# SECTION 4

# CIRCUIT DESCRIPTION

## 4.1 GENERAL

### 4.1.1 INTRODUCTION

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

The 3422 is available with a reference oscillator stability of ±2.5 PPM. The TCXO (Temperature Compensated Crystal Oscillator) is soldered directly to the RF board. The TCXO is not field serviceable.

**Table 4-1 Reference Frequency**

| Band | Frequency |
|---|---|
| Band 4 | 14.85 MHz |
| Band 6 | 17.5 MHz |
| Band 7 | 17.5 MHz |

### 4.1.2 SYNTHESIZER

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 21.45 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 Synth Data pins of J201. This programming is performed by user supplied hardware and 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).

### 4.1.3 RECEIVER

The receiver is a double-conversion type with intermediate frequencies of 21.45 MHz / 450 kHz. Varactor tuned LC bandpass filters reject the image, half IF, injection, and other unwanted frequencies. A four-pole crystal filter enhances receiver selectivity.

### 4.1.4 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 customer-supplied equipment.

## 4.2 SYNTHESIZER/ VCO

The synthesizer output signal (produced by a VCO) 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.

Synthesizer programming provides the data necessary for the internal prescaler and counters. One input signal is the reference frequency. This frequency is produced by the 14.85 MHz reference oscillator (TCXO). The other input signal is the VCO frequency.

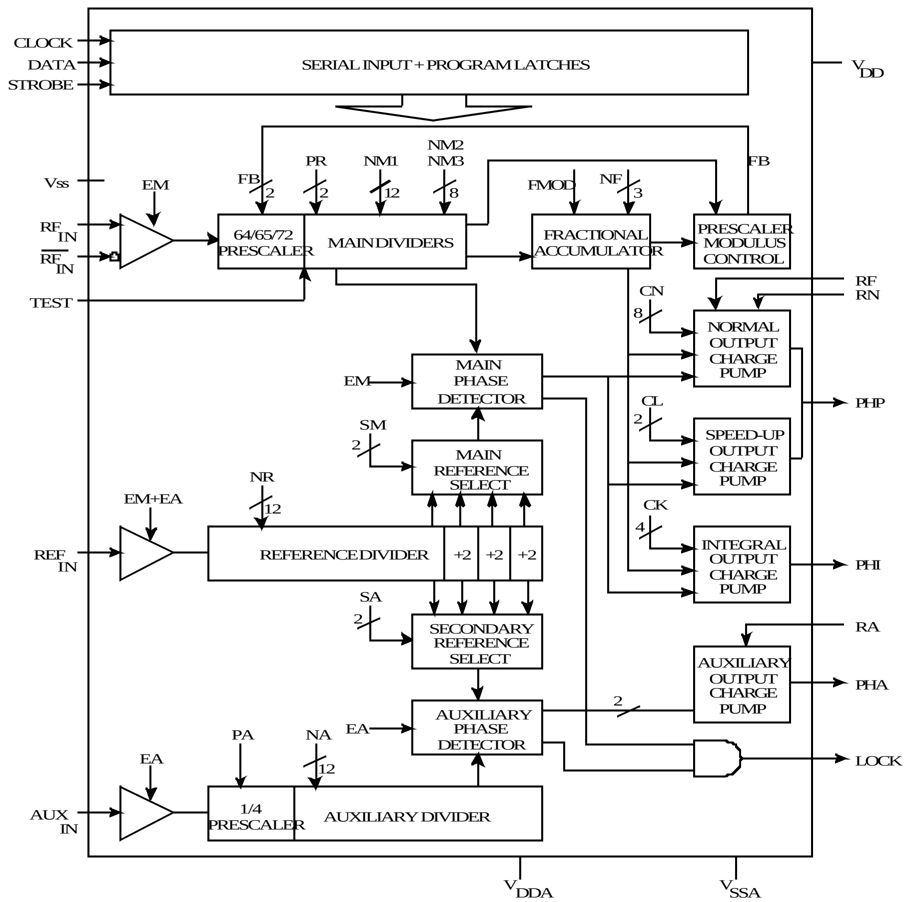


**Figure 4-1 U811 Synthesizer Block Diagram**

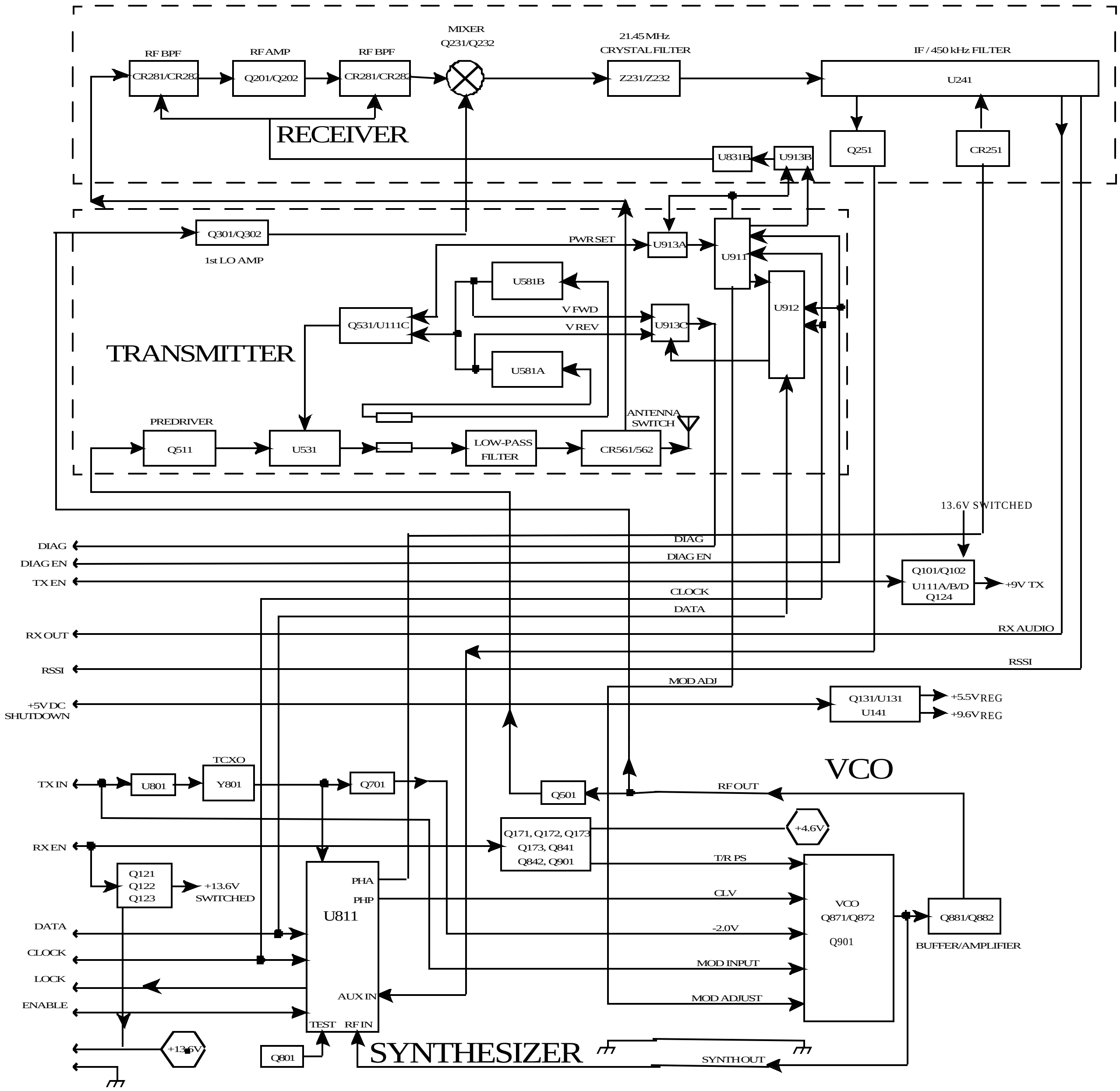


**Figure 4-2 Transceiver Block Diagram**

## 4.2.1 VOLTAGE-CONTROLLED OSCILLATOR

The VCO is formed by Q872, several capacitors and varactor diodes, and air wound coil L872. It oscillates at the transmit frequency in transmit mode and first injection frequency in the receive mode (132-174 MHz in transmit and 153.45-195.45 MHz in receive).

Biasing of Q872 is provided by R873, R874 and R876. The LC Tank Circuit is formed by C872, C874, C875, L872, and C873 which starts and maintains oscillation.

The VCO frequency is controlled in part by DC voltage across varactor diodes CR852, CR853 and CR854. As voltage across a reverse-biased varactor diode increases, its capacitance decreases. Therefore, VCO frequency increases as the control voltage increases. CR852/CR853 and CR854 are paralleled varactors to divide the capacitance and improve linearity. The varactors CR852/CR853 are biased at -2.0V so the control line voltage can operate closer to ground. CR854 is pin shifted in when transmitting to increase the VCO gain in transmit. The control line is isolated from tank circuit RF by choke L852/L853. The amount of frequency change produced by CR852/CR853/CR854 is controlled by series capacitor C854.

The -2.0V applied to the VCO is derived from the TCXO frequency that is amplified by Q902, rectified by CR902 and filtered by C912, C917, C918 and C920 and loaded by resistor R919.

### 4.2.2 VCO AND REFERENCE OSCILLATOR MODULATION

Both the VCO and reference oscillator (TCXO) are modulated in order to achieve the required frequency response. The TCXO responds to the lower modulating frequencies approximately 0-200 Hz. The VCO responds to the higher modulating frequencies (200 Hz and above). Potentiometers R825 and R827 set the VCO modulation sensitivity so that it is equal to the reference oscillator modulation sensitivity.

The VCO frequency is modulated using a similar method. The transmit audio/data signal from J201, pin 6 is applied across varactor diode CR861 which varies the VCO frequency at an audio rate. Series capacitors C855/C856 set the amount of deviation produced along with CR862 and C865. R863 provides a DC ground on the anodes of CR861/CR862, and isolation is provided by R862 and C863.

The DC voltage on CR862 can be varied 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 CR852/CR853/CR855 gets lower). CR862 also balances the modulation signals applied to the VCO and TCXO. The D/A Converter U911 can be programmed to apply a compensating voltage to CR862 to adjust the modulation sensitivity between the TCXO and VCO.

The DC voltage applied across CR862 comes from the modulation adjust control R827 on the RF board. R826 applies a DC biasing voltage to CR862; C821 provides DC blocking. RF isolation is provided by C865 and R862.

### 4.2.3 CASCODE AMPLIFIERS/VCO (Q871/Q872)

The output signal on the collector of Q871 is coupled to buffer amplifier Q872 which forms a cascode amplifier. This is a shared-bias amplifier which provides amplification and also isolation from the stages that follow. The signal is coupled and matched from the collector of Q872 through inductors and capacitors and a T-pad to amplifier Q882.

### 4.2.4 AMPLIFIER (Q882)

Amplifier Q882 provides final amplification of the VCO signal. Bias for Q882 is provided by Q881 and several resistors. Matching to the transmitter and receive first injection is provided by L891 and C892. A 6 dB T-pad is used to isolate the transmitter and receive first injection.

### 4.2.5 VOLTAGE FILTER (Q901)

Q901 on the RF board is a capacitance multiplier to provide filtering of the 8.6V 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. Therefore, 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.

### 4.2.6 VCO FREQUENCY SHIFT (Q841)

The VCO must be capable of producing frequencies from approximately 132-195.45 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. 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 CR851. When a pin diode is forward biased, it presents a very 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 (+5V), 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 CR851 for a high impedance.

The capacitive leg on the VCO board is formed by C852, CR851 and C853. 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 CR851 and provides an RF ground through C852 and C853 is effectively connected to the tank circuit. This decreases the resonant frequency of the tank circuit.

### 4.2.7 SYNTHESIZER INTEGRATED CIRCUIT (U811)

This device contains the following circuits: R (reference), Fractional-N, NM1, NM2 and NM3; phase and lock detectors, prescaler and counter programming circuitry.

Frequencies are selected by programming the R, Fractional-N, NM1, NM2 and NM3 in U811 to divide by a certain number. These counters are programmed by user supplied programming circuitry.

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. Refer to Section 3 for detailed programming instructions.

### 4.2.8 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. *This pin must be monitored for a lock condition. If an unlock condition is sensed, the transmitter must not be allowed to become active per FCC regulations.*

## 4.3 RECEIVER CIRCUIT DESCRIPTION

### 4.3.1 PRESELECTOR FILTER, RF AMPLIFIER (Q202)

Capacitor C201 couples the receive signal from the antenna switch to the LC preselector filter composed of L201-L203, CR281, CR282, C202-C207. (The antenna switch is described in Section 4.4.4.) The preselector filter is a 2-pole discrete LC varactor tuned bandpass filter adjusted to pass only a narrow band of frequencies to the receiver. This attenuates the image and other unwanted spurious frequencies.

The preselector filter is tuned in frequency by varying the reverse bias voltage of varactors CR281/CR282. The filter control voltage is either generated by Digital to Analog Converter (DAC) U911 or R920 and amplified by U831 to generate a higher voltage swing to the varactors and minimize filter loss. R206 and capacitors C281-C285 filter the varactor voltage and provide RF isolation. The control voltage source is chosen by U913.

Impedance matching between the helical filter and RF amplifier Q202 is provided by C207 and L204. CR201 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 a three pole discrete LC varactor tuned bandpass filter composed of filter L212-L214, L221-L224, CR283-CR285, C214-C217, C221-C223. L211 and C213 provide impedance matching between Q202 and this filter. Resistor R205 is used to lower the Q of L211 to make it less frequency selective. The same control voltage that adjusts to two pole filter on frequency adjusts this filter as well. The inductors are factory tuned to align the filter tracking and should not be adjusted.

### 4.3.2 MIXER (U231), AMPLIFIER (Q231)

First mixer U231 mixes the receive frequency with the first injection frequency to produce the 21.45 MHz first IF. Since high-side injection is used, the injection frequency is 21.45 MHz above the receive frequency. The RF signal is coupled to the mixer through C232.

The output of U231 is coupled to buffer Q231. C232, R233 and Q231 match the 50 ohm output of U231. The output of Q231 is matched to crystal filter Z231 via L231 and C234. This filter presents a low impedance to 21.45 MHz and attenuates the receive, injection, and other frequencies outside the 21.45 MHz passband.

### 4.3.3 FIRST LO AMPLIFIER/BUFFER (Q301, Q302)

The first LO amplifier provides amplification and buffering of the receive first injection. R305-R307 form a 3 dB 50 ohm pad. C303 couples the signal to C304 and L301 which match Q302 to 50 ohms. L302 and C307 match Q302 to the mixer Q232. Q301, R301-R304 provide biasing for Q302. R308 enhances the stability of Q302. C302 and C306 provide RF decoupling.

### 4.3.4 CRYSTAL FILTER (Z231/Z232)

The output of Q231 is matched to the crystal filter, Z231/Z232 by L231, C234 and C237. This filter presents a low impedance to 21.45 MHz and attenuates the receive, injection and other frequencies outside the 21.45 MHz passband.

Z221 and Z222 form a 2-section, 4-pole crystal filter with a center frequency of 21.45 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. C241, and C242 adjust the coupling of the filter. L242, C244, C245 and R243 provide impedance matching between the filter and U241.

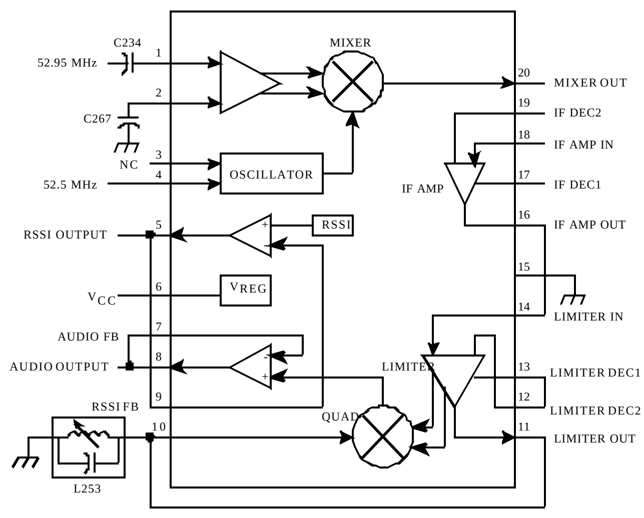


**Figure 4-3 U241 Block Diagram**

### 4.3.5 FM IF (U241)

U241 contains the second oscillator, second mixer, limiter, detector, and squelch circuitry (see Figure 4-3). The second LO oscillator is built into U241 which provides the base and emitter connections for an internal oscillator transistor. The oscillator tank circuit consists of L251, C253 and CR251. Oscillator feedback is provided by C254, C256 and C257. The oscillator frequency is adjusted by applying a control voltage across R253 to CR251. The control voltage is provided by the charge pump of the auxiliary synthesizer in U811.

The emitter of the oscillator transistor is connected to the common collector buffer amplifier Q251 by C251. R257-R259 and R254 provide bias for Q251. R254 additionally provides an RF load to decrease the buffer level. C258, C259 and L252 filter the unwanted harmonics from the oscillator output. The output of Q251 is coupled to the auxiliary synthesizer phase detector by C814. The oscillator is phase locked at 21.9 MHz with L251 adjusted to center the control voltage.

The output of the internal double-balanced mixer is the difference between 21.45 MHz and 21.9 MHz which is 450 kHz. This 450 kHz signal is fed out on pin 3 and applied to second IF filters Z241 and Z242. These filters have passbands of 9 kHz (12.5 kHz BW), or 20 kHz (25 kHz BW) at the -6 dB points and are used to attenuate wideband noise.

The output of Z241/Z242 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.

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 9. The audio/data output of U241, pin 9 is applied to J201, pin 13.

U241, pin 5 is an output for the RSSI circuit which provides a current proportional to the strength of the 450 kHz IF signal. The voltage developed across R275 is applied to J201, pin 12.

## 4.4 TRANSMITTER CIRCUIT DESCRIPTION

### 4.4.1 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.

### 4.4.2 PRE-DRIVER (Q511)

Pre-driver Q511 is biased Class A by R511 and R512 and R515. L513, C517 and C518 match Q511 to U531. 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.

### 4.4.3 FINAL (U531), COMPARATOR (U111C)

RF module U531 has an RF output of 1W to 5W and operates on an input voltage from 10-16V.

Power control is provided by U581, U111, Q531 and a directional coupler A531. The power is adjusted by Power Set Control R535 that provides a reference voltage to U111C. U111C drives Q531 and PA module U531.

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

If the power output of U531 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 U531. If the power output of U531 increases, the forward peak detector voltage increases and U111C decreases the forward bias on Q531. The decrease on Q531 decreases the output power of U531.

The output of CR591/CR592 is 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 U531 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/U912 for outputs on J201.

The low-pass filter consists of L551-L554, and C552-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.

### 4.4.4 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.

L561 and C563 form a discrete quarter-wave line. When CR561 is forward biased, this quarter-wave line is effectively AC grounded on one end by C563. 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/ C563 match the antenna to 50 ohms in transmit and receive.

### 4.4.5 TRANSMITTER 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 13.6V 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 since it uses the 5.5V regulated supply as a reference.

The output on U111B, pin 7 is applied to comparator U111D, pin 12, the non-inverting input. 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 on U111D, pin 13 causes a correction by U111D to stabilize the 9V transmit output. R125/R126 establish 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.

## 4.5 VOLTAGE REGULATORS

### 4.5.1 +9.6 AND +5.5V REGULATED

The +5V 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 U141, pin 1 and R131 is a pull-up resistor. The 13.6V from J201, pin 2 is on U141, pin 6. U141 establishes a +9.6V reference output on pin 4. C145 stabilizes the voltage and C146 provides RF decoupling. C144 provides RF bypass and C118 provides RF decoupling. C137 is a bypass capacitor for U131.

The low from the collector of Q131 is also applied to the control line of U131, pin 1. C136 decouples RF and R131 is a pull-up resistor. The 13.6V from J201, pin 2 is on U131, pin 6. U141 establishes a +5.5V output on U131, pin 4. C135 stabilizes the voltage and C136 provides RF decoupling. C137 is a bypass capacitor for U131.