SECTION 4

CIRCUIT DESCRIPTION

4.1 INTRODUCTION

The main subassemblies of this transceiver are the RF board, VCO board, PA module, and TCXO. A block diagram of the transceiver is located in Figure 4-1.

The VCO board is enclosed by a metal shield and soldered directly to the RF board. The VCO is not field serviceable. Return the transceiver to the Dataradio factory for repairs.

The 3412 has a reference oscillator stability of ±1.5 PPM. The 17.5 MHz TCXO (Temperature Compensated Crystal Oscillator) is soldered directly to the RF board. The TCXO is not field serviceable. Return the transceiver to the Dataradio factory for repairs.

4.2 GENERAL OPERATION

4.2.1 SYNTHESIZER / VCO

The VCO (voltage-controlled oscillator) output signal is the receiver first injection frequency in the Receive mode and the transmit frequency in the Transmit mode. The first injection frequency is 52.95 MHz above the receive frequency. The frequency of this oscillator is controlled by a DC voltage produced by the phase detector in synthesizer chip U811.

Channels are selected by programming counters in U811 to divide by a certain number. This programming is performed over a serial bus formed by the Synth Clock, Synth Enable, and Data pins of J201. This programming is performed by the user supplied hardware/software (see Section 3).

The frequency stability of the synthesizer in both the receive and transmit modes is established by the stability of the reference oscillator described in the preceding section. These oscillators are stable over a temperature range of -30° to +60° C (-22° to +140° F).

4.2.2 RECEIVER

The receiver is a double-conversion type with intermediate frequencies of 52.95 MHz / 450 kHz. Two helical bandpass filters reject the image, half IF, injection, and other unwanted frequencies. A four-pole crystal filter and an 8-pole ceramic filter enhance receiver selectivity

4.2.3 TRANSMITTER

The transmitter produces a nominal RF power output of 5W at 13.3V DC, adjustable down to 1W. Frequency modulation of the transmit signal occurs in the synthesizer. Transmit audio processing circuitry is contained in the Loader board or customer-supplied equipment.

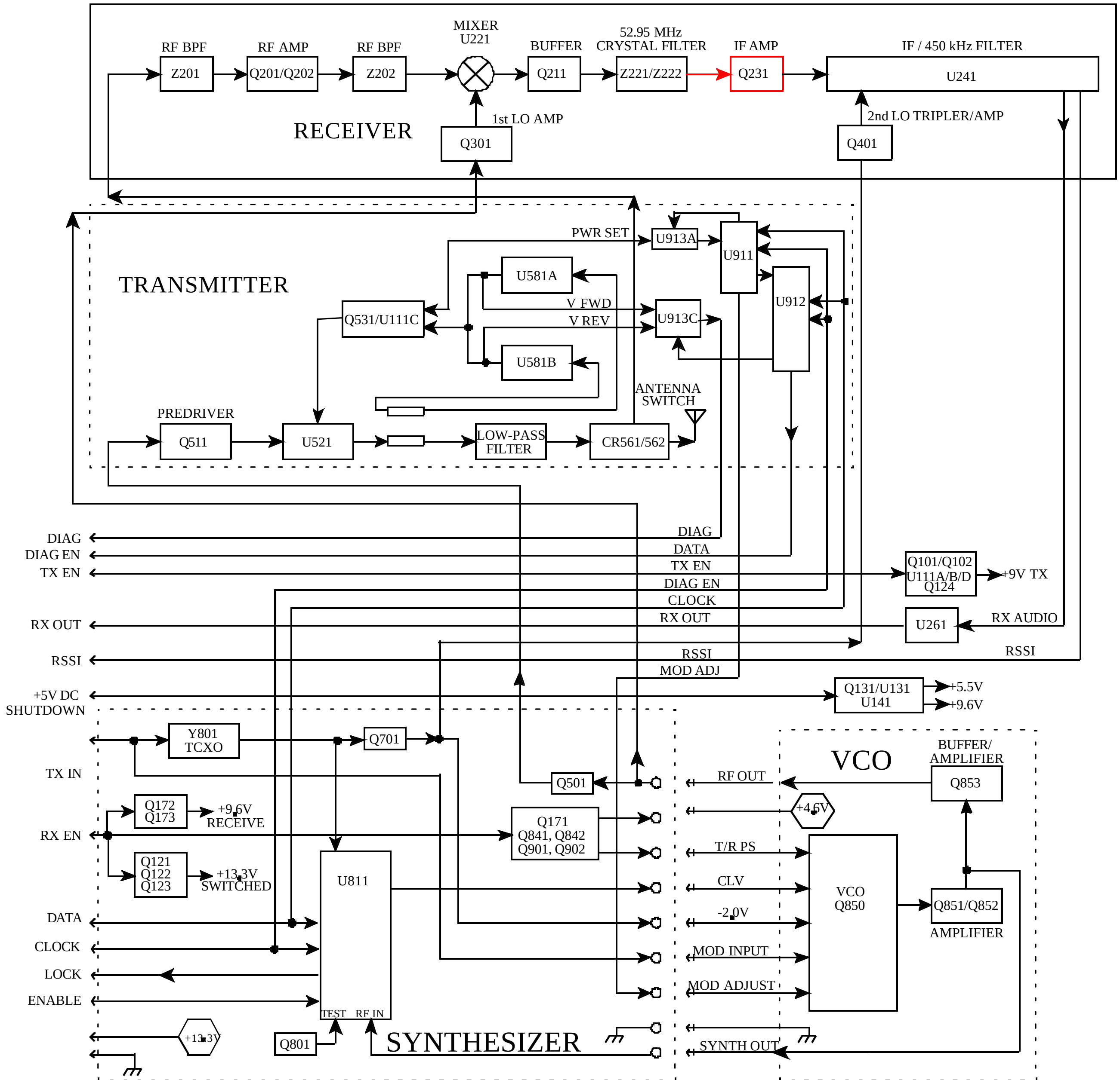

Figure 4-1 Transceiver Block Diagram

4.3 SYNTHESIZER / VCO

A block diagram of the transceiver is shown in Figure 4-1 and a block diagram of Synthesizer IC U811 is shown in Figure 4-2. As stated previously, the synthesizer output signal is produced by a VCO (voltage controlled oscillator). The VCO frequency is controlled by a DC voltage produced by the phase detector in U811. The phase detector senses the phase and frequency of the two input signals and causes the VCO control voltage to increase or decrease if they are not the same. The VCO is then “locked” on frequency.

Programming of the synthesizer provides the data necessary for the internal prescaler and counters. One input signal is the reference frequency. This frequency is produced by the 17.5 MHz reference oscillator (TCXO). The other input signal is the VCO frequency.

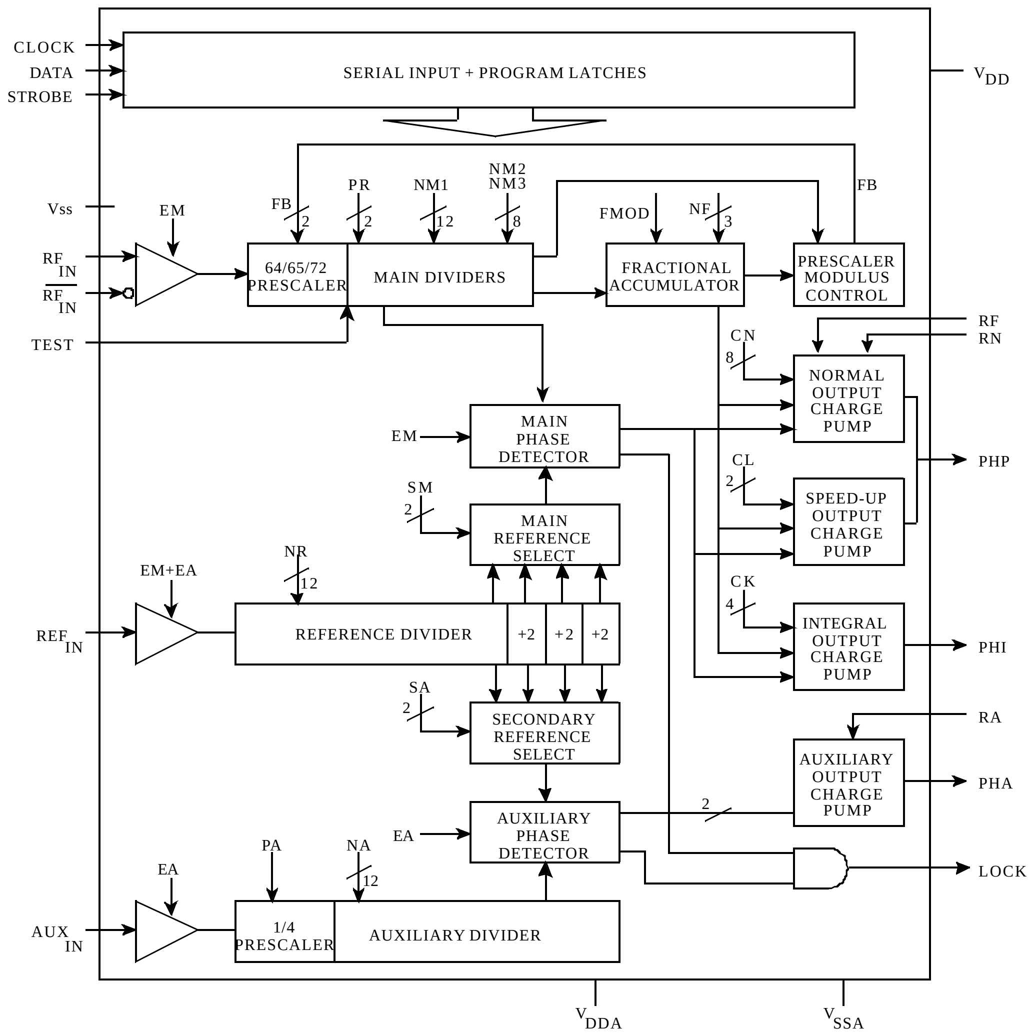

Figure 4-2 U811 Synthesizer Block Diagram

4.3.1 VOLTAGE-CONTROLLED OSCILLATOR

The VCO is formed by Q850, several capacitors and varactor diodes, and ceramic resonator Z850. It oscillates at the transmit frequency in transmit mode and first injection frequency in the receive mode (380-512 MHz in transmit and 432.950-564.950 MHz in receive).

Biasing of Q850 is provided by R862, R867, and R868. An AC voltage divider formed by C859, C861, C862, and Z850 which initiates and maintains oscillation and also matches Q850 to the tank circuit.

The VCO frequency is controlled in part by DC voltage across varactor diodes CR854, CR855, CR856 and CR851. As voltage across a reverse-biased varactor diode increases, its capacitance decreases; VCO frequency increases as the control voltage increases. CR854/CR855 and CR856/CR851 are paralleled varactors to divide the capacitance and improve linearity. The varactors are biased at -2.0V so the control line can operate closer to ground. The control line is isolated from tank circuit RF by choke L851/L854 and decoupling capacitor C854. The amount of frequency change produced by CR854/CR855/CR856/CR851 is controlled by series capacitor C853.

The -2.0V applied to the VCO is derived from the 17.5 MHz TCXO frequency that is amplified by Q701, rectified by CR701 and filtered by C706, C707, C708 and C709 on the RF board.

4.3.2 VCO AND REFERENCE OSCILLATOR MODULATION

Both the VCO and reference oscillator (TCXO) are modulated in order to achieve the required frequency response. If only the VCO were modulated, the phase detector in U811 would sense the frequency change and increase or decrease the VCO control voltage to counteract the change (especially at the lower audio frequencies).

If only the reference oscillator frequency is modulated, the VCO frequency would not change fast enough (especially at the higher audio frequencies). Modulating both VCO and reference oscillators produces a flat audio response. Potentiometers R825, R826 and R827 set the VCO modulation sensitivity so that it is equal to the reference oscillator modulation sensitivity. The transmit audio/data signal from J201, pin 6 is applied across varactor diode CR852 which varies the VCO frequency at an audio rate. Series capacitors C856/C870 couple the VCO to CR852. R854 provides a DC ground on the anodes of CR852/CR853, and isolation is provided by R852 and C855. C858 is an RF bypass. C853 provides isolation.

The DC voltage across CR853 provides compensation to keep modulation relatively flat over the entire bandwidth of the VCO. This compensation is required because modulation tends to increase as the VCO frequency gets higher (capacitance of CR854/CR855/CR856/CR851 gets lower). CR853 also balances the modulation signals applied to the VCO and TCXO. The DIAG on J201, pin 14 can also adjust the modulation.

The DC voltage applied across CR853 comes from the modulation adjust control R827 on the RF board. R826 applies a DC biasing voltage to CR852; C821 provides DC blocking. RF isolation is provided by C858, R853 and R847.

4.3.3 CASCODE AMPLIFIERS/VCO (Q851/Q852)

Q851/Q852 form a cascode amplifier to provide reverse isolation for the VCO. Q851 is configured as a common emitter and Q852 as a common base. The output signal is taken from the collector of Q851 and coupled to the base of amplifier Q853 through coupling capacitors C868, C871 and a PI-attenuator made up of R859 and R875.

4.3.4 AMPLIFIER (Q853)

Amplifier Q853 provides final amplification of the VCO signal. Bias for Q853 is provided by R871, R872 and R874. L856/C874 provide a match to the transmitter and first injection frequency. The T-pad attenuator made up of R892, R893 and R894 provides 6 dB of isolation between the transmitter and first injection frequency.

4.3.5 VOLTAGE FILTER (Q901)

Q901 on the RF board is a capacitance multiplier to provide filtering of the 4.6V supply to the VCO. R901 provides transistor bias and C901 provides the capacitance that is multiplied. If a noise pulse or other voltage change appears on the collector, the base voltage does not change significantly because of C901. Base current does not change and transistor current remains constant. CR901 decreases the charge time of C901 when power is turned on. This shortens the start-up time of the VCO. C902 and C903 are RF decoupling capacitors.

4.3.6 VCO FREQUENCY SHIFT (Q841)

The VCO must be capable of producing frequencies from 403-564.95 MHz to produce the required receive injection and transmit frequencies. If this large of a shift was achieved by varying the VCO control voltage, the VCO gain would be undesirably high. Therefore, capacitance is switched in and out of the tank circuit to provide a coarse shift in frequency.

This switching is controlled by the T/R pin shift (RX_EN) on J201, pin 4, Q841/Q842 and pin diode CR850. When a pin diode is forward biased, it presents a vary low impedance to RF; and when it is reverse biased, it presents a very high impedance. The capacitive leg is switched in when in transmit and out when in receive.

When J201, pin 4 is high in receive (+3-16V), Q173 is turned on and the collector voltage goes low. A low on the base of Q172 turns the transistor on and the regulated +9.6V on the emitter is on the collector for the receive circuitry. Q171 applies a low on the base of Q841, the transistor is off and the collector is high. With a high on the base of Q842 and a low on the emitter, this reverse biases CR850 for a high impedance.

The capacitive leg on the VCO board is formed by C851, CR850, C852 and C876. When J201, pin 4 is low in transmit, Q842 is turned on and a high is on the emitter, Q171 is turned off and the collector voltage goes high. A low on the base of Q173 turns the transistor off and the regulated +9.6V is removed from the receive circuitry. With a high on the base of Q841 the transistor is on and the collector is low. With a low on the collector of Q842 and a high on the emitter, this forward biases CR850 and provides an RF ground through C851 and C852/C876 are effectively connected to the tank circuit. This decreases the resonant frequency of the tank circuit.

4.3.7 SYNTHESIZER IC (U811)

Synthesizer chip U811 is shown in Figure 4-2. This device contains the following circuits: R (reference), Fractional-N, NM1 and NM2; phase and lock detectors, prescaler and counter programming circuitry.

Frequencies are selected by programming the R, Fractional-N, NM1 and NM2 in U811 to divide by a certain number. These counters are programmed by Loader board or a user supplied programming circuit. More information on programming is located in Section 3.

The counter divide numbers are chosen so that when the VCO is oscillating on the correct frequency, the VCO-derived input to the phase detector is the same frequency as the reference oscillator-derived frequency. The VCO frequency is divided by the internal prescaler and the main divider to produce the input to the phase detector.

4.3.8 LOCK DETECT

When the synthesizer is locked on frequency, the SYNTH LOCK output of U811, pin 18 (J201, pin 7) is a high voltage. When the synthesizer is unlocked, the output is a low voltage. Lock is defined as a phase difference of less than 1 cycle of the TCXO. ***The Lock Detect must be monitored at all times. The transceiver should be disabled in the event of an unlocked condition per FCC regulations.***

4.4 RECEIVER CIRCUIT DESCRIPTION

4.4.1 HELICAL FILTER (Z201), RF AMPLIFIER (Q201)

Capacitor C205 couples the receive signal from the antenna switch to helical filter Z201. Z201 is a bandpass filter tuned to pass only a narrow band of frequencies to the receiver. This attenuates the image and other unwanted frequencies. The helicals are factory set and should not be tuned.

Impedance matching between the helical filter and RF amplifier Q202 is provided by C206, C207 and L201. CR231 protects the base-emitter junction of Q202 from excessive negative voltages that may occur during high signal conditions. Q201 is a switched constant current source which provides a base bias for Q202. Q201 base bias is provided by R202/R203. Current flows through R201 so that the voltage across it equals the voltage across R202 (minus the base/emitter drop of Q201). In the transmit mode the receive +9.6V is removed and Q201 is off. This removes the bias from Q202 and disables the RF amplifier in transmit mode. This prevents noise and RF from being amplified by Q202 and fed back on the first injection line.

Additional filtering of the receive signal is provided by Z202. L202, C208 and C209 provide impedance matching between Q202 and Z202. Resistor R205 is used to lower the Q of L202 to make it less frequency selective.

4.4.2 MIXER (U211)

First mixer U211 mixes the receive frequency with the first injection frequency to produce the 52.95 MHz first IF. Since high-side injection is used, the injection frequency is 52.95 MHz above the receive frequency. The RF signal is coupled to the mixer through C215.

4.4.3 FIRST LO AMPLIFIER (Q301)

The first injection frequency from the VCO is coupled to the first local oscillator amplifier Q301 through C301. L301/C302 match Q301 to the VCO. Bias for Q301 is provided by R301, R302 and R303, R306 and C307. Impedance matching to the mixer is provided by L302, R305 and C306 decouples RF signals.

4.4.4 BUFFER (Q211), CRYSTAL FILTER (Z221/Z222), IF AMP (Q231)

The output of U211 is coupled to buffer Q211. C213, R213 and Q211 match the 50 ohm output of U211. Bias for Q211 is provided by R211 and R213. The output of Q211 is matched to crystal filter Z221 via L211, C214 and R212.

Z221 and Z222 form a 2-section, 4-pole crystal filter with a center frequency of 52.95 MHz and a -3 dB passband of 8 kHz (12.5 kHz BW) or 15 kHz (25 kHz BW). This filter establishes the receiver selectivity by attenuating the adjacent channel and other signals close to the receive frequency. C221, C222, and L221 adjust the coupling of the filter. L222, C223 and C233 provide impedance matching between the filter and Q231.

IF amplifier Q231 amplifies the 52.95 MHz IF signal to recover filter losses and improves receiver sensitivity. Biasing for Q231 is provided by R231, R232, R233, R234 and R235 and C232, C235 ground RF signals. The output of Q231 is coupled to U241 by C234.

4.4.5 SECOND LO AMP/TRIPLER (Q401)

The input frequency to Q401 is 17.5 MHz from TCXO Y801 coupled through C402. Bias for Q401 is provided by R401, R402, R403 and R404. C403, C404 ground RF signals. L401, L402, C405, C406 and C407 pass the third harmonic (52.5 MHz) to the input of U241, pin 4. The output of the amplifier is coupled to U241, pin 4 by C408, C409 and L403 form a 450 kHz notch.

4.4.6 SECOND MIXER/DETECTOR (U241)

U241 contains the second oscillator (see Figure 4-3), second mixer, limiter, detector, and squelch circuitry. The 52.95 MHz IF signal is mixed with a 52.5 MHz signal produced by second LO amplifier/tripler Q401 from TCXO Y801.

The output of the internal double-balanced mixer is the difference between 52.95 MHz and 52.5 MHz which is 450 kHz. This 450 kHz signal is fed out on pin 20 and filtered by IF filter Z251. The filtered signal is fed back into U241 on pin 18 to an internal IF amplifier. After amplification the signal is fed out on pin 16 where it is filtered by Z252 and then fed back into U241, pin 14 to the limiter.

The output of Z252 is applied to a limiter-amplifier circuit in U241. This circuit amplifies the 450 kHz signal and any noise present; then limits this signal to a specific value. When the 450 kHz signal level is high, noise pulses tend to get clipped off by the limiter; however, when the 450 kHz signal level is low, the noise passes through the limiter. C275/C276 decouple the 450 kHz signal.

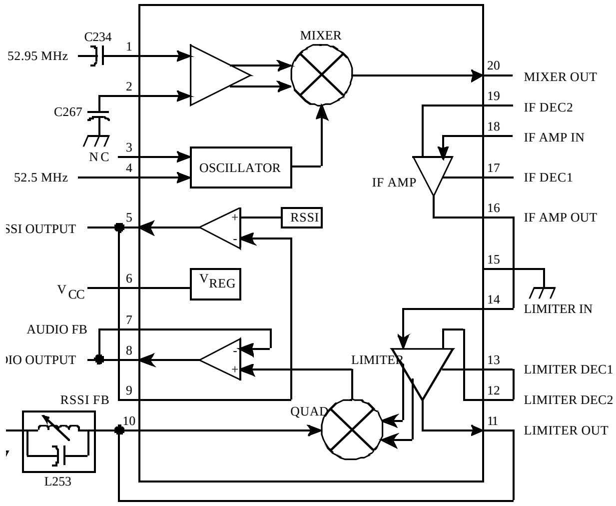

Figure 4-3 U241 Block Diagram

From the limiter stage the signal is fed to the quadrature detector. An external phase-shift network connected to pin 8 shifts the phase of one of the detector inputs 90° at 450 kHz (all other inputs are unshifted in phase). When modulation occurs, the frequency of the IF signal changes at an audio rate as does the phase of the shifted input. The detector, which has no output with a 90° phase shift, converts this phase shift into an audio signal. L253 is tuned to provide maximum undistorted output from the detector. R255 is used to lower the Q of L253. From the detector the audio and data signal is fed out on pin 8.

The audio/data output of U241, pin 8 is fed to the audio amplifier U261. U261 amplifies and inverts the detected audio/data signal and shifts the DC bias level to +2.5V DC at the output on pin 13. The gain is set at approximately 2.5 by R262/R263. R264/R265 provide a 1.3V DC reference bias voltage for U241. The audio output of U261 is applied to J201, pin 13.

U241, pin 5 is an output for the RSSI circuit which provides a voltage proportional to the strength of the 450 kHz IF signal. The RSSI voltage is applied to J201, pin 12.

4.5 TRANSMITTER CIRCUIT DESCRIPTION

4.5.1 BUFFER (Q501)

The VCO RF output signal is applied to R892, R893 and R894 that form a resistive splitter for the receive first local oscillator and the transmitter. The VCO signal is then applied to a 50 ohm pad formed by R501, R502, and R503. This pad provides attenuation and isolation. Q501 provides amplification and additional isolation between the VCO and transmitter. Biasing for this stage is provided by R504 and R505, and decoupling of RF signals is provided by C503. Impedance matching to the predriver is provided by L511 and C512.

4.5.2 PRE-DRIVER (Q511)

Pre-driver Q511 is biased Class A by R511, R512, R513 and R515. L513, C517 and C518 match Q511 to U521. R514 provides a resistive feedback path to stabilize Q511 and C515 provides DC blocking. C516 bypasses RF from the DC line, and R513 provides supply voltage isolation and ties the +9V transmit supply to the circuit.

4.5.3 FINAL (U521), COMPARATOR (U111C)

RF module U521 has an RF output of 1 to 5W and operates on an input voltage from 10-16V.

Power control is provided by U581, U111, Q531 and a stripline directional coupler. The power is adjusted by Power Set Control of U911 (when using diagnostics) and by R535 (when not using diagnostics). U111C and Q531 provide Power Control for PA module U521.

One end of the stripline directional coupler is connected to a forward RF peak detector formed by R591, CR591, C591 and U581A. The other end of the stripline directional coupler is connected to a reverse RF peak detector formed by R593, CR592, C593 and U581B.

If the power output of U521 decreases due to temperature variations, etc., the forward peak detector voltage drops. This detector voltage drop is buffered by U581A and applied to inverting amplifier U111C which increases the forward bias on Q531. The increase on Q531 increases the power output level of U521. If the power output of U521 increases, the forward peak detector voltage increases and U111C decreases the forward bias on Q531. The decrease on Q531 decreases the output power of U521.

The output of CR591 and CR592 are fed to U581A/B respectively. If the output of either buffer increases, the increase is applied to the inverting input of U111C. The output of U111C then decreases and Q531 decreases the input voltage to U521 to lower the power. The control voltage is isolated from RF by ferrite bead EP532 and C531 decouples RF.

The forward/reverse power voltages from U581A/B are also applied to U913 for Diagnostic outputs on J201, pin 14.

The low-pass filter consists of C552, L551, C553, L552, C554, L553, C555, L554 and C556. The filter attenuates spurious frequencies occurring above the transmit frequency band. The transmit signal is then fed through the antenna switch to antenna jack J501.

4.5.4 ANTENNA SWITCH (CR561, CR562)

The antenna switching circuit switches the antenna to the receiver in the receive mode and the transmitter in the transmit mode. In the transmit mode, +9V is applied to L555 and current flows through diode CR561, L561, diode CR562, and R561. When a diode is forward biased, it presents a low impedance to the RF signal; conversely, when it is reverse biased (or not conducting), it presents a high impedance (small capacitance). Therefore, when CR561 is forward biased, the transmit signal has a low-impedance path to the antenna through coupling capacitor C562.

C583, L561, and C564 form a discrete quarter- wave line. When CR561 is forward biased, this quarter-wave line is effectively AC grounded on one end by C564. When a quarter-wave line is grounded on one end, the other end presents a high impedance to the quarter-wave frequency. This blocks the transmit signal from the receiver. C561/C562 matches the antenna to 50 ohms in transmit and receive.

4.5.5 TRANSMIT KEY-UP CONTROL

Q121, Q122 and Q123 act as switches which turn on with the RX_EN line. When the line goes low Q121 is turned off, which turns Q122 on, turning Q123 on. This applies 13.3V to U111 before the TX_EN line goes high.

U111A/B provide the key-up and key-down conditioning circuit. C116 and R117 provide a ramp-up and ramp-down of the 9V transmit supply during key-up and key-down which reduces load pull of the VCO during key-up. The conditioning provides a stable 9.0V output by using the 5.5V reference from the 5.5V regulated supply.

The output on U111B, pin 7 is applied to the non-inverting input of comparator U111D, pin 12. The output of U111D, pin 14 is applied to the base of current source Q124. The output of Q124 is on the emitter and is applied back to the inverting input of comparator U111D, pin 13. A decrease or increase at U111D, pin 13 causes a correction by U111D to stabilize the 9V transmit output. R125/R126 establishes the reference voltage on U111D, pin 13. C123 provides RF bypass, C124 provides RF decoupling and C125 stabilizes the output. The 9V transmit voltage is then distributed to the circuits.

4.6 VOLTAGE REGULATORS

4.6.1 +9.6 AND +5.5V REGULATED

The +5-16V applied on J201, pin 5 is applied to the base of Q131 turning the transistor on. This causes the collector to go low and applies a low to the control line of U131, pin 2 and R132 provides supply voltage isolation. The 13.3V from J201, pin 2 is on U131, pin 6 and produces a +5.5V reference output on U131, pin 4. C132 stabilizes the voltage and C131/C133 provide RF decoupling. C134 provides RF bypass and C136 provides RF decoupling. C135 helps to stabilize the voltage when the +5.5V supply first turned on.

The low from the collector of Q131 is also applied to the control line of U141, pin 2. The 13.3V from J201, pin 2 is on U141, pin 6 and produces a +9.6V output on U141, pin 4. C144 provides RF bypass and C146 provides RF decoupling. C145 helps to stabilize the voltage when the +9.6V supply first turned on.