

# BIZCOMUSA 700 THEORY OF OPERATION

## 7. THEORY OF OPERATION

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## 7.1 INTRODUCTION

**Electronic components.** Most of the BIZCOMUSA 700 electronic components are contained on two printed circuit board assemblies, namely, ASY-0700-01 RF board and ASY-0700-02 Digital board. The RF board contains two frequency synthesizers, transmit circuitry up to the 10 mW level, receiver RF and IF circuits and RF transmit/receive switch. The digital board contains the radio system microcontroller, LCD, digital signal processor (DSP) subsystem and audio components. The RF PA assembly is mounted to the RF board and provides amplification to the 2 W PEP output level. Voltage regulators and power control circuits are resident on both the Digital and RF boards.

**Transmitter.** The transmitter uses direct modulation, i.e., in-phase and quadrature (I/Q) audio frequency baseband modulation developed by the DSP and associated DACs is modulated directly onto the carrier at the FCC channel center frequency. The resultant modulator output is single sideband (SSB) for trunked voice operation and it is linearly amplified to the 2 W PEP level. The 220 MHz carrier is derived from the sum of the nominal 175 MHz and 45 MHz synthesizer frequencies.

**Receiver.** The receiver implements RF amplification with step AGC capability, low-side injection of the 175 MHz synthesizer output for first conversion to the 45 MHz first IF, followed by a stage of 45 MHz IF amplification (with step AGC) and high-side injection second conversion to the 455 kHz second IF. The 455 kHz IF is linearly amplified and sampled directly by the analog-to-digital converter (ADC) and further receive demodulation and signal processing is done within the DSP.

**Modulation.** The modulation format used for normal trunked or conventional voice operations is equivalent to upper sideband suppressed carrier. Although the BIZCOMUSA700 is fully compatible with BIZCOMUSA's ESP 500/1000/1100 series 220 MHz models, it uses quadrature I/Q modulation rather than the filter method of SSB signal generation. (Other names for this technique are "phasing" method and "Weaver" method.) As a result, The BIZCOMUSA700's suppressed carrier frequency is at the center of the assigned channel/emission rather than at the lower frequency edge of the emission.

FCC rules for 220 MHz narrowband 5 kHz spaced channels provide for a 4 kHz authorized bandwidth, i.e., assigned channel frequency  $\pm 2$  kHz. In the BIZCOMUSA700, voice audio frequencies in the range of 300 to 1600 Hz is emitted from 1650 to 350 Hz below the assigned channel frequency while voice audio frequencies from 1600 to 2900 Hz are emitted from 350 to 1650 Hz above the assigned channel frequency. (A one kHz test tone would appear 950 Hz below the assigned channel frequency.) Continuous DTL trunking control data are emitted as 300 bps FSK centered at the channel frequency with a bandwidth of approximately  $\pm 150$  Hz. The DTL FSK signal is larger than and therefore masks the suppressed carrier during normal radio

operation. Finally, a continuous pilot tone is emitted 1950 Hz above the carrier frequency. The pilot tone serves as a frequency and amplitude reference for the system and is processed in the receiver for use in the AFC and AGC systems.

## 7.2 DIGITAL CONTROL/COMPUTER

### 7.2.1 Microcomputer (U2) and associated components

**General.** U2 is the radio system master controller. Its program responds to inputs from the user interface (keypad and buttons) and controls the front-panel LCD. It orchestrates all aspects of receiver and transmitter power supply control, function and timing. It encodes DTL trunking data for transmission and decodes received DTL data. It also controls the operation of the DSP subsystem.

**Interrupts.** "Reset" is the only external interrupt used in normal operation.

**Clock.** An 8 MHz crystal (Y1) controls the microcomputer clock frequency which is internally divided to provide a 2 MHz instruction cycle rate (E clk) visible at U2 pin 28.

**Reset circuit.** C1, R7 and CR6 provide a slow-rising, fast-falling voltage to the microcomputer's reset pin.

**Firmware.** The operating system firmware is programmed into the 8-bit microcomputer's on-board OTPROM program memory during the manufacturing board test process.

**Serial Comm Interface (SCI).** The async data port (RxD, TxD) is routed to the external accessory connector which allows serial communications with the PIU750 Programming Interface Unit.

**Serial Peripheral Interface (SPI).** MISO, MOSI and SCK are used to transfer synchronous data to the two frequency synthesizers, main AFC DAC register (U8), LCD controller (U1), and DSP Input Control Register (U10).

**ADC Channels.** Four of the available 8 ADC channels in U2 are used for sensing analog inputs. The analog input range is 0 (VRL) to 5 volts (VRH). PE0 senses AGC feedback voltage from receiver RSSI output. PE1 senses battery voltage from resistive divider R4 and R5. PE2 senses transmit ALC detector voltage. PE3 senses unprocessed analog receiver AFC from DSP DAC U16.

**Keypad interface.** Organized as a 4X5 matrix, PE4-PE7 provide row sense and PG0-PG4 provide column drive.

**Serial EEPROM interface.** PC6 (CLK) and PC7 (DATA) are used to read/write factory and field programmable radio configuration information from/to U6, which is a 16k-bit nonvolatile memory.

**Other I/O pins.** Ports A, B, and C provide chip selects, power control, and other control/sense functions which are described in Sections 7.2.2 and 7.7.

### 7.2.2 Digital Control

Digital Board microcomputer port controls from U2:

- PA3. Monitors DSP squelch control output from U15, pin 5.
- PA5. DSP IRQ2. High except strobes low at DTL data rate when transmitting.
- PA6. TX power enable. High level normally turns on Q2 to enable transmit power circuits on RF board. Q1 provides a fail-safe to keep Q2 off if PB3 is also high.
- PA7. Factory test point.
- PB0. DSP A/D input select. High for receive, low for transmit. U7D inverts PB0. During reception, 455 kHz RX IF signal is routed through U7B to the DSP A/D input at U14 pin 2. During transmission, amplified microphone audio from U9C pin 8 is routed through U7C to U14 pin 2.
- PB1. BPF enable. This pin is high to enable the 455 kHz bandpass filter via U7A at all times except during initial factory testing.
- PB2. DSP Power. This line goes high shortly after power-up, turns on Q4 and enables U5, a 5 volt regulator used for DSP system power.
- PB3. RX power enable. Turns on Q3 to enable receiver power on RF board. Also Turns on Q1 to ensure that Q2 is off and TX power is disabled.
- PB4. Latch strobe for U8 and U10. After SPI serial data is written to U8 and U10, this line strobes momentarily high to load the parallel register outputs with the new data. Note that serial data from U2 (MOSI) is shifted through U8 before entering U10.
- PB5. LCD Enable. Enables the LCD controller, U1, for serial display data transfer.
- PC1. DTL data input from DSP output register, U15 pin 4.
- PC2. "Busy" signal input from DSP output register, U15 pin 4. High when busy.
- PC3. Local Mic. Normally high unless external speaker/mic is installed. When high, internal speaker common lead is grounded via U17A and common base internal mic amp, Q7, is enabled. When low, internal speaker and mic are disabled.
- PC6,7. EEPROM serial clock and data.
- PD2,3. SPI data input (MISO) and output (MOSI).
- PD4. SPI shift clock. Clock rate and duty ratio varies.
- PD5. DSP reset. Goes high shortly after power-up.

RF Board, PTT Board and accessory connector microcomputer port controls from U2:

- PA0. Monitor switch. High except goes low when PTT board Monitor switch is depressed.
- PA1. Synthesizer lock detect. Normally high but goes low if either synthesizer is unlocked.
- PA2. PTT Switch. High except goes low when PTT switch is depressed.
- PB6. Synth 1 En. Strobes high when Channel Synthesizer data is loaded.

- PB7. Synth 2 En. Strobes high when Fixed 45 MHz Synthesizer data is loaded.
- PC4. AGC Coarse. High when received signal level is low. See discussion of AGC operation.
- PC5. AGC Fine. High when received signal level is low. See discussion of AGC operation.
- PD0. Dual purpose accessory connection. Receives asynchronous serial data from PIU if PIU attached or monitors external PTT if external speaker/microphone accessory is attached.
- PD1. Dual purpose accessory connection. High when no accessories are connected. Asynchronous serial data is transmitted when PIU is attached. Alternately, this line is grounded when external speaker/microphone accessory is attached.
- PD3,4. SPI data and clock out for loading synthesizers on RF board.
- PG7. Green LED (Call light) control. Normally high to keep Q5 off. Not used in BIZCOMUSA700.

### 7.3 DIGITAL SIGNAL PROCESSOR (U12) and associated components

**General.** The DSP is responsible for most transmit and receive signal processing at frequencies less than 455 kHz. Acting on commands from U2, it loads and runs one of three signal processing programs: initialization/test, receive, or transmit.

**Operational Overview.** Operating commands and data from U2 are read into the DSP via input control register, U10. Microcomputer U2 also provides DSP reset control and tx dtl data interrupt to DSP IRQ2. The DSP is a bus-oriented processor but has its own on-board 24-bit wide program RAM and 16-bit wide data RAM. The DSP loads the desired signal processing program from byte-wide boot PROM U11 into its program memory and then runs that program continuously until another program is requested by U2. The DSP's two synchronous serial ports control operation of the 12-bit analog-to-digital converter, U14, and the dual 10-bit digital-to-analog converters, U16 (which includes dual audio filters). It also outputs the logical signals busy, dtl data, DSP squelch and aux out via U15, a four-bit output register. The 9.8304 MHz DSP clock can be viewed at U12 pin 21.

Typical program operation sequence: Upon radio power-up, the initialization program is first run which includes volume set tone. Thereafter, the receive program operates except during transmission when the transmit program is used. Based on occasional need, some progress tones and special test functions are provided by the initialization/test program.

**DSP Transmit program.** The DSP Transmit program includes the following functions:

- 1) Amplified and low pass filtered microphone audio is sampled by U14 at 19.2 ksps. Microphone gain selection is applied as commanded by U2 via U10.
- 2) Initial processing includes first stage amplitude compression, voice bandwidth limiting, 6 dB/octave preemphasis and peak limiting.
- 3) The signal is converted to I and Q baseband segments.
- 4) Quadrature pilot and trunking data carriers are generated.
- 5) Trunking bits are collected from U2 via U10 and are applied as FSK to the data carrier.
- 6) Additional voice compression is carried out as voice level exceeds reference pilot level.
- 7) Inverse amplitude modulation of pilot and data carrier levels is applied as voice level rises -- with a 6 dB limit on pilot and data carrier amplitude reduction.

- 8) Voice segments are shifted to desired frequencies for transmission as described in 7.1.
- 9) I and Q channels of voice, pilot and data signals are summed to form composite baseband.
- 10) I and Q baseband analog signals extending from 0 to 2 kHz are produced at the ITX and QTX DAC outputs of U16 via the DSP serial ports at a sampling rate of 38.4 ksp/s. U16 contains integral low pass filtering.
- 11) Upon command from U2 via U10, DTMF or special transmit test tones are generated and substituted for the voice signal.
- 12) An approximate 150 Hz square wave is output from U15 DTL data output to verify DSP activity to U2.

**DSP Receive program.** The DSP Receive program includes the following functions:

- 1) U14 undersamples the 455 kHz IF signal at 19.2 ksp/s to produce an internal digital IF.
- 2) The digital IF is converted and low pass filtered to form digital I and Q baseband channels.
- 3) The pilot signal is isolated by filters and used to perform correction of multipath distortion as well as amplitude and frequency correction related to signal strength and carrier frequency. The pilot signal is further processed to produce analog DSP AFC output from U16 ITX DAC and to produce signal present ("busy") logic output from U15.
- 4) The trunking data signal is isolated by filters, demodulated, and the bits are output from U15.
- 5) The lower and upper voice segments are shifted to normal audio frequencies, audio amplitude expansion and 6 dB/octave deemphasis is performed, and analog voice audio is produced at U16 QTX DAC output.
- 6) "Key beep" and "busy" tones are substituted for voice audio output on command by U2.
- 7) Squelch control as commanded by U2 is passed through to U15 DSP squelch out.

**DSP Initialization/Test program.** The DSP Initialization/Test program includes the following functions:

- 1) Initializes serial clocks, ADC and DACs.
- 2) Generates audible progress or error tones.
- 3) Contains factory test software

**DSP ADC and DAC reference levels.** The "no-signal" dc output reference level from DSP DACs U16 at pins 16,17,20, and 21 is approximately 2.4 vdc and is approximately twice the voltage measured at the buffered DAC reference at U9 pin 14. The DACs are capable of  $2.4 \pm 0.75$  volt peak outputs. DAC dc offset errors are reduced to low levels by U16's internal start-up calibration routine. VREF at U14 pin 1 is non-critical but is also approximately 2.4 vdc. U14's allowable signal input range is 0 to 2.4 volts at pin 2 and the "no-signal" bias is approx. 1.2 volts.

**DSP ADC and DAC clock logic.** Master 614.4 kHz serial data shift clock is sourced from U12 pin 30 (SCLK0). DAC frame sync (DAC sample rate clock) for U16 is sourced by U12 pin 26 (RFS0) at 38.4 kHz. ADC frame sync (ADC sample rate clock) for U14 is sourced by U12 pin 33 (RFS1) at 19.2 kHz and inverted by U13C for use as a conversion strobe. SCLK0 and RFS1 are ANDed and slightly delayed by U13A, U13B and C35. The resulting waveform at U14 pin 4 is a burst of 16 serial clock cycles interrupted by a duration equal to 16 serial clock cycles.

## 7.4 SYNTHESIZERS/AFC

**General:** Two RF synthesizers in the BIZCOMUSA700 provide the two needed receiver conversion frequencies. During transmission, the two synthesizer frequencies are summed to produce the transmit carrier frequency source. Both synthesizers are contained on the RF board assembly and their registers are loaded serially by the microcomputer.

**VCTCXO.** The BIZCOMUSA700 synthesizers' stable frequency source is provided by U1, a voltage-controlled temperature compensated crystal oscillator with nominal 10.275116 MHz frequency and  $\pm 1.5$  ppm frequency stability from  $-30^{\circ}$  to  $+60^{\circ}$  C. During transmission a previously determined fixed tuning voltage is applied to the voltage control input to accurately set the transmitter carrier frequency. During reception, AFC is applied (from digital board U9A) to the voltage control input to allow tuning the receiver to match the frequency of the transmitter being received. A base station tracking algorithm employed by the microcomputer allows the BIZCOMUSA700 to maintain frequency accuracy similar to that of the base station ( $\pm 0.1$  ppm) even as the TCXO natural frequency varies with time or ambient temperature.

**Fixed Synthesizer, 45.4555 MHz (U3).** This synthesizer operates at a fixed ratio of 9091/2055 times the TCXO frequency. The phase detector error from U3 pin 13 passes through an active loop filter, U6, before being applied to varactor CR2 in the series-tuned voltage controlled crystal oscillator (VCXO) formed by Q1, Q2 and Y1. The output signal from Q2 is fed back to U3 via C31 to close the loop. Trimmer C26 allows calibration of the VCXO.

**Channel Synthesizer (U2).** This synthesizer operates in nominal 5 kHz steps. When transmitting to the repeater base station, its frequency is  $(35108 + \text{FCC Chnl no.})/2055$  times the TCXO frequency. When transmitting simplex (talkaround), the ratio is  $(34908 + \text{FCC Chnl no.})/2055$  times the TCXO frequency. When actively receiving the base station, the nominal frequency is  $(34999 + \text{FCC Chnl no.})/2055$  times the TCXO frequency. AFC varies the frequency several hundred Hertz when no signal is being received. An example follows:

FCC Channel 1 (220.0025 MHz base transmit, 221.0025 MHz mobile transmit)

RX		TX Repeat		TX Simplex	
Chnl Synth	175.0020	Chnl synth	175.5470	Chnl synth	174.5470
First IF	45.0005	Fixed synth	45.4555	Fixed synth	45.4555
Sum = RX freq	220.0025	Sum = TX carr.	221.0025	Sum = TX carr.	220.0025

The channel synthesizer VCO is a separate module (VCO1) attached to the RF board. Its operating frequency range is 174.5 to 177 MHz. The phase detector error from U2 pin 13 passes through an active loop filter, U4, before being applied to the VCO1 voltage control input. The loop is closed by feeding the output from VCO1 back to U2 via C11. A trimmer capacitor in the VCO module allows calibration of the loop.

**AFC Subsystem.** Main AFC is output from the microcomputer, U2, via the AFC DAC which consists of U8, RN1 and U9A on the digital board. Main AFC adjusts the frequency of the TCXO which, in turn, varies synthesizer frequency. The Main AFC DAC voltage range is 0 to 5 volts in 256 steps and the tuning rate referred to 220 MHz is about 300 Hz per volt or 6 Hz per step.

DSP AFC is output as an analog voltage output from DSP ITX DAC U16 pin 17. The voltage difference relative to 2.4 volts indicates the signed error between received pilot frequency and local pilot frequency. This voltage is input to the microcomputer at PE3 ADC and used in the main AFC calculation.

Main AFC is generated from the sum of three variables: DSP AFC, base station frequency tracking memory value stored in EEPROM, and a 4 Hz triangular sweep voltage used only during signal acquisition phase.

When a system is selected, the microcomputer retrieves the frequency tracking value saved in EEPROM for that system and adds it to the DSP AFC value. When no signal is present (as evidenced by lack of "busy" from DSP), the triangular sweep voltage is also added to the AFC

and forces the receiver to tune well above and below the nominal frequency determined by the frequency tracking memory. When a pilot signal appears in the pilot passband, the "busy" signal activates and the microcomputer stops the triangle wave at its current position. It then monitors the DSP AFC value while slowly adjusting the main AFC until a precise tuning match is achieved when the DSP AFC error nears zero.

AFC memory update. When a trunking "turnoff" code is received from the base station, the microcomputer compares the current main AFC value with the tracking value stored in EEPROM. If there is a significant difference, the value in EEPROM is updated to the current value of main AFC. In this manner, the BIZCOMUSA700 maintains better than 0.25 ppm frequency matching with the base station as environmental conditions vary and tcxo aging occurs. Individual tracking values are maintained for each of the systems selectable in the BIZCOMUSA700.

## 7.5 RECEIVER

### 7.5.1 Receiver RF circuits

**General.** See sheet 2 of ASY-0700-01 RF Board Schematic for the following discussion. The signal path through the receiver uses linear amplification except for the received signal strength indicator (RSSI) portion of the 455 kHz IF amplifier. The maximum voltage gain of the receiver prior to the DSP system is 70 dB. The receiver gain is reduced in three 25 dB steps according to signal strength.

**Antenna Circuit.** During reception, PIN diodes CR3 and CR5 of the RF T/R switch circuit are not conductive. The received signal passes from the antenna jack through an LC network which acts as a low pass filter and into FL1 via C63. At high signal strengths, the AGC Coarse control line from the microcomputer goes low, turns on Q9 and causes CR8 to conduct current as a shunt attenuator at FL1 pin 1.

**RF Amplifier/filter.** FL1 is a 3-section helical filter centered at 220 MHz which provides most of the RF front end filtering. U18 is a two-stage cascaded RF amplifier which provides net 20 dB gain between antenna jack and U18 pin 1. When AGC Coarse is activated by going low, U18 is disabled and the signal is attenuated approximately 50 dB including the attenuation due to CR8.

**First Conversion Mixer and 45 MHz IF.** U7 is an active mixer which is provided 175 MHz LO drive by the channel synthesizer to produce a 45.0005 MHz 1st IF. The output at U7 pin 4 is matched into FL2 (4-pole 45 MHz fundamental mode IF filter) by C36 and L17. U8 is operated as a 45 MHz amplifier with step gain control. At low signal strengths, the AGC Fine control line is high and Q3 is on. This biases U8 pin 6 for maximum gain. Above a threshold, AGC Fine control line goes low and turns Q3 off. The bias provided by divider R78 and RV2 sets the gain 25 dB below maximum. Differential output drive from U8 is fed to the second mixer inside U9.

**Second Conversion Mixer and 455 kHz IF.** U9 is a multifunction receiver chip which includes a linear mixer with gain, a limiting IF amplifier with RSSI output and an unused FM detector. The fixed synthesizer provides 45.4555 MHz LO to the mixer to produce the desired output signal at 455 kHz from pin 20. This is followed by FL4 which is a 6-element ceramic bandpass filter. The output of FL4 feeds the limiting IF amp. at pin 18 and is also coupled to Q4, the final linear IF amplifier. Q4 is a common emitter bipolar amp which provides linear gain to adequately drive the A-D converter on the digital board. A 455 kHz fixed tuned LC bandpass filter is in the collector circuit of Q4 but resides on the digital board. As noted before, the net max. voltage gain between antenna jack and TP13 is about 70 dB. The limiting IF amp produces a RSSI signal which is linear with respect to logarithmic changes in signal strength. An internal op amp in U9 is used to amplify and buffer the RSSI signal. RV1 calibrates the RSSI voltage.

**AGC operation.** The microcomputer monitors the RSSI voltage fed into its PE0 A-D converter. RSSI voltage rises about one volt for 15 dB increase in RF signal strength. Initially, both AGC Coarse and Fine controls are high for maximum gain. When signal reaches a threshold of about one volt p-p at TP13 (about -66 dBm input signal ), the microcomputer drops the AGC Fine control to the low level which drops the receiver IF gain 25 dB. As signal strength continues to rise, the threshold is reached again. AGC coarse line is set low and AGC fine is set high for a net gain reduction of approx. 50 dB. Finally, when the signal strength exceeds the threshold again, both AGC Coarse and AGC fine control lines are set low for approx. 75 dB gain reduction. Similarly, as the signal weakens, a low threshold is crossed which increases the gain in 25 dB steps. Hysteresis avoids gain instability. The net effect is that 130 dB variation in input signal level is reduced to a 60 dB dynamic range suitable for the DSP A-D converter. The DSP receive program then provides fast, fine resolution digital AGC to achieve constant audio output level.

### 7.5.2 Receiver audio circuits

**General.** Refer to ASY-0700-02 Digital/Audio board and ASY-0700-01 RF Board Sheets 1 and 3 schematic wiring diagrams.

**Audio Path.** Receiver audio, including progress tones, is output from DSP QTX DAC U16 pins 20 and 21 but only pin 20 is of interest. The audio signal is ac coupled by C20 and passed to the volume control pot. via the RF board. The volume control wiper is passed back from the RF board and applied through R49 to the audio input of the audio power amplifier, U3. Speaker audio from U3 pin 5 is ac coupled by C24 and applied passed to SPKR (the internal speaker) wire attached to the RF board. SPKR COM returns from the RF board to the digital board and is grounded through U17A when external speaker/microphone is not attached to the radio. A weak dc bias is supplied by R54 through the internal speaker to ensure that U17A does not conduct on audio peaks when external speaker microphone is attached. A separate path from U3 pin 5 through C26 supplies audio to the external speaker/microphone if attached. The audio amplifier is capable of 0.5 watts into 8 ohms at 10% THD.

**Squelch circuit.** The DSP squelch line from U15 pin 5 is high when audio is squelched. This is coupled through RC time constants to the shunt squelch gate, U17B, and to U3. The time constants reduce squelch thumping. U17B shorts volume control wiper audio to ground at U3's audio input. The squelch input at U3 pin 2 effectively disables the audio amplifier. When DSP SQUELCH goes low, U17B turns off and U3 returns to normal audio amplification.

## 7.6 TRANSMITTER

### 7.6.1 Transmitter Audio Circuits.

**General.** Refer to ASY-0700-02 Digital/Audio board and ASY-0700-01 RF Board Sheets 1 and 3 schematic wiring diagrams.

**Microphone audio path.** Microphone audio is sourced from either the internal electret microphone or the external speaker/microphone. When the internal microphone is in use, mic amp Q7 acts a common base audio amp with the emitter circuit supplying dc bias to the mic element. When the accessory speaker/mic is in use, Q7 is disabled and external microphone audio is applied from the accessory connector via the RF board. U9B amplifies and buffers either mic audio source and then feeds to U9C which is an active 3-pole analog 3.3 kHz audio lowpass filter serving as an anti-alias filter for the DSP ADC. During transmission, gate U7C is closed and gate U7B is open which routes transmit audio to U14 pin 2 for analog-to-digital conversion.

**Transmitter I/Q audio path.** Low pass filtered transmit audio is output from the DSP DACs at U16 pins 16,17, 20 and 21. Only pins 16 and 21 are of interest during transmission. These two complex audio signals contain the composite baseband transmit audio in phase quadrature with 0 to 2 kHz bandwidth. These signals are each coupled through an RC lowpass filter to the I and Q modulation inputs of the RF modulator. The RC filters remove residual noise above their 3 kHz cutoff frequency.

### 7.6.2 Transmitter RF Circuits.

**General.** The transmitter consists of carrier generation circuits, RF modulator, transmit amplifiers and RF T/R switch. Schematic wiring diagrams for most of these circuits are shown on sheet 3 of ASY-0700-01 RF board.

**Carrier generation circuits.** The 220 to 222 MHz carrier is generated by mixing together the 175 MHz and 45 MHz synthesizer signals and amplifying the sum frequency. See Section 7.4 for frequency details. U10 is an active mixer with inputs from the two synthesizers. RV8 allows setting carrier level to the desired amplitude. An adjustable LC circuit at the output of U10 pin 4 matches the signal into MMIC amplifier U11. The output of U11 is coupled into FL5 which is a 3-pole helical filter that removes unwanted mixer products outside the 220 to 222 MHz range. U12 is a second amplifier which brings the 220 to 222 MHz carrier signal up to the desired +2 dBm level to drive the I/Q modulator.

**RF I/Q modulator.** U13 integrates a dual mixer, internal summer and quadrature LO network. LO and RF ports are nominally 50 ohms. An example using a trigonometric identity demonstrates how it produces the desired low level transmit signal at 220 MHz.

Assume a single pilot tone is to be transmitted above the carrier frequency.

I channel audio input:	$V_{pi} \cos(W_{pt})$	$W_{pt}$ is audio pilot frequency in radians.
Q channel audio input:	$V_{pq} \sin(W_{pt})$	
I-mixer LO :	$V_{ci} \cos(W_{ct})$	$W_{ct}$ is carrier frequency in radians.
Q-mixer LO:	$V_{cq} \sin(W_{ct})$	

Each mixer by itself creates a double sideband two-tone signal:

I-mixer output:	$V_{pi} V_{ci} [\cos(W_{ct} + W_{pt}) + \cos(W_{ct} - W_{pt})]/2$
Q-mixer output:	$V_{pq} V_{cq} [-\cos(W_{ct} + W_{pt}) + \cos(W_{ct} - W_{pt})]/2$

If amplitudes are exactly equal, i.e.,  $V_{pi} V_{ci} = V_{pq} V_{cq}$ , the difference between I-mixer and Q-mixer output cancels the lower sideband:

$$V_{out} = V_{pi} V_{ci} \cos(W_{ct} + W_{pt})$$

This is the desired single frequency output at the sum of the RF carrier and audio pilot frequencies.

If the amplitudes are not exactly equal, then the lower sideband does not cancel perfectly and it appears as distortion at the carrier minus the pilot frequency. The amplitude of the undesired sideband relative to the desired sideband is called the opposite sideband suppression.

Not shown is potential degradation due to phase quadrature inaccuracies which will also result in incomplete cancellation of the unwanted sideband.

Also not shown is degradation due to differential dc offsets at the mixer inputs which cause an additional carrier frequency signal at the output (carrier leakage). The carrier level relative to the desired output level is called carrier suppression.

RV10 allows minimization of the opposite sideband. RV5 and RV9 allow minimization of carrier leakage.

Note that if the phase of either audio channel above is inverted, the difference of the mixer outputs will create a signal at carrier frequency minus audio frequency. This is the general method used to create an equivalent upper sideband signal extending below and above the carrier frequency. See Section 7.1 for more details on the composite transmit signal.

**Transmit amplifier chain.** The low-level 220 MHz transmit signal from U13 pin 15 is coupled through RV4 to MMIC amplifier U14 for 18 dB linear gain to about 0 dBm. RV4 sets the TX drive level. U14 drives discrete transistor amplifier U16 for about 10 dB linear gain and about +10 dBm output level. The signal then couples to the RF power amplifier board where two bipolar RF gain stages provide about 23 dB or more gain to the 2 watt PEP level. The power amplifier stages are class AB linear amplifiers and each has a pot. for setting quiescent current and minimizing IMD products.

**RF antenna switch circuit.** See sheet 2 of the RF board schematic wiring diagram. When transmitting, 7.2 volts is present at R46. This causes dc current to flow through the path L6, CR3, L8, CR5 and the red (TX indicator ) portion of LED1. Pin diodes CR3 and CR5 exhibit low RF impedance in this condition. The RF amplifier output passes through CR3, the low pass filter formed by C65,L7,and C58, and coupling capacitor C59 to the antenna jack. CR5 keeps significant RF power from reaching the receiver. Impedance transformation from CR5 back through C64 and L8 results in very little undesired RF path loading at CR3 cathode.

## 7.7 POWER CONTROL

### 7.7.1 DC power control

**Battery power.** See sheet 3 of the RF board schematic wiring diagram. Battery power enters through 2 Amp fuse F1 to become 7.2 VA. CR7 provides reverse polarity protection. 7.2 VA is connected directly to the two collector circuits of the RF power amplifier stages, the drain of 7.2 V transmit power switch Q8, and through the top panel ON/OFF Vol switch to provide 7.2 VB to the remaining radio circuits.

**Battery monitor.** On the digital board, U2 PE1 analog-digital converter monitors battery voltage. When battery nears full discharge, the LCD battery icon is turned on. When battery reaches full discharge, normal radio operation is terminated and error tones sound until the audio circuits cease to function.

**Digital Board dc power circuits.** 7.2 V is sourced from the RF board switched 7.2 VB at J1 39-40. It is applied through R52 to 5 volt regulators U4 and U5. 7.2 V is also routed to audio power amp U3 and display backlight LEDs CR1 and CR2. All other components on the digital board receive power from either CPU5V (U4) or DSP5V (U5) as marked. RF board transmit circuits are activated by Q2's collector being pulled to ground. RF board receive circuits are activated by Q3's collector pulling to ground.

**RF Board dc power circuits.** 7.2 VB sources power to 5 volt regulators U15 and U19 and

power to the external accessory connector. U15 is a source of continuous 5 volts for the RF board. When the /RX power control line is pulled low by Q3 on the digital board, Q5 turns on and supplies 5VRX power. When the /TX power control line is pulled low by Q2 on the digital board, Q8 turns on to supply 7.2VTX power and regulator U19 turns on to supply 5VTX.

**LCD Backlight circuit.** Q701, Q702, and Q703 on the PTT switch board are part of a timer circuit which keeps the LCD backlight LEDs lit for a few seconds after the lamp button is pushed. When the lamp button is pushed, C702 is charged to several volts. This turns on Q702 and Q703 while the charge on C702 leaks off through R702. Q703 draws enough current to light the LEDs. Q701 is on when radio power is first applied in order to keep C702 discharged.

## 1.4 Test Equipment Required

- 1.4.1 7.2 VDC 3 Amp Power Supply with Ammeter
- 1.4.2 RF Spectrum Analyzer (**SA**)
- 1.4.3 30 dB 5 Watt Attenuator
- 1.4.4 Bird Wattmeter w/ 5W Element (**WMETER**) Wattmeter to be calibrated  $\pm .1W$  of Bird Wattmeter Model 43 SN242241 with Element SN242241A at **2 W CW**.
- 1.4.5 RF Signal Generator (**SG**)
- 1.4.6 AF Generator
- 1.4.7 Sinadder Linear 5 (**SINADDER**)
- 1.4.8 ASY-0700-01-TF7 Battery Eliminator (**TF1**)
- 1.4.9 220 MHz Frequency Counter (**FC**)
- 1.4.10 ASY-0700-01-TF8 Test Connector (**TF2**)
- 1.4.11 220 MHz Test Antenna (**ANT**)
- 1.4.12 Digital Multimeter (**DMM**)

1.0 SEA700 Adjustment Functions:

- 1.1 UUT RV1 RSSI Calibrate
- 1.2 UUT RV2 AGC Fine Gain Adjust (25dB Step)
- 1.3 UUT RV3 ALC Sensitivity Adjust
- 1.4 UUT RV4 TX RF Level Adjust
- 1.5 UUT RV5 Carrier Balance Adjust
- 1.6 RF PA RV6 Driver Bias Adjust
- 1.7 RF PA RV7 Final Bias Adjust
- 1.8 UUT RV8 L.O. Level Adjust
- 1.9 UUT RV9 Carrier Balance Adjust
- 1.10 UUT RV10 Opposite Sideband Balance
- 1.11 UUT C26 45.4575 MHz Adjustment
- 1.12 UUT C72 Matching Network Adjustment

2.0 Test Mode Functions:

2.1 RX Mode:

	<u>Key</u>	<u>Description</u>
2.1.1	1	Open Squelch
2.1.2	2	Carrier Squelch
2.1.3	3	AFC Lock (Set to 2.5V)
2.1.4	4	AGC Gain Lock (Set to Maximum Gain)
2.1.5	5	Set Cv to 00
2.1.6	6	Set VCXO to LOW
2.1.7	7	Set VCXO to HIGH
2.1.8	8	Decode the LTR
2.1.9	#	Function/s OFF - Switch to TX

2.2 TX Mode:

	<u>Key</u>	<u>Description</u>
2.2.1	1	TX ON, No Tone
2.2.2	2	TX ON, 1KHz Test Tone
2.2.3	3	TX ON, Pilot Tone
2.2.4	4	TX ON, 4-Tone
2.2.5	5	TX ON, 2- Tone
2.2.6	6	TX ON, Full Power Test Tone (2W CW)
2.2.7	7	Set VCXO to HIGH
2.2.8	#	Function/s OFF - Switch to RX

2.3 Test Mode Enable:

- 2.3.1 With radio power OFF.
- 2.3.2 Press and hold the "M" key and the "#" key.
- 2.3.3 Set the radio power to ON.
- 2.3.4 When the LCD displays "R" release the "M" and "#" keys.

## Radio Tests and Alignments

### 1.0 Voltage Test

#### 1.1 Radio Setup

- 1.1.1 Connect the **7.2V DC Power Supply** to **BATTERY ELIMINATOR**.
- 1.1.2 Connect the **RADIO MIC CONNECTOR** to **TF2**.
- 1.1.3 Slide **BATTERY ELIMINATOR** onto the **Radio**.
- 1.1.4 Connect the **DMM** to the **Radio**.
  - 1.1.4.1 Black lead (**GND**) to **Radio GND**.
- 1.1.5 Connect the **Radio RF Output** to the **50 Ohm 5W Load**.

#### 1.2 Equipment Setup

- 1.2.1 **Set DMM**  
**Measurement = Volts**  
**Range = Auto**

#### 1.3 Voltage Checks

- 1.3.1 Press and hold the "M" and "#" key and set **VOL. POT** to **ON**  
  
**LCD DISPLAY = SYS 1 and MODE 1 and R \_\_\_\_\_.**  
  
A **Long Tone** is heard from the **Radio**.

Connect the DMM Positive Lead (**RED**) to the following points:

	Signal Name	Location	Test Point	Limit (Volts)
1.3.2	5V cont.	UUT	<b>C96 +</b>	<u><b>4.75V to 5.25V</b></u>
1.3.3	5V RX	UUT	<b>TP8</b>	<u><b>4.75V to 5.25V</b></u>
1.3.4	5V TX	UUT	<b>TP10</b>	<u><b>&lt; 0.1V</b></u>
1.3.5	7.2V TX	UUT	<b>Q8/D</b>	<u><b>&lt; 0.1V</b></u>

- 1.3.6 Press the **UUT PTT**.

Connect the DMM Positive Lead (**RED**) to the following points:

	Signal Name	Location	Test Point	Limit (Volts)
1.3.7	5V RX	UUT	<b>TP8</b>	<u><b>&lt; 0.1V</b></u>
1.3.8	5V TX	UUT	<b>TP10</b>	<u><b>4.75V to 5.25V</b></u>
1.3.9	7.2V TX	UUT	<b>Q8/D</b>	<u><b>&gt; 6.90V</b></u>

- 1.3.10 **UUT LED1** (TX LED) is **ON**
- 1.3.11 Release the **UUT PTT** switch.

## 2.0 PA Bias Preset Adjustment

### 2.1 Radio Setup

2.1.1 Connect the **7.2V DC Power Supply** to **BATTERY ELIMINATOR**.

2.1.2 Connect the **RADIO MIC CONNECTOR** to **TF2**.

2.1.3 Slide **BATTERY ELIMINATOR** onto the **Radio**.

2.1.4 Connect the **DMM** to the **Radio**.

2.1.4.1 Black lead (**GND**) to **Radio GND**.

2.1.5 Connect the **Radio RF Output** to the **50 Ohm 5W Load**.

### 2.2 Equipment Setup

2.2.1 **None**

### 2.3 PA Bias Adjustment

2.3.1 Press and hold the "M" and "#" key and set **VOL. POT** to **ON**

**LCD DISPLAY = SYS 1 and MODE 1 and R \_\_\_\_\_.**

A **Long Tone** is heard from the **Radio**.

2.3.2 On the **RADIO** press and release the **# KEY**.

**LCD DISPLAY = SYS 1 and GRP 1 and T 0.**

2.3.3 On the **RADIO** press and release the **1 KEY**.

**LCD DISPLAY = SYS 1 and GRP 1 and T 1.**

2.3.4 Monitor the power supply **Ammeter**.

2.3.5 Adjust the **RF PA VR7** until the power supply ammeter reads **950mA** to **1000mA**.

Limit: **Ammeter = 950mA to 1000mA**

2.3.6 Adjust the **RF PA VR6** until the power supply ammeter **Increases 25mA**.

Limit: **Ammeter = 975mA to 1025mA**

2.3.7 On the **RADIO** press and release the **# KEY**.

**LCD DISPLAY = SYS 1 and GRP 1 and T 0.**

### 3.0 LIGHT SWITCH TEST

#### 3.1 Radio Setup

3.1.1 Connect the **7.2V DC Power Supply** to **BATTERY ELIMINATOR**.

3.1.2 Connect the **RADIO MIC CONNECTOR** to **TF2**.

3.1.3 Slide **BATTERY ELIMINATOR** onto the **Radio**.

3.1.4 Connect the **DMM** to the **Radio**.

3.1.4.1 Black lead (**GND**) to **Radio GND**.

3.1.5 Connect the **Radio RF Output** to the **50 Ohm 5W Load**.

#### 3.2 Equipment Setup

3.2.1 **None**

#### 3.3 LIGHT SWITCH TEST

3.3.1 Press and hold the "M" and "#" key and set **VOL. POT** to **ON**

**LCD DISPLAY = SYS 1 and MODE 1 and R\_\_\_\_\_.**

A **Long Tone** is heard from the **Radio**.

3.3.2 On the **UUT** press the **L SWITCH**.

Limit: **LCD LEDs** turn **ON**

3.3.3 On the **UUT** release the **L SWITCH**.

Limit: **LCD LEDs** stay **ON** for 5 seconds Minimum then **OFF**

## 4.0 SYNTHESIZER TEST

### 4.1 Radio Setup

4.1.1 Connect the **7.2V DC Power Supply** to **BATTERY ELIMINATOR**.

4.1.2 Connect the **RADIO MIC CONNECTOR** to **TF2**.

4.1.3 Slide **BATTERY ELIMINATOR** onto the **Radio**.

4.1.4 Connect the **DMM** to the **Radio**.

4.1.4.1 Black lead (**GND**) to **Radio GND**.

4.1.5 Connect the **Radio RF Output** to the **50 Ohm 5W Load**.

### 4.2 Equipment Setup

4.2.1 **Set DMM**  
**Measurement = Volts**  
**Range = Auto**

### 4.3 10.275 MHz Clock

4.3.1 Press and hold the "M" and "#" key and set **VOL. POT** to **ON**

**LCD DISPLAY = SYS 1 and MODE 1 and R \_\_\_\_\_.**

A **Long Tone** is heard from the **Radio**.

4.3.2 On the **RADIO** press and release the **3 KEY** and **4 KEY**.

**LCD DISPLAY = SYS 1 and MODE 1 and R GL.**

4.3.3 Connect the **COUNTER** to **UUT U1 pin 3** (VCTCXO OUTPUT).

4.3.4 Monitor **Counter** and adjust **U1** to **10.275116 MHz ±3 Hz**.

Limit: **COUNTER = 10.275113 MHz to 10.275119 MHz**

### 4.4 VCO Lock Check

4.4.1 Connect the **DVM** to **UUT U2 pin 11** (VCO Lock OUTPUT).

Limit: **DVM = 4.5V DC to 5.25V DC**

#### 4.5 VCO Control Voltage Adjustment

4.5.1 Connect the **DVM** to UUT VCO1 pin 5 (VT INPUT).

4.5.2 Monitor DVM and adjust VCO1 to 2.00V DC ±0.25V.

Limit: **DVM** = 1.75V DC to 2.25V DC

#### 4.6 VCXO Control Voltage Adjustment

4.6.1 Connect the **DVM** to UUT TP5 (VCXO CV).

4.6.2 Connect the **COUNTER** to UUT TP14 (VCXO OUTPUT).

4.6.3 Monitor the **DVM**, **COUNTER** and the **TF CR4**.

4.6.4 Adjust the UUT C26 until the **DVM** reads 2.5V DC.

Limit: **DVM** = 2.4V DC to 2.6V DC

Limit: **COUNTER** = 45455.250 KHz to 45455.750 KHz

#### 4.7 VCXO Control Voltage Tracking Check

4.7.1 Connect the **DVM** to UUT TP5 (VCXO CV).

4.7.2 Connect the **COUNTER** to UUT TP14 (VCXO OUTPUT).

4.7.3 Monitor the **DVM**, **COUNTER**.

4.7.4 On the **RADIO** press and release the 6 KEY.

NOTE: HIGH VCXO RANGE

**LCD DISPLAY** = SYS 1 and MODE 1 and R - GL .

Limit: **DVM** = 4.70V DC to 5.25V DC

Limit: **COUNTER** > 45458.800 KHz

4.7.5 On the **RADIO** press and release the 6 KEY.

NOTE: NORMAL VCXO RANGE

**LCD DISPLAY** = SYS 1 and MODE 1 and R GL .

Limit: **DVM** = 2.40V DC to 2.60V DC

Limit: **COUNTER** = 45455.250 KHz to 45455.750 KHz

4.7.6 On the **RADIO** press and release the 7 KEY.

NOTE: LOW VCXO RANGE

**LCD DISPLAY** = SYS 1 and MODE 1 and R + GL .

Limit: **DVM** = 0.00V DC to 0.25V DC

Limit: **COUNTER** < 45451.000 KHz

4.7.7 On the **RADIO** press and release the **7 KEY**.  
NOTE: NORMAL VCXO RANGE

**LCD DISPLAY = SYS 1 and GRP 1 and R GL .**

Limit: **DVM = 2.40V DC to 2.60V DC**

Limit: **COUNTER = 45455.250 KHz to 45455.750 KHz**

## 5.0 RX TEST

### 5.1 Radio Setup

- 5.1.1 Connect the **7.2V DC Power Supply** to **BATTERY ELIMINATOR**.
- 5.1.2 Connect the **RADIO MIC CONNECTOR** to **TF2**.
- 5.1.3 Slide **BATTERY ELIMINATOR** onto the **Radio**.
- 5.1.4 Connect the **DMM** to the **Radio**.
  - 5.1.4.1 Black lead (**GND**) to **Radio GND**.
- 5.1.5 Connect the **Radio RF Output** to the **SIGNAL GENERATOR**.

### 5.2 Equipment Setup

- 5.2.1 **Set DMM**
  - Measurement = Volts**
  - Range = Auto**
- 5.2.2 RF Signal Generator (**SG**):
  - RF Output = ON**
  - Frequency = 220.0025 MHz**                      **Amplitude = -70 dBM**
  - Mod Level = 63% AM**                              **Modulation = OFF**
- 5.2.3 AF Generator:
  - AUDIO FREQUENCY = 2.9 KHz**
  - AUDIO LEVEL OUT = 1.5 Vpp**
- 5.2.4 Oscilloscope (**SCOPE**)
  - Channel = CH1 (Active) Volts/Div = .2 Volts**
  - Coupling = AC**                                      **Time/Div = .5 mS**
  - BW = 20 MHz**                                      **Trigger = AUTO AC CH1 NEG**

### 5.3 RX HELICAL ALIGNMENT

5.3.1 Press and hold the "M" and "#" key and set **VOL. POT** to **ON**

**LCD DISPLAY = SYS 1 and MODE 1 and R \_\_\_\_\_ .**

A **Long Tone** is heard from the **Radio**.

5.3.2 On the **RADIO** press and release the **SYS KEY**.

**LCD DISPLAY = SYS 11 and MODE 1 and CH001 .**

5.3.3 On the **RADIO** press and release the **2 KEY** and **3 KEY** and **4 KEY**.

**LCD DISPLAY = SYS 2 and MODE 1 and R GLC.**

5.3.4 Connect the **SCOPE** to **UUT TP13** (RX IF OUTPUT).

5.3.5 Monitor the **SCOPE** and adjust **FL1** for maximum level as read on the Scope.

Limit: **SCOPE  $\geq$  .6 VPP**

### 5.4 RSSI ADJUST

5.4.1 Connect the **DVM** to **UUT TP6** (ACG FEEDBACK).

5.4.2 Monitor the **SCOPE** and adjust the **SG** for **.6 VPP** as read on the Scope.

Limit: **SCOPE = .58 Vp-p to .62 Vp-p.**

5.4.3 Monitor the **DVM** and adjust **UUT RV1** for **4.1 VDC** as read on the DVM.

Limit: **DVM = 4.00 VDC to 4.2 VDC**

## 5.5 FINE AGC ADJUST

5.5.1 Increase the **SG RF Output Level** by 25dB.

5.5.2 On the **RADIO** press and release the 4 KEY.

**LCD DISPLAY = SYS 2 and MODE 1 and R LC.**

5.5.3 Monitor the **SCOPE** and adjust RV2 for .6Vp-p as read on the SCOPE.

Limit: **SCOPE = .58 Vp-p to .62 Vp-p.**

## 5.6 RX IF LIMITING CHECK

5.6.1 Adjust the **Radio Vol Pot** for MIN LEVEL.

5.6.2 Set **SG:**

**RF Output = ON**  
Frequency = 220.0215 MHz      Amplitude = -70 dBM  
Mod Level = 63% AM              Modulation = EXT ON

5.6.3 Set **SCOPE**

**Volts/Div = .5 Volts**  
Channel = CH1 (Active)      Trigger = AUTO AC CH1 NEG  
Coupling = AC              Time/Div = .5 mS      BW = 20 MHz

5.6.4 On the **TF** press and release the 3 KEY and 4 KEY.

**LCD DISPLAY = SYS 2 and GRP 1 and R G C.**

5.6.5 Connect the **SCOPE** to TF2 (EXTERNAL SPEAKER OUTPUT).

5.6.6 Monitor the **SCOPE** and adjust the **Radio Vol Pot** for .4 VPP to .8 VPP as read on the **Scope**.

5.6.7 Connect the **SCOPE** to UUT TP13 (RX IF OUTPUT).

5.6.8 Monitor the **SCOPE** and increase SG AMPLITUDE until distortion can be heard in the 1KHz audio tone.

Limit: **SCOPE > 2.0 VPP**

## 5.7 SINAD CHECK

### 5.7.1 Set **SG**:

RF Output = ON  
Frequency = 220.0015 MHz      Amplitude = -70 dBM  
Mod Level = 63% AM              Modulation = EXT ON  
Press Store 11

### 5.7.2 Connect the **SINADDER** to **TF2** (EXTERNAL SPEAKER OUTPUT).

LIMIT: **SINAD > 27 dB**

### 5.7.3 Set **SG Amplitude = -113 dBM**

Limit: **SINAD > 12 dB**

## 5.8 10.275MHz CLOCK OSCILLATOR ADJUST

### 5.8.1 Set **SG**:

RF Output = ON  
Frequency = 220.0015 MHz      Amplitude = -70 dBM  
Mod Level = 63% AM              Modulation = EXT ON  
Press Store 11

### 5.8.2 Connect the **DMM** to **UUT U1/1** (TCXO CV).

### 5.8.3 Monitor the **DMM** and adjust **U1** (VCTCXO) for **2.50 VDC** as read on the **DMM**.

Limit: **DMM = 2.4 VDC to 2.6 VDC**

## 5.9 LOCK TEST

### 5.9.1 Set **SG**:

**RF Output = OFF**                      **RF Output = ON**  
Frequency = 220.0012 MHz              Amplitude = -113 dBm  
Mod Level = 63% AM                      Modulation = EXT ON

Limit: Radio should **Lock** on to the signal and **Open** the **SQ** in less than 1 sec. A steady **1 KHz Tone** should be Heard.

### 5.9.2 Set **SG: RECALL 13**

**RF Output = OFF**                      **RF Output = ON**  
Frequency = 220.0218 MHz              Amplitude = -113 dBm  
Mod Level = 63% AM                      Modulation = EXT ON

Limit: Radio should **Lock** on to the signal and **Open** the **SQ** in less than 1 sec. A steady **1 KHz Tone** should be Heard.

## 5.10 AGC CHECK

### 5.10.1 Set **SG**:

RF Output = ON                                      Frequency = 220.0215 MHz  
Amplitude = -113 dBm              Mod Level = 63% AM  
Modulation = EXT ON

### 5.10.2 Set **SINADDER**:

**Measurement = AC VOLTS**

5.10.3 Monitor the **SINADDER** and adjust the **Radio Vol Pot** for -10 dBm as read on the **SINADDER**.

5.10.4 Monitor the **SINADDER** and adjust the **SG AMPLITUDE** in 1 dB steps to a level of **0 dBm**.

Limit: **Amplitude Increases** < +8 dB from the level set in step 5.10.3 at any time.

### 5.10.5 Set **SG**:

**RF Output = OFF**

## 6.0 TX TEST

### 6.1 Radio Setup

- 6.1.1 Connect the **7.2V DC Power Supply** to BATTERY ELIMINATOR.
- 6.1.2 Connect the **RADIO MIC CONNECTOR** to TF2.
- 6.1.3 Slide **BATTERY ELIMINATOR** onto the Radio.
- 6.1.4 Connect the **DMM** to the Radio.
  - 6.1.4.1 Black lead (**GND**) to Radio GND.
- 6.1.5 Connect the **Radio RF Output** to the WMETER to 30 dB 5 Watt Attenuator to the SA.

### 6.2 Equipment Setup

- 6.2.1 Set **SA**:

<u>CF</u> = <u>220.0025 MHz</u>	<u>SP</u> = <u>20 KHz</u>
<u>REFLEV</u> = <u>-20 dBm</u>	<u>CF STEP</u> = <u>220.0025 MHz</u>
<u>ATTEN</u> = <u>20 dB</u>	<u>ST</u> = <u>.5 sec</u>
<u>DL</u> = <u>-56 dBm</u>	<u>BW</u> = <u>10KHz</u>

### 6.3 TX HELICAL ALIGNMENT:

- 6.3.1 Press and hold the "M" and "#" key and set **VOL. POT** to ON  
**LCD DISPLAY** = SYS 1 and MODE 1 and R .  
A Long Tone is heard from the **Radio**.
- 6.3.2 On the **RADIO** press and release the SYS KEY until the LCD reads:  
**LCD DISPLAY** = SYS 11 and GRP 1 and CH 001 .
- 6.3.3 On the **RADIO** press and release the T/A KEY.  
**LCD DISPLAY** = SYS 11 and GRP 1 and TLKARND.
- 6.3.4 On the **RADIO** press and release the 5 # # KEYS.  
**LCD DISPLAY** = SYS 1 and GRP 1 and T 0.
- 6.3.5 Connect the **SA Scope Probe** to UUT TP12 (TX LO OUTPUT).
- 6.3.6 On the **RADIO** press and release the 1 KEY

LCD DISPLAY = SYS 11 and GRP 1 and T 1.

6.3.7 Monitor the **SA** and adjust FL5 for maximum level as read on the SA.

6.3.8 On the **RADIO** press and release the # KEY.

LCD DISPLAY = SYS 11 and GRP 1 and T 0.

#### 6.4 TX LO FILTER ALIGNMENT:

- 6.4.1 On the **RADIO** press and release the **1 KEY**  
**LCD DISPLAY = SYS 11 and GRP 1 and T 1.**
- 6.4.2 Monitor the **SA** and adjust **C72** for maximum level as read on the SA.
- 6.4.3 On the **RADIO** press and release the **# KEY**.  
**LCD DISPLAY = SYS 11 and GRP 1 and T 0.**
- 6.4.4 Remove the **SA** Scope Probe from **UUT TP12** (TX LO OUTPUT).

#### 6.5 CARRIER SUPPRESSION ALIGNMENT

- 6.5.1 Set **SA**:

<b>CF</b> = <u>220.0025 MHz</u>	<b>SP</b> = <u>20 KHz</u>
<b>REFLEV</b> = <u>3 dBm</u>	<b>CF STEP</b> = <u>220.0025 MHz</u>
<b>ATTEN</b> = <u>20 dB</u>	<b>ST</b> = <u>.5 sec</u>
<b>DL</b> = <u>-56 dBm</u>	<b>BW</b> = <u>300Hz</u>

- 6.5.2 On the **RADIO** press and release the **3 KEY**  
**LCD DISPLAY = SYS 11 and GRP 1 and T 3.**
- 6.5.3 Monitor the **SA** and adjust **RV5** and **RF9** for minimum carrier as read on the SA.  
  
Limit: **Carrier  $\leq$  25dB below the Pilot**  
  
NOTE: Repeat the adjustment of RV5 and RV9 for minimum carrier.
- 6.5.4 On the **RADIO** press and release the **# KEY**.  
**LCD DISPLAY = SYS 11 and GRP 1 and T 0.**

## 6.6 OPPOSITE SIDEBAND ALIGNMENT

### 6.6.1 Set SA:

**CF** = 220.0025 MHz                      **SP** = 20 KHz  
**REFLEV** = 3 dBm                              **CF STEP** = 220.0025 MHz  
**ATTEN** = 20 dB                                **ST** = .5 sec  
**DL** = -56 dBm                                **BW** = 300Hz

### 6.6.2 On the **RADIO** press and release the **3 KEY**

**LCD DISPLAY** = SYS 11 and GRP 1 and T 3.

### 6.6.3 Monitor the SA and adjust **RV8** for minimum Opposite Sideband as read on the SA.

Limit: **Opposite Sideband**  $\leq$  **30dB below the Pilot**

### 6.6.4 On the **RADIO** press and release the **# KEY**.

**LCD DISPLAY** = SYS 11 and GRP 1 and T 0.

## 6.7 FOUR TONE ALIGNMENT

### 6.7.1 Set SA:

**CF** = 220.0025 MHz                      **SP** = 20 KHz  
**REFLEV** = 3 dBm                              **CF STEP** = 220.0025 MHz  
**ATTEN** = 20 dB                                **ST** = .5 sec  
**DL** = -56 dBm                                **BW** = 300Hz

### 6.7.2 On the **RADIO** press and release the **4 KEY**

**LCD DISPLAY** = SYS 11 and GRP 1 and T 4.

### 6.7.3 Monitor the SA and adjust **RV4** so that the top of the **Two High Tones** are **10dB Below** the **Reference Level** read on the SA.

### 6.7.4 Monitor the SA and adjust **RF PA RV6** for minimum **NOISE** as read on the SA.

### 6.7.5 Monitor the SA and adjust **RF PA RV7** for minimum **NOISE** as read on the SA.

### 6.7.6 Repeat steps 6.7.4 and 6.7.5 until minimum **NOISE** is attained.

Limit: **NOISE BELL**  $\leq$  **LIMIT LINE**

Limit: **Current**  $\leq$  **1.25A**

### 6.7.7 On the **RADIO** press and release the **# KEY**.

**LCD DISPLAY** = SYS 11 and GRP 1 and T 0.

## 6.8 TX POWER ALIGNMENT

### 6.8.1 Set SA:

**CF** = 220.0025 MHz                      **SP** = 20 KHz  
**REFLEV** = 3 dBm                              **CF STEP** = 220.0025 MHz  
**ATTEN** = 20 dB                                **ST** = .5 sec  
**DL** = -56 dBm                                **BW** = 300Hz

### 6.8.2 On the RADIO press and release the 6 KEY

**LCD DISPLAY** = SYS 11 and GRP 1 and T 6.

### 6.8.3 Monitor the WMETER and adjust RV4 for 2W CW as read on the wattmeter.

Limit: **WMETER** = 1.8W CW ± .2W

### 6.8.4 On the RADIO press and release the # KEY.

**LCD DISPLAY** = SYS 11 and GRP 1 and T 0.

## 6.9 ALC ALIGNMENT

### 6.9.1 Adjust RV3 Fully CCW.

## 6.10 TX FREQUENCY ALIGNMENT

### 6.10.1 Connect the RF Output from the 50 Ω Load to the FC.

### 6.10.2 On the RADIO press and release the 6 KEY

**LCD DISPLAY** = SYS 11 and GRP 1 and T 6.

### 6.10.3 Monitor the FC and adjust UUT U1 for 220.0025 MHz as read on the FC.

Limit: **FC** = 220.0025 MHz ± 50 Hz

### 6.10.4 On the RADIO press and release the # KEY.

**LCD DISPLAY** = SYS 11 and GRP 1 and T 0.

## 7. END OF TEST

### 7.1 Set UUT VOL. POT to OFF.

### 7.2 Disconnect the TF2 from the UUT J1.

### 7.3 Disconnect the LOAD from the ANT CONNECTOR.

### 7.4 Remove the TF8 from the UUT.

## 12. FIELD TESTING AND ALIGNMENT

### 12.1 Introduction.

This section provides abbreviated test procedures for quickly verifying basic radio performance plus complete procedures for setting all alignment points in the radio. All alignment points are associated with the RF board assembly (ASY-0700-01) and the RF PA. The digital/audio board assembly (ASY-0700-02) contains no manual adjustment points.

Avoid making unnecessary adjustments. The frequency and RF power output of the SEA700 is carefully calibrated at the SEA factory. After the SEA700 is properly programmed to receive one or more active local repeater systems, its receive and transmit frequency converges to the frequency of the selected repeater as trunking data turnoff codes are received from the repeater. Frequency accuracy of approximately  $\pm 0.25$  ppm ( $\pm 60$  Hz) is achieved. In other words, the radio will quickly adjust its own frequency to work reliably with the selected system as radio ambient temperature varies or crystal aging occurs. This greatly reduces the need for routine manual frequency calibration. See Section 7.4 for more details.

### 12.2 Test Mode Operation.

The SEA700 provides built-in aids for field testing. Two test systems are preprogrammed at the SEA factory (but can be altered or erased using the PIU700). After test mode is entered, systems 11 (Test Sys 1) and 12 (Test Sys 2) become selectable via the SYS button in addition to regular systems 1 through 10. Several test conditions are selectable via the DTMF keypad for transmitter and receiver testing.

**Entering Test Mode.** Test Mode can be entered only during radio power-up. Press and hold both the side M (monitor) and front # keys or jumper together pins 4 and 5 of the accessory connector as the radio is turned on. After display indicates radio serial number it will display R. As selected by the # key, R indicates receive tests and T indicates transmitter tests. Early models require system 1 to be activated (programmed) before test systems will operate.

#### **Test Mode exceptions to normal operation.**

- a. Systems 11 (Test Sys 1) and 12 (Test Sys 2) are added to regular systems, if any.
- a. LCD is used to indicate status of R or T tests.
- b. Transmitter time-out-timer is disabled.
- b. Transmitter shutdown due to antenna (ALC) fault is disabled.
- c. Synthesizer unlock detection is disabled.
- d. DSP fault detection is disabled.
- e. DTMF keypad is used to select test functions.
- f. Scan, search, auto-login and interconnect operations may not function normally.

**Factory settings for Test Systems.** System 11: Conventional, Area = 0, Home = 1. Mode 1 name = "CHNL001", RX ID = 1, TX ID = 1, talkaround and call indicator enabled. Repeater 1 = channel 001 (221.0025 MHz TX repeat, 220.0025 MHz receive and transmit talkaround.) All other settings are default. System 12: same as System 11, except Mode 1 name = "CHNL200" and Repeater 1 = channel 200 (221.9975 MHz TX repeat, 220.9975 MHz receive and transmit talkaround.) These systems can be accessed for programming by pressing <Shift F3> in the data manager edit system programming screen.

**Available Test Functions.** The # key cancels active tests and also toggles between receive (R) tests and transmit (T) tests. Several receive test selections can be used in combination. Selection of any transmit test simultaneously keys the transmitter.

**a. Receive test functions:**

Key/Test Number	LCD Indication	Test Function
1	O	Open Squelch
2	C	Carrier Squelch
3	L	AFC Lock (Hold AFC constant at 2.5V)
4	G	AGC Gain Lock (Hold at maximum RF/IF Gain)
5	0 (zero)	Reset frequency tracking memory of all systems to zero.
6	-	Check VCXO frequency low limit
7	+	Check VCXO frequency high limit
8	See below	Received trunking data decode
#	R or T 0	Cancel current test(s) and/or Switch to TX tests

Activation of Test R5 should be avoided except just prior to frequency calibration test.

Tests R6 and R7 force the 45.4555 MHz VCXO frequency to its end limits. Normal signal reception will be interrupted during these tests.

Test R8 is provided for convenience only. SEA does not guarantee its performance. Select Test R8 after pushing # key which initially gives no LCD indication. After receiving a programmed ID in the selected system, information from the last received trunking data word will be displayed indefinitely. The format is xxyyzzz where xx = GOTO, yy = HOME, and zzz = received ID. FREE channel is not displayed.

**b. Transmit test functions.**

Key Number	LCD Indication	Description
1	T 1	Tx on; no modulator audio, suppressed carrier only
2	T 2	Tx on; pilot tone, trunk data and 1KHz test tone
3	T 3	Tx on; pilot tone and trunk data only
4	T 4	Tx on; pilot, trunking data, 500 Hz and 2400 Hz tones
5	T 5	Tx on; 500 and 2400 Hz tones only
6	T 6	Tx on; Full power carrier (2W CW at chnl center freq.)
#	T 0 or R	Cancel current test and/or Switch to RX tests

**12.3 Test Equipment**

**12.4 Receiver Test Modulation**

-SEA700 Adjustment Points  
Basic Performance Check

- Radio Tests
  - DC Voltage Test
  - PA Bias Preset
  - Light Switch Test
  - Synthesizer Test