4.0 Circuit Description

4.1 Frequency Determination and Stabilization

Transmitter 1:
Frequency stability is maintained by a TCXO, Y101, which is stable to +/- 1.5 PPM over the radio's operating temperature. The 12.8 MHz signal is buffered and amplified by Q102 and Q103 and is used as the reference for each loop in the synthesizer.

The synthesizer contains five phase-locked-loops, which provide the radio with four signals. The first LO determines receiver tuning. The second LO normally stays fixed on one of two frequencies, depending if high or low side injection is selected for use in the receiver. A 12.8 MHz clock oscillator provides the system clock on the DSP Motherboard and the exciter divider provides the transmit frequency that can be frequency modulated. The exciter frequency is generated by dividing down the first LO to obtain the desired frequency output. The dividers are under control of the microprocessor.

Transmitters 2 through 4:
These transmitters are purchased as modules from Motorola, and are FCC certified as hand held radios. The frequency determining and stabilizing circuits are contained inside these modules. Only two modules may be installed in the RT-5000 at a time. The following modules are used:

Transmitter 2: 136 – 174 MHz, FCC ID: AZ489FT3790
Transmitter 3: 450 – 512 MHz, FCC ID: AZ489FT4783
Transmitter 4: 806 – 870 MHz, FCC ID: AZ489FT5774

4.2 Modulation Limiting

Transmitter 1:
The DSP/Logic board handles both the audio processing and the logic functions of the radio. In transmit mode, the microphone audio is applied to an A/D converter (U4) where the analog signal is digitized and passed to the DSP. The DSP (U5) performs the audio processing of the AM and FM modulation. Once the DSP has processed the audio, it sends the digital information to a D/A converter (U6) for conversion back to analog. Following the converter, the audio signal is furthered filtered by a 4-pole butterworth filter (U2).

For FM transmit mode, the audio is first pre-emphasized in the DSP and passed to a limiter, which sets the maximum deviation to 2.5 kHz or 5.0 kHz depending on the channel spacing. Following the limiter, the audio is passed through a 6-pole butterworth splatter filter with a corner frequency of 3 kHz. This filter in combination with the analog filter following the D/A, attenuates signals above 3 kHz at a rate much steeper than 100 log f(Hz)/3000. All FM transmit modes used these filters.

For AM transmit mode, the audio is passed through a limiter to keep the AM modulation below 100%. Following the limiter, the signal passes through a 6-pole bessel 3 kHz low pass filter to attenuate signals above 3 kHz. This filter in combination with the analog filter, attenuates signals above 3 kHz at a rate greater that 60 log f(Hz)/3000.

The limiting functions in both the AM and FM mode are set in the factory using a computer. The limiter values for the different limits are stored in EEPROM (U15). The microcontroller (U11) passes the number to the DSP, which limits the magnitude of any digital signal to that level.

Transmitter 2 through 4:
The audio follows the same path as in transmitter 1 except pre-emphasis is not added or limiting applied in the DSP. The pre-emphasis and modulation limiting are handled inside of the Motorola module.

4.3 Suppression of Spurious Radiation

Transmitter 1:
There are two antennas – low split and high split. The low split antenna covers 29.7 MHz to 400 MHz range and the high split antenna covers 400 to 960 MHz range. There is a low split amplifier chain and a high split amplifier chain. Following the low split amplifier chain are 5 bands of elliptic low pass filters, which are selected via series/shunt pin diode switches. The low split bands and filter components are as follows:
29.7 - 50 MHz, L101 – L109, C100, C120, C121, C141, C147
50 – 88 MHz, L111 – L119, C102, C122, C124, C193
88 – 144 MHz, L138 – L144, C105, C106, C108, C117, C148, C149
144 – 240 MHz, L120 – L126, L128, C110 – C112, C116, C143
240 – 400 MHz, L130 – L136, W100, C126, C132, C135, C140

Following the high split amplifier chain are two bands of elliptic low pass filters, which are selected via series/shunt pin diode switches. The high split bands and filter components are as follows:

400 – 625 MHz, L201 – L206, C201- C205
625 – 960 MHz, W299 – W203, C209 – C212, C219

Each filter is enclosed in a shielded enclosure.

Transmitter 2: An external amplifier (Q19) is added in the RT-5000 to boost the Motorola module's power to 10W. C24, L20, C37, C38, L19, C39, C41, L21, C42, and C40 comprise a 7 pole elliptic low pass filter that attenuates the harmonics generated in the 10W amplifier. The second harmonic is attenuated below –60dbc.

Transmitter 3 and 4:

Low pass filtering is preformed inside the module after the power amplifier to attenuate the harmonics to the required level.

4.4 Limitation of Output Power

Transmitter 1:
There are 2 amplifier chains as discussed in 4.3, low split and high split. On the low split amplifier chain, a coaxial directional coupler samples off a small amount of the forward power and delivers it to the detector diode, CR115. The RF level is detected and rectified by CR115 and capacitors C137 and C123. Op-amp U200-D, transistor Q100 and diode CR100 provide a slight forward bias to the detector diode thereby increasing the linear operating range of the detector and providing a reduction in change over temperature. On the high split amplifier chain, a microstrip directional coupler samples off a small amount of the forward power and delivers it to the detector CR207. The RF level is detected and rectified by CR207 and capacitors C224 and C221. The detector diode is provided a slight forward bias by the same circuit used on the low split detector. The detected power level is applied to U1-C.

The feedback/power control loop, which consists of op-amps U1-A, U1-B, U1-C, U1-D, U5-A, U5-B, U5-C and gain controlled amplifier U6. U6 obtains a fixed dc reference voltage from one of 6 variable resistors (R69- R74). The resistors are used to set the reference levels for low split high and low power FM, low split high and low power AM and high split high and low power FM. The AM modulation is applied to U1-B and summed in at U5-B to modulate the DC references and vary the output power. U6 has 2 control voltages, one a 2.5V inner loop reference voltage supplied by the junction of R3 and R84. A second varying voltage, which comes from the output of op-amp U5-A, has two input signals summed together by diode CR7.

The main inner loop signal applied to U5-A, which comes from the output of U5-C, changes in proportion to the peak level of the signal detected by CR3. The second input comes from temperature control circuit U1-A and thermistor R89, which along with components R27, R28, R29, R31 and R16 set a trip point of approximately +85 °C. The power is reduced by 3 dB when the heat sink temperature reaches +85 °C.

The detected RF signal which is applied to the negative terminal of op-amp U1-C is compared at its positive terminal with the output signal of gain control amplifier U6 which acts as the master power control voltage. If the inner loop control voltage applied to pin 3 of U6 changes, the loop will produce the voltage required for the pin diode attenuator that will maintain the desired output power. The output from U1-C is applied to the pin diode attenuator control transistors Q11 for low split and Q16 for high split, which are emitter followers. Either Q12 or Q14 will be turned on, grounding this signal and leaving the corresponding pin diode attenuator in the high impedance state.

CR5/CR6 and CR1/CR4 are pin diode attenuators that provide variable attenuation of the +10dbm signal from the synthesizer depending on the amount of current through them.

The output of the attenuator is the drive level to the first stage of the power amplifier. The control loop adjusts the attenuation so the required RF output power is produced.

Transmitter 2:
An amplifier external to the Motorola module is used to boost the power level to 10W for the 10W mode. The power out of the Motorola module is adjusted in the factory - to provide the proper input level to the 10W amplifier - using Motorola's proprietary Radio Service Software (RSS).

In the 10W mode, RF is routed from the module through a pin diode switch (CR1) to Q19. Q19 is an n-channel enhancement mode MOSFET that is capable of 20W of output power. It is matched and biased for 10W of output power after the losses of the harmonic filter and pin diode switch. C48, C49 and C9 are dc blocking caps. L27, C52 and L28 provide impedance matching from 50 ohms to the Q19 input impedance. C54 and C53 provide a RF ground at one end of L28 while allowing a dc bias voltage to be applied to the gate via L28. The dc bias voltage sets the quiescent drain current when no RF is applied. R42 is adjusted to set the required quiescent drain current, and this adjusts the output power level.

L29, C56, C50 and L25 provide the optimum load impedance on the output of Q19 to obtain the 10W output. C51 is a dc blocking cap and L26, R38, R40 and R39 provide negative feedback. An amplifier's gain increases as the frequency decreases and this can cause it to be unstable. Negative feedback feeds part of the output signal back to cancel with the input signal thus lowering the gain at the lower frequencies and keeping the amplifier stable. It also flattens the gain over the operating frequency range, leveling the power out.

In the 1W mode, RF is bypassed around the 10W amplifier using pin diode switches CR2 and CR21. The power out of the Motorola module is adjusted in the factory using Motorola's proprietary Radio Service Software (RSS).

Transmitters 3 and 4:
The power control is built into the Motorola modules. The power out of the Motorola module is adjusted in the factory using Motorola's proprietary Radio Service Software (RSS).

4.5 Digital Modulation

Transmitters 2 through 4:
These transmitters use analog or digital modulation. The transmit digital modulation is C4FM, which is limited to a discrete set of four deviation levels. The modulation is preformed by an algorithm inside the DSP in the module. This algorithm will result in deviation levels that are limited to four discrete levels.