THEORY OF OPERATION
RF BOARD

RECEIVER

RF amplifier and bandpass filters.

The incoming RF signal from the input connector J101 passes backwards through the transmitter lowpass filter and the electronic T/R switch to a two pole bandpass filter formed around L101 and L102. This filter is of Cohn type with 1.5 dB insertion loss and a bandwidth of 25 MHz. This filter is followed by a low noise amplifier stage formed around Q101. This amplifier has a gain of about 17 dB with a noise figure of 2 dB and serves to amplify the incoming RF signal above the noise of the following stages. Following this stage is a four pole Cohn filter formed around L103 through L106. This filter has an insertion loss of 4 dB and a bandwidth of 25 MHz. The two filter sections are narrow enough to filter out the spurious responses of the first mixer while wide enough to support a performance bandwidth of 20 MHz.

1st mixer, 1st IF filters, and 1st IF amplifier.

IC101 is an active double balanced mixer which converts the incoming RF signal to the first intermediate frequency (IF) of 43.65 MHz. This mixer has a gain of 0 dB and a noise figure of 10 dB. Its differential output is matched to the first IF filter, YF101, by L107, L108, C128, and C137. An IF amplifier based around Q102 is used to provide gain. Its output drives another IF filter section, YF102, which is identical to YF101. These two filters serve the double function filtering out the spurious responses of the second mixer and, with the second IF filter, of removing signals at the adjacent and further removed channels.

2nd IF IC

The output of YF102 drives the mixer internal to IC102. IC102 is an integrated FM IF IC which contains a mixer, high gain limiting IF amplifier, FM discriminator (detector), and other support circuitry. The mixer in IC102 converts the RF signal at the first IF to the second IF of 450 kHz. The output of the mixer exits the IC and is filtered by the second IF filter, YF103. The output of the filter re-enters the IC and drives the high gain limiting amplifier. Because the discriminator inside IC102 is sensitive to both amplitude and frequency modulation components, a limiter must precede it to remove any amplitude modulation. In addition, the noise based carrier detection system available with this product requires that the RF signal at the discriminator stay constant in amplitude as the RF input signal level varies. The output of the limiter amplifier drives the discriminator. The resonator for the discriminator is YF104.

Receiver audio and carrier detection

The recovered audio from pin 9 of IC102 is filtered and DC shifted by IC103A and associated components. IC103B is a simple inverter and is used to provide inverted audio for those applications which may require it.

Two methods of carrier detection are available on this radio. One is based upon the absolute RF signal level at IC102's input and the other is based upon the magnitude of the ultrasonic noise on the recovered audio. IC102 has circuitry which develops a DC current which is proportional to the input RF signal level. Passing this current through a resistor (R115) creates a voltage which varies from about 0.5 volts at no signal input to about 3 volts with −70 dBm at the antenna connector. In addition, a voltage can be developed which is proportional to the amount of noise present on the recovered audio signal. This is effected by filtering the recovered audio such that only frequencies above the normal modulation range remain. This prevents modulation components from being detected as noise. The filter is formed around an op-amp internal to IC102 between pins 10 and 11 and the components connected to these two pins. The filtered output at pin 11 is rectified by Q103B and then filtered. The output varies from about 3 volts for a 0 dB SINAD signal to about 0.5 volts for a 20 dB SINAD signal.

2nd local oscillator.

The two mixers in this radio act to produce an output signal whose frequency is equal to the difference between the frequency present at the RF input port and the frequency at the local oscillator port. To convert signals at the first IF frequency of 43.65 MHz to that of the second IF at a frequency of 450 kHz, a local oscillator signal at a frequency of 43.2 MHz (43.65 – 0.45) is used. This signal is created by tripling the output of the radio's 14.4 MHz master reference oscillator, Y101. Transistor Q112 acts as a frequency tripler. Its associated components are used to bias the transistor at an harmonic rich bias point and to filter the output such that only the third harmonic remains for use as the 2nd local oscillator.

VCO and Synthesizer

The synthesizer is responsible for generating the carrier in transmit and the first local oscillator in receive. A voltage-controlled oscillator (VCO) is an oscillator whose frequency can be controlled by an external signal. The synthesizer, almost wholly contained within IC108, divides the VCO frequency by digital dividers and compares the result with an accurate reference. An error signal, proportional to the frequency error is created which is routed to the frequency control input of the VCO. This action locks the VCO to a frequency which is equal to the reference frequency multiplied by the divider number. To set the VCO frequency, different divider numbers can be programmed into the synthesizer. In most synthesizer designs, the divider must be an integer, which forces the reference frequency to be equal to the synthesizer step size. The synthesizer IC used in this radio, however, allows the use of non-integer values for the divider which in turn allows the reference frequency to be much higher than normal. This creates a synthesizer whose output has lower noise, lower spurious levels, and a higher switching speed s. The reference frequency is derived by digitally dividing the frequency of the 14.4 MHz master oscillator. When locked, the VCO attains the same relative frequency stability as that of the master oscillator.

The VCO itself is a voltage follower Colpitts oscillator formed around Q108. One of the elements in the resonant circuit is a varactor diode, CR106, whose capacitance when reverse biased varies as a function of the applied voltage. Since the oscillator frequency is controlled by the resonant circuit, varying the voltage on the varactor diode effects a change in frequency. To serve as a local oscillator for the first mixer, the VCO operates at a frequency 43.65 MHz below that of the desired receive frequency. In transmit, the VCO's oscillating frequency range is shifted upward by about 44 MHz by switching C190 and L115 into the resonant circuit. The VCO has a tuning range of about 30 MHz when its tuning voltage is varied between 1 and 4 volts. To frequency modulate the VCO for transmit, another varactor diode, CR105, is lightly coupled into the resonant circuit.

The output of the VCO is amplified to a level of about 0 dBm by Q107 and Q106. Q111 with R172 and C196 act as a very low noise power supply filter for the VCO.

TRANSMITTER

PA Driver Stages

The output of the last VCO buffer drives Q105 through R151. The signal level at this point is about –10 dBm. Q105 amplifies this signal to about +5 dBm. Q104 further amplifies the signal to +17 dBm, the level required by the PA module. The supply voltage to these two stages is switched on in transmit by Q113.

PA Module, Lowpass filter, and T/R switch

When driven by +17 dBm, the PA module is capable of producing 5 watts or more of power at the antenna connector. Pin 2 of the module is used for power control. The output power level can be varied from less than 0.5 watts to full power by changing the voltage at this pin.

To reduce carrier frequency harmonics of the PA module output to acceptable levels, a lowpass filter is inserted between the module and the antenna connector. This filter is of elliptic design and formed around a buried stripline transmission line and C164, C165, and C166.

To isolate the PA module from the receiver, an electronic T/R switch is used. The switch is formed around PIN diodes CR101 and CR104 which are turned on in transmit and are off in receive. CR104 switches the PA module into and out of the circuit while CR101 protects and isolates the receiver input when the radio is in transmit.

MISCELLANEOUS FUNCTIONS

Two on-board regulators are used to provide the 5 volts DC used by most of the circuitry in the radio. IC106 is a low noise, low dropout regulator which provides 5 volts to all the portions of the radio which do not get switched on or off as the radio changes from transmit to receive. This regulator is enabled by the XCVR-EN (J102, pin 5) input. When this regulator is not enabled, the radio is essentially powered down. IC107 is an identical regulator which supplies power to those circuits which are to be powered-up only in receive and to the switches in the VCO which shift the VCO frequency range to that needed as the 1st local oscillator. The regulator is enabled through IC105E and IC105F by the RX-EN (J102, pin 4) input.

The transmitter PA module driver stages and the T/R switch are powered by +7.2 volts through Q113. Q113 is enabled by the TX-EN (J102, pin3) input through delay and sequencing circuitry formed around IC105 and Q115 and Q114. The sequencing circuitry delays PA turn-on until the driver stages and T/R switches are on and delays driver stage and T/R switch shutdown until the PA module has ramped down in power. This prevents “keyclicks” from abrupt transmitter turn-on and turn-off.