end of this chapter.

RECEIVE FRONT END

Connector J4 on the main PC board conducts the RF signal from the front panel ANTENNA connector to the antenna switch network. In the receive mode, one port of the antenna switch conducts the receive signal to the input of helical filter Z1.

The output of Z1 is fed to RF amplifier Q1. The output of Q1 goes to helical filter Z2. The output of Z2 goes to M1, a double-balanced mixer whose local oscillator injection signal is derived from the VCO output.

HIGH IF

The 45 MHz High IF signal from M1 enters the IF amplifier. The output of IF amplifier connects to L25 as an input matching transformer. The receive signal is then passed to FL1A and FL1B. FL1A and FL1B are components of a 4-pole crystal filter that provides some of the IF selectivity of the receiver. The output of FL1B is conducted to U32, which contains the low IF amplifier and other functions.

LOW IF

U32 contains several circuit sections: mixer, oscillator, IF amplifier/limiter, quadrature detector and received signal strength indication driver. The second 44.55 MHz LO for U32 is derived from the TCXO. A frequency tripling circuit multiplies the 14.85 MHz TCXO signal and triples it up to 44.55 MHz. This is consequently mixed with the 45 MHz IF to form the 450 kHz IF.

The 450 kHz output of the second mixer is fed to a ceramic filter set consisting of FL2 and FL3. This filter set provides the main adjacent channel selectivity of the receiver.

The output of FL3 is fed to the limiter amplifier input pin of U32. The limiter output is fed to a quadrature detector circuit tuned by discriminator coil T1; recovered audio is passed to U3A audio buffer.

A secondary output of the IF subsystem of U32 gives a received signal strength indication (RSSI) voltage. The RSSI signal is used by the remote maintenance module and is available at the INTERFACE connector J1-21 through a buffer and scaler, U3C.

RECEIVE AUDIO

The unfiltered recovered audio from the IF discriminator passes through amplifiers U3A, U3B and configuration jumper J14.

The output of the squelch gate goes to the modem receive audio amplifier, U5A. U5A is an amplifier with the gain set by potentiometer R25. R25 is used to adjust the receive audio level supplied to the modem and remote maintenance boards.

U5D and U5C are an audio lowpass filter that removes noise from the receive audio. The output of this filter goes to external modems through J1.

SQUELCH

The squelch circuit consists of a high-pass filter, noise amplifier, noise rectifier and a comparator.

The high pass filter U6A removes low frequencies of the detected IF output. The output of U6A goes to a gain stage, U6B, which amplifies the high frequency noise. The gain of U6B is set by R41, which is the squelch threshold adjustment.

The amplified high frequency noise output from U6B goes to a full-wave rectifier, which compares this DC voltage with a fixed reference voltage. U6C, which rectifies the noise signal. The output of this stage goes to a squelch comparator, U6D whose output is the receiver unsquelch sensor (RUS) line, and is used to control squelch gate U26A in the receive audio path. This gate is also controlled by the RX MUTE signal from U19D.

The RUS logic signal is also fed to the modem and is used to gate the DCD output from the modem. In addition, this signal appears at J1 pin 10 through a 1 kΩ resistor.

POWER SUPPLY

The + 13 volt DC input appears when an external power source is connected to J2. From J2, the + 13V is conducted to the internal transceiver circuits through F1, a 4 ampere fuse. The fuse protects the transceiver in the event the external, in-line fuse is either defeated or replaced with one of a higher rating.

Z4 is a EMI power line filter. C77 is a electrolytic capacitor. These two devices help provide a noise free power source for the transceiver circuits. A 17 volt zener diode across C77 provides over-voltage and reverse polarity protection.

U38 provides a regulated + 8 volts for most transceiver circuits. U13 provides a regulated + 5 volts, which supplies power to the microcontroller and the logic circuitry.

U45 is a low voltage protection device. It will disable the radio when the input voltage becomes less than 10 volts. The output from U45 drives the radio disable circuit Q15 which disables the 8 volt and 5 volt regulators, U38 and U13.

A precision reference DC voltage of + 2.5V is supplied by U4; this is used by the FSK modem circuitry.

The RX/TX signal from the microcontroller applies + 8 volts to the RF amplifier, high IF amplifier and tripler circuit in the receive mode, and is shut off in the transmit mode.

Q19 supplies a biasing signal to the transmitter amplifiers and antenna switch. Q19 is turned on during transmit by the microcontroller.

The main transmit power control signal from the microcontroller, TXE2, is first conditioned by U46 whose output is sent to the power control potentiometer R69. The wiper of R69 is connected to U44B which is a power-leveling circuit. U44B drives U44A, Q41 and Q43 which form an adjustable voltage regulator. The output of this regulator feeds the power control pin on U33

The transmitter can be turned off, independent of microcontroller control, by the synthesizer out-of-lock signal. An out-of-lock condition at the synthesizer will bring the O/L line high, overriding the power control signal TXE2.

TRANSMIT POWER AMPLIFIER

The power amplifier chain of the transmitter section consists of U40 and U33. U40 is a driving amplifier for U33. The output of U40 is fed to hybrid power module U33. The power control of U33 is controlled by the power control regulator Q3 and U44A.

The RF output of U33 is fed through a directional coupler to the antenna switching network.

ANTENNA SWITCH

The antenna switch consists of PIN diodes and a filter network. In the receive mode, PIN diodes are unbiased and effectively disconnected from the circuit. Under this circumstance, the received signal is free to pass to the input of helical resonator Z1 through a low pass filter.

During the transmit mode, the PIN diodes are biased ON by the Q19. When the diodes are conducting, one diode provides a low impedance path for the transmit signal to the ANTENNA connector and the other diode shorts out the capacitor in the switching circuit. With the capacitor shorted, the filter network is equivalent to a quarter wave transmission line with no RF current flowing through the inductor.

DIRECTIONAL COUPLER

The directional coupler is used during diagnostic measurements of forward and reflected power at the ANTENNA connector. The directional coupler consists of an in-line transmission line section that conducts RF energy from power amplifier U33 to the antenna switch. Coupled line sections located immediately adjacent to, and either side of the transmission line, receive a sample of the RF energy passing through the coupler. Rectifiers mounted on each end of coupled line sections produce DC voltages. These DC voltages are proportional to the power levels appearing on the coupled lines.

The directional coupler provides a forward power measurement that can be displayed through local diagnostics when the radio has the Remote Maintenance Module installed.

KEYLINE AND CONTROL CIRCUITS

There are three push-to-talk (PTT) inputs to the keyline control circuit. Three negative inputs and one positive going input. The negative going inputs come from J1-16, the modem, and the audio processing board. These are inverted and added to the positive going input coming from J1 pin 14. This signal drives the keyline inverter U19A.

RADIO DISABLE

J1-Pin 12, is the input to the radio disable circuit. The radio disable circuit minimizes power consumption by shutting off all of the transceiver circuits except for Q15 and CR32B. This allows the user to inhibit transceiver functions with an open-collector interface circuit.

J1-Pin 12 should be left open to permit the transceiver to function normally.

If J1-Pin 12 is grounded U13 and U38 are disabled. Since U38 supplies current to nearly all of the transceiver circuits, current consumption in the transceiver is reduced essentially to zero. This eliminates the need to externally switch the +13 volts applied to the transceiver.

AUDIO/DATA MODULATION INPUT SWITCHING

One section of U15, switch U15X, controls data appearing at the RXD terminal, Pin 3 of J1, switching between modem data and microcontroller data from U16. Another section, U15Z, switches the transmit audio path between the modem transmit audio output and the external transmit audio input to the transceiver from J1.

U15Z is controlled by means of a modem enable line which is tied to +10 volts when the modem option is installed.

Without the modem installed, the normal state of U15Z is such that transmit audio from J1 Pin 9 modulates the transmitter. With the modem installed, the external transmit audio from J1 is cut off, and modem transmit audio is selected.

Should the positive-going push-to-talk (PTT) input on J1-14 be driven high (to key the transmitter—such as when the external order wire option is used), U19B pulls the control line for U15Z low. This allows external transmit audio in from J1 to modulate the transmitter, and cuts off any audio coming from the modem.

MICROCONTROLLER/EEPROM

The microcontroller, U16, controls many of the on-board functions of the transceiver. Some of the control functions are:

- Frequency Programming and Control of the Synthesizer
- Modem RTS/CTS Delay
- Transmitter Time-out Timer
- Transmit Soft Carrier Dekey Delay
- Transmit Squelch Tail Eliminator Delay
- Loopback/Diagnostic Functions

U16 runs a predetermined routine that controls its functions; this routine is permanently programmed within the IC and cannot be altered. All programmable functions and values are stored by the microcontroller in an electrically erasable, programmable, read-only memory (EEPROM) IC, U18. These include operating parameters such as frequency, time-out timer limits, soft carrier dekey times, and CTS delay time, as well as model and factory serial numbers. U16 and U18 share a common clock and exchange data through data lines.

The microcontroller can be reset by several different means. An error output from U13 drives the reset line low causing the microcontroller to reset or the internal modem can drive the reset line from J8. The error signal from U13 resets U16 allowing a stable initialization when 13 Vdc is first applied to the transceiver.

The inhibit line on U13 is controlled indirectly by the radio enable line available at J1-12. The inhibit line on U13 will force a microcontroller reset through the error output line.

DIAGNOSTICS DATA CONTROL

Communications between the microcontroller U16 and an external terminal, PC or the HHT is accomplished by means of the TXD (J1–Pin 2) and RXD (J1–Pin 3).

U16 constantly monitors transmit data input on J1–Pin 2, and ignores all data unless the OPEN command from the external programmer is detected or a ground is detected on J1–Pin 23. The receive data output on J1–Pin 3 is normally connected to the output of the modem demodulator when a modem is used. When the OPEN command is detected, U16 switches the receive data path from the modem to its own data output port in order to allow it to communicate directly with the terminal.

The receive data control pin of U16 controls the normally high base of Q8. When the diagnostic channel is opened, Q8 is turned off, thus switching the state of gate U15X. This allows data from the microcontroller to appear at the RXD output (J1-Pin 3).

TRANSMIT AUDIO

The transmit audio circuit consists of a variable gain amplifier, active low-pass filter, and a summing amplifier. The variable gain amplifier U28C gain is set by R168. The transmit audio then passes through a low pass filter consisting of U28B and associated components. The output of U28B, and transmit audio from the remote maintenance board, are summed together in amplifier U28D.

Transmit audio is also fed to the VCO input by means of a R179, which is the high frequency (HF) compensation control. This control provides a balanced transmit audio frequency response.

PLL/SYNTHESIZER

The temperature compensated 14.85 MHz crystal oscillator (TCXO) generates the reference frequency for the phase-lock loop (PLL) circuit.

U36 is a CMOS PLL synthesizer consisting of a phase detector, a programmable reference divider, a programmable feedback divider, and prescaler. Data input is serially loaded from U16; this data consists of binary coded numbers representing the reference and feedback (VCO RF sample) divider ratios required to produce the final transmit frequency. The reference divider is programmed only on power-up, with a power reset or with a PLL out-of-lock condition. The feedback divider value changes according to the transmit/receive frequencies entered by the PTX and PRX commands, and is reloaded from the EEPROM every time a transmit-to-receive or receive-to-transmit transition occurs.

The phase detector output of U36 is fed to the VCO tuning input through an R-C loop filter. A sample of transmit audio modulation of the VCO is fed to the loop filter from the wiper of R179.

The lock detector output of U36 is applied to U28A. When the PLL is in lock, U36 shuts off U28A and keeps the O/L line low. An out-of-lock condition causes U28 to drive the O/L line high. The O/L line inhibits the transmit regulator, as previously described in the POWER SUPPLY section; also, it is conducted to J1-Pin 25, through a 1 kΩ resistor.

RS-232 DATA INTERFACE

U31 is an RS-232 line driver/receiver integrated circuit with an input/output disable function. It has an internal +5 volts to ±10 volt converter that allows it to provide an RS-232

compatible output. Transient protection for the five RS-232 I/O lines from J1 is accomplished by means of zener protection diodes. Static discharge or over-voltage condition appearing on J1 will be shunted to ground with these devices before reaching U31.

In the data signal interface between the plug-in modem assembly and the main transceiver board (i.e., the plug in modem option), the signals are inverted from standard RS-232 signal polarity. The inverted signals, namely RXD(L), TXD(L), DCD(L), RTS(L), and CTS(L), are fed directly to U31.

Header J11 allows the TTL option to be selected. When the pins 1 and 2 of J11 are connected together, U31 is disabled. This effectively removes U31 from the circuit.

LED INDICATORS

U29 and U5 drive the LEDs. U29 is a non-inverting buffer. A jumper across J11, pins 3 and 4 is required to enable the LEDs.

PWR

This LED, CR31B, is illuminated if more than 10 volts is applied to the radio. It flashes if the VCO is Out-of-Lock. U5B is a flasher circuit.

RTS

This LED, CR31A, is illuminated if any of the Push-To-Talk lines is active.

TX

This LED, CR32B, is illuminated if the transmitter power control is active.

TXD

This LED, CR32A, is illuminated if the RS-232 transmit data line is low.

CD

This LED, CR33B, is illuminated if the receiver detects a carrier strong enough to break squelch.

RXD

This LED, CR33A, is illuminated if the RS-232 receive data line is low.