Theory of Operation

1.0 General Radio Technical Description

The frequency plan for this Dual-Mode handset was developed to satisfy the following conditions:

1. Minimum number of local oscillators in the product (one VC-TCXO* and two oscillators).
2. All on-board oscillators locked to the same reference (VC-TCXO) i.e. no free running signals in the product.

* TCXO (VC1): The frequency for this TCXO is 19.44 MHz and is powered from 3.0v regulator U26. The overall frequency variation is +/- 2.5ppm over the temperature range of -30°C to +60°C. This TCXO also has an AFC adjust pin that provides frequency adjustment up to +/- 5ppm. This allows (via DSP DAC) any frequency errors to be corrected by the Base Station OCXO. The TCXO frequency is used as reference for all synthesizers in this design and is also the clock for the DSP processor.

1.1 Detailed Radio Technical Description

Refer to the enclosed RF block diagram. The key property of this radio and its frequency plan is the sharing of a single synthesized local oscillator (around 1GHz) for both bands, resulting in reduced cost and size. The other two VHF oscillators are fixed frequency and they are phased locked. The number of local oscillators in this product is at its theoretical minimum.

The antenna operates at Cellular band (824-895MHz). An inductor capacitor network matches the antenna to 50 ohms.

From the duplexer antenna port of U19 a sample is taken for detecting the output power (R92) and this signal goes to the input of the log amplifier (SW1), that has > 60dB detecting range. The output of log amplifier called TX_LEVEL and is an input signal to the ADC in U2. In the base-band processor firmware there are look-up tables used to calibrate the output power to the IS-137 levels. This is done by using the DAC on the base-band processor to adjust the AGC level on the U47(MAX2364).

Duplexer is used to isolate the RX band from TX band specially in AMPS mode and its other functions are to attenuate output of band signals, image reject and attenuate the second and higher harmonics that are generated in final power amplifier. In the receive section, the signal is filtered and amplified using an on-chip LNA (MAX2324) U24. Then the received signal enters the 800 MHz LNA inside the MAX2324. MAX2324 has another control signal that called gain, which can by-pass the LNA (by-pass switch on/off) and this will reduce the front-end gain, when a high level signal is received in the antenna port. The threshold for this can be set by reading the RSSI value in DAC in the base band side and by doing this we can increase the dynamic range of the RX by 20 dB. After the LNA, there is SAW FILTER, U22 for Cellular band, which is used here to further attenuate TX signal and also to attenuate image signals and other out of the band signals. An on-chip image rejection mixer, which is used to facilitate the conversion. Another function of the MAX2324 is LIN pin, which it can set the front end LNAs to high linearity mode when we have high level signal at antenna port it can be set to low linearity mode. This way, we can save power consumption and extended back-up battery time. The output signal from mixer is differential and there is balan U39, which converts the differential IF1 outputs to single ended.

Once the received channel is converted to 119.64MHz it is filtered through a “signal matched” MCF filter that is used for channel selectivity and amplified in the Saturn IC. Saturn IC U29 has an IF amplifier with typical gain of 52 dB and also has AGC with 100 dB dynamic range. Also Saturn has internal VCO with external tank circuit that is used to generate the second Local oscillator in the RX chain. The frequency for this VCO is twice the local oscillator frequency (local oscillator frequency = 119.7 MHz). For locking this VCO we are using the RX side synthesizer inside Scorpio, but before entering the synthesizer portion of the Scorpio, the VCO frequency is divided by 8 inside Saturn. Also,

there is a QPSK Demodulator inside Saturn that converts the IF1 frequency (119.64 MHz) to IF2 60KHz in quadrature phase form (I, I_, Q, Q_).

The Mitel Scorpio IC has two separate paths, one is TX and another is RX path. The input for the RX path are I and Q signals at an IF2 of 60 KHz. These I and Q signals are filtered by a 60KHz switched capacitor band pass filter. The third down conversion is happening in side the Scorpio and by dividing the 19.44 MHz by 324 we generate the third local oscillator at 60 KHz. Then at output of the QPSK demodulator we have base band, I and Q signals. Scorpio also provides 56 to 76 dB of voltage gain (programmable) so that the base band outputs can be input directly to an A to D converter. The internal FM discriminator is used for demodulating AMPS (analog) signals. The receive path also provides RSSI (receive signal strength indicator). In the transmit path, I and Q base band signals comes from the D to A converters and they can be fed directly to Scorpio that provides reconstruction filters and a variable gain buffer. In the analog mode, the 60kHz IF is hard limited and demodulated to recover base-band audio. The two independent VHF frequency synthesizer blocks are in the Scorpio ICs, but only one of them is used to phase lock the second local oscillator in the receiver path. The transmit synthesizer is not used in this design. In the transmit section, the MAX 2364 integrated circuit has an internal IF VCO that with external tank circuits oscillates at 239.28 MHz and by using internal synthesizer and external loop filter will be locked at 239.28 MHz. We have different loop bandwidth for loop filter for Tx_IF synthesizer. In digital mode. Q8 transistor is OFF and Q6 transistor is ON. The loop filter is C258, C197 and R107. R111 and C244 forms a third pole to attenuate the reference frequency at 120 KHz. In AMPS mode we have to use direct modulation and because of this we have to use a narrow bandwidth loop filter in this mode. Q8 transistor will be ON and at the same time Q6 transistor will be OFF to allow modulation signals (Audio, Data) be directly modulated with IF_VCO (239.28 MHz). In digital mode the DSP will generate the I, _I, Q and _Q which will be modulated with Tx_IF frequency (QPSK modulation) and up-converted to the IF frequency. Then we have an AGC amplifier with 60dB dynamic range.

The IF outputs are differential and we use LPF to reduce the sub harmonics, then we enter differentially to the IF input ports on MAX2364. The MAX2364 has a high frequency synthesizer that is used here (with external loop filter) to phase lock the main 1 GHz local oscillator, that is shared between Rx and Tx portion. In MAX2364, we have a second up-converter, that converts the Tx_IF frequency to Tx RF frequency (824-850 MHz). Also, after up-converter we have some gain control in the RF driver amplifier (<20dB).
The power output from MAX 2364 can be +7 dBm linear. These signals enter to U17 saw filter (0836LK). With center frequency at 836 MHz +/- 12.5MHz, 3 dB bandwidth. This filter is used here to reject local oscillator leakage and any out of band signals and also reduce Tx noise in Rx band.

The RM805 (U52) is the main power amplifier with 29 dB gain and up to 35 dBm linear output power. This amplifier requires only one positive DC voltage. The DC voltage can be between 3 and 5.0 volts. PA_C836 Pin (Vref) used here to be able to turn OFF/ON the main power amplifier with frame clock (50 HZ/20ms) signal in TDMA mode. In AMPS mode PA_C836 (Vref) will stay at 3.1 VDC, which will keep the main PA ON all time.. The PA (U52) output enters to duplexer (U19). The duplexer is used here to isolate Rx and Tx portion of the circuit. Also in Tx portion to attenuate all unwanted signals generated inside the circuit. The Rx side of the duplexer used here to reject image frequency and all unwanted signals from air entering through the antenna and also attenuates the Tx signal levels at LNA input (LNA should be operating normally when transmitter output is at maximum power in AMPS mode).

2.0 Base-band Functions

Refer to the enclosed base-band block diagram. A single chip TDMA/ base-band processor, U2 (PrairieComm PCI3620) performs all base-band functions. It's internal DSP also handles all the AMPS transmit modulation functions (modulation levels, deviation limiting and audio filtering). The processor section also handles all I/O and user interface (keyboard, display) functions.

3.0 Power Supply distribution

An AC adapter converts the mains power to +6 VDC +/- 5%. U14 regulates this voltage to 4.3 volts to supply the base-band and radio sections. The base-band processor also monitors the 4.3 volts and shuts down the transmitter if this voltage falls below 3.9 volts. U15 provides additional regulation for the LCD display section. An optional four (4) AA alkaline batteries provides backup power in case of a power failure.