

ENGINEERING STATEMENT

For Certification of

TRISQUARE COMMUNICATIONS

Model No. GMRS480
FCC ID: 09GGMRS480

I am an Electronics Engineer, a principal in the firm of Hyak Laboratories, Inc., Springfield, Virginia. My education and experience are a matter of record with the Federal Communications Commission.

Hyak Laboratories, Inc. has been authorized by Trisquare Communications to make certification measurements on the GMRS480 transceiver. These tests were made by me or under my supervision in our Springfield laboratory.

Test data and documentation required by the FCC for certification are included in this report. The data verifies that the above mentioned transceiver meets FCC requirements and certification is requested.

Rowland S. Johnson

Dated: May 7, 2001

A. INTRODUCTION

The following data are submitted in connection with this request for type acceptance of the GMRS480 transceiver in accordance

with Part 2, Subpart J of the FCC Rules.

The GMRS480 is a hand-held, battery operated, UHF, frequency modulated, 2 W transceiver intended for voice communications applications in the 462.5500 - 462.7250 MHz band under Part 95 in the GMRS service.

B. GENERAL INFORMATION REQUIRED FOR TYPE ACCEPTANCE
(Paragraph 2.983 of the Rules)

1. Name of applicant: Trisquare Communications
2. Identification of equipment: FCC ID: 09GGMRS480
 - a. The equipment identification label is submitted as a separate exhibit.
 - b. Photographs of the equipment are submitted as separate exhibits.
3. Quantity production is planned.
4. Technical description:
 - a. 16k0F3E emission
 - b. Frequency range: 462.5500-462.7250 MHz.
 - c. Operating power of transmitter is fixed at the factory at 2 watts conducted.
 - d. Maximum power permitted under FCC Part 95 (interstitial) is 5 watts ERP. The GMRS480 fully complied with that power limitation.
 - d. The dc voltage and dc currents at final amplifier:

Collector voltage: 5.9 Vdc
Collector current: 0.84 A
 - f. Function of each active semiconductor device:
See Appendix 1.
 - g. Complete circuit diagram is submitted as a separate exhibit.
 - h. A draft instruction book is submitted as a separate exhibit.
 - i. The transmitter tune-up procedure is submitted as a separate exhibit.

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B. GENERAL INFORMATION (continued)

- j. A description of circuits for stabilizing frequency is included in Appendix 2.
- k. A description of circuits and devices employed for suppression of spurious radiation and for limiting modulation is included in Appendix 2.
- l. Not applicable.

5. Data for 2.985 through 2.997 follow this section.

C. RF POWER OUTPUT (Paragraph 2.985(a) of the Rules)

1. Conducted:

RF power output at the SMA connector was measured with a Bird 4421 RF power meter and a Narda 765-20 attenuator as a 50 ohm dummy load. Maximum power was 2.0 watts.

2. ERP(d) by substitution, 1.2 W.

D. MODULATION CHARACTERISTICS

1. A curve showing frequency response of the transmitter is shown in Figure 1. Reference level was audio signal output from a Boonton 8220 modulation meter with one kHz deviation. Audio output was measured with an Audio Precision System One TRMS voltmeter and tracking generator.

2. Modulation limiting curves are shown in Figure 2, using a Boonton 8220 modulation meter. Signal level was established with an Audio Precision System One. The curves show compliance with paragraphs 2.987(b) and 95.633(b).

3. Figure 3 is a graph of the post-limiter low pass filter which meets the requirements of paragraph 95.633(b) in providing a roll-off of $60\log f/3$ dB where f is audio frequency in kHz. Measurements were made following EIA RS-152B with an Audio Precision System One on the Boonton 8220 modulation meter audio output.

4. Occupied Bandwidth (Paragraphs 2.989(c), 90.209(b)(4), and 95.629(a) of the Rules)

Figure 4 is a plot of the sideband envelope of the transmitter output taken with a Tektronix 494P spectrum analyzer. Modulation corresponded to conditions of 2.989(c)(1) and consisted of 2500 Hz.

C. MODULATION CHARACTERISTICS (continued)

tone at an input level 16 dB greater than that necessary to produce 50% modulation at 2462 Hz, the frequency of maximum response. Measured modulation under these conditions was 4.2 kHz.

The plot is within the limits imposed by Paragraph 90.211(h) for frequency modulation. The horizontal scale (frequency) is 10 kHz per division and the vertical scale (amplitude) is a logarithmic presentation equal to 10 dB per division.

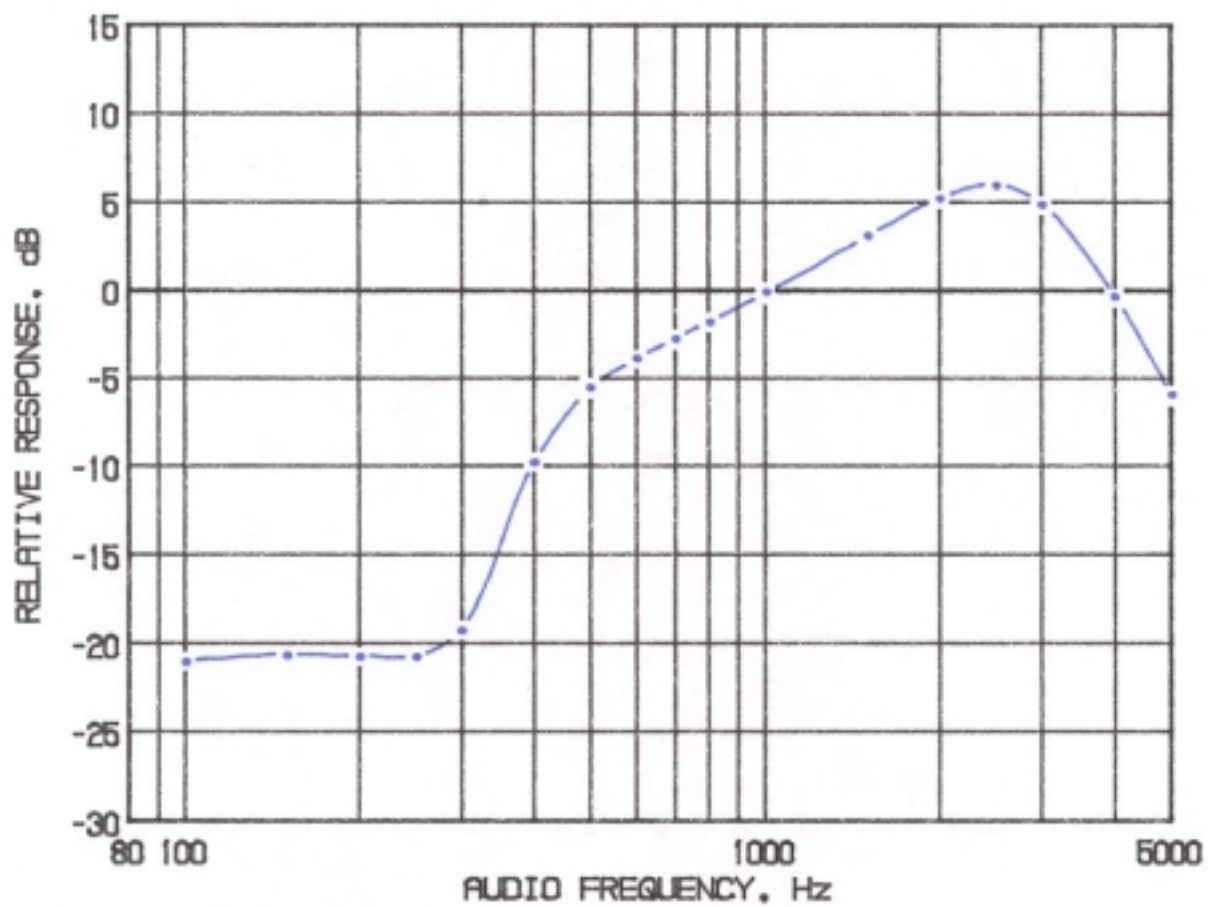
5. Emission Designator Calculation:

$$(2D + 2F) \quad 2 \times 5.0 + 2 \times 3.0 = 16k0F3E$$

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FIGURE 1

MODULATION FREQUENCY RESPONSE



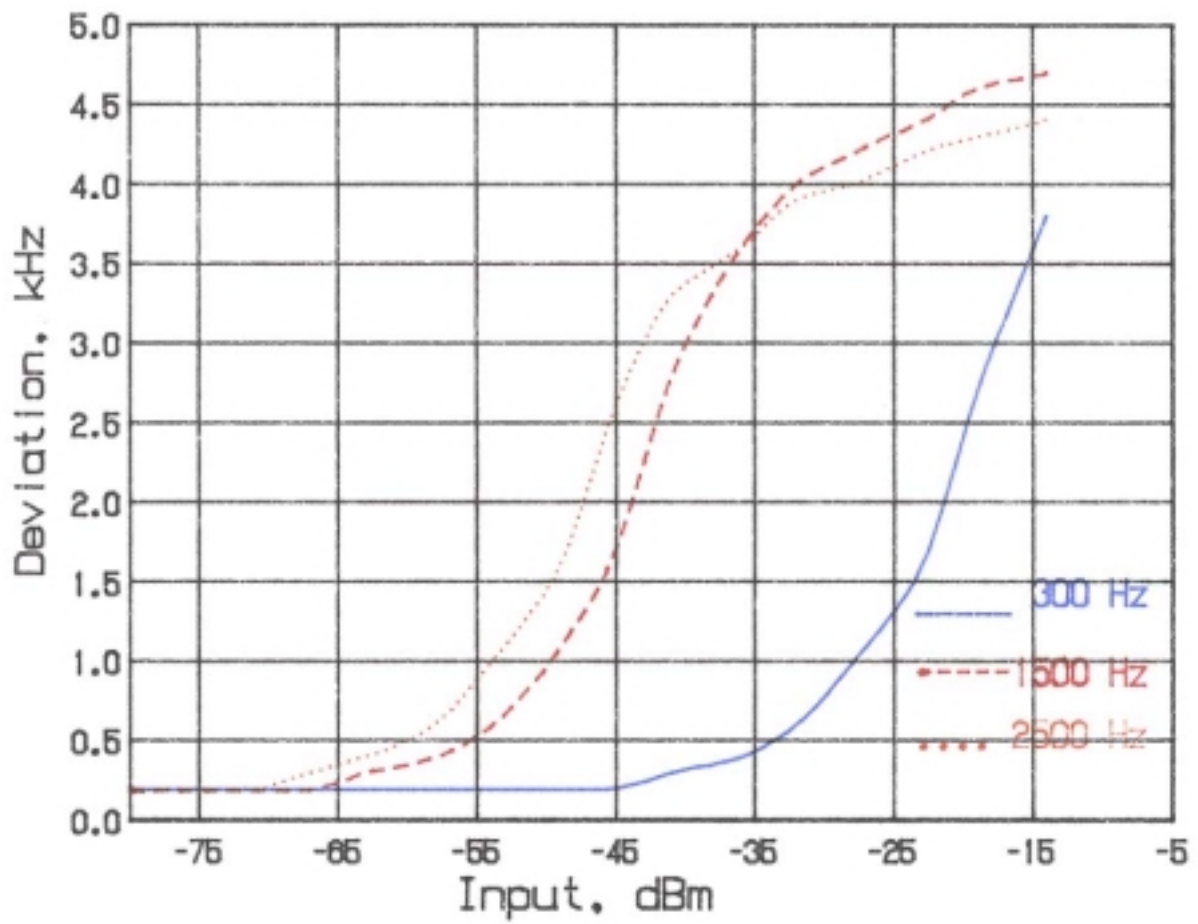
MODULATION FREQUENCY RESPONSE
FCC ID: O9GGMRS480

FIGURE 1

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FIGURE 2

AUDIO LIMITER CHARACTERISTICS

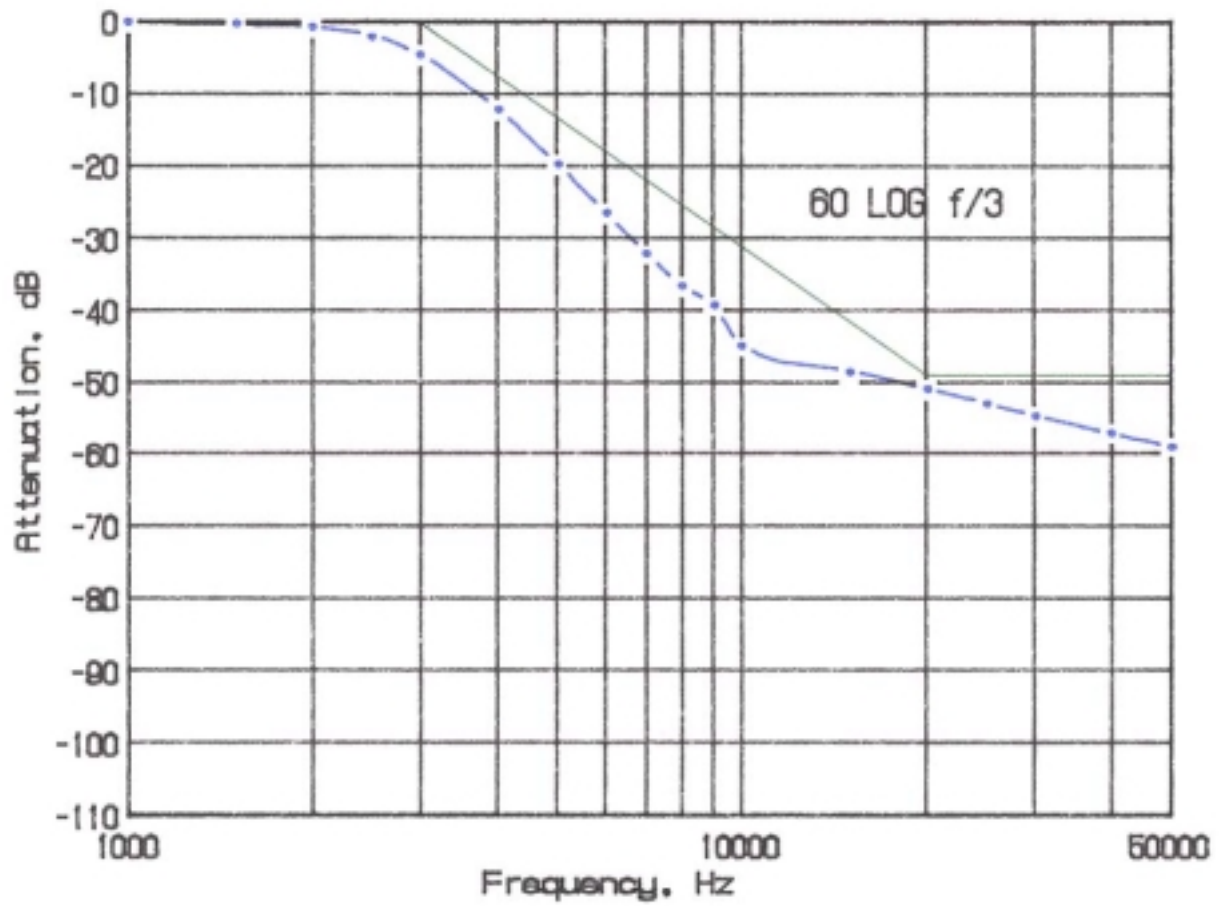


AUDIO LIMITER CHARACTERISTICS
FCC ID: 09GGMRS480

FIGURE 2
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FIGURE 3

AUDIO LOW PASS FILTER RESPONSE



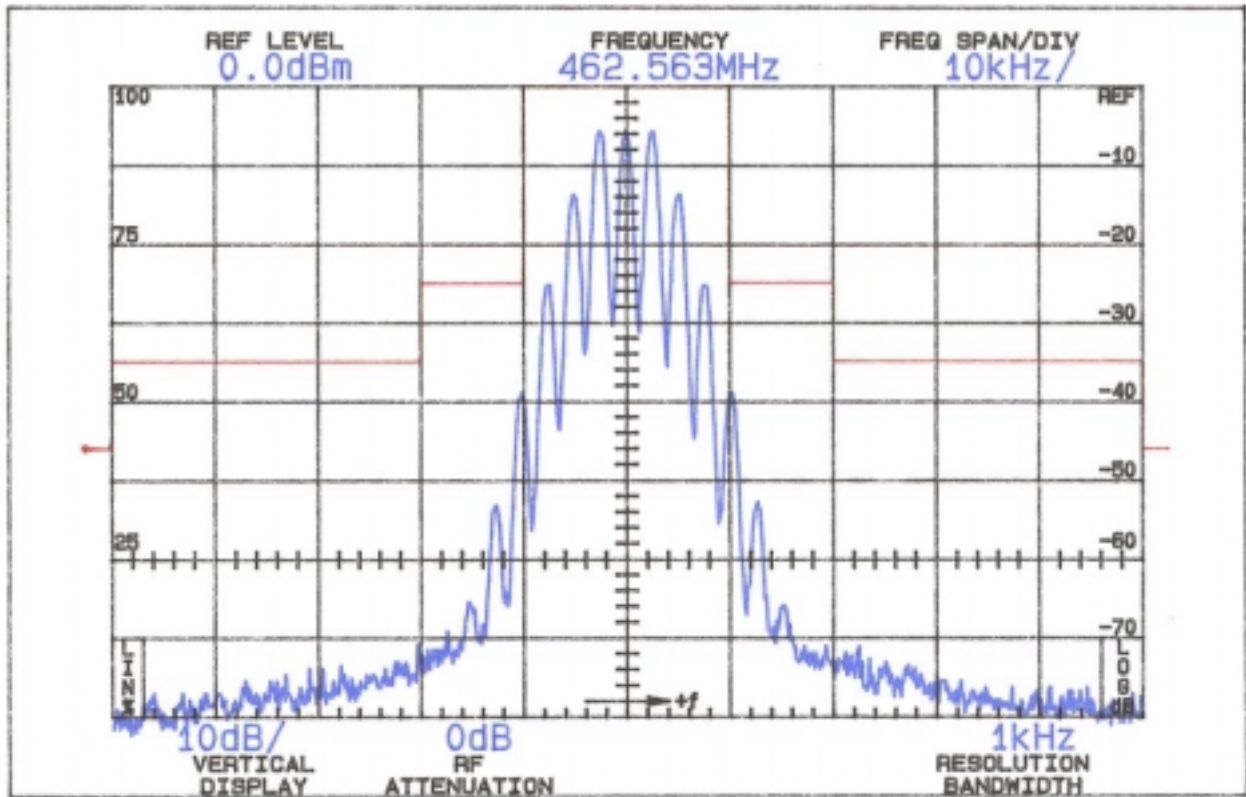
AUDIO LOW PASS FILTER RESPONSE
FCC ID: 09GGMRS480

FIGURE 3

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FIGURE 4

OCCUPIED BANDWIDTH



ATTENUATION IN dB BELOW
MEAN OUTPUT POWER
Required

On any frequency more than 50%
up to and including 100% of the 25
authorized bandwidth, 20 kHz
(10-20 kHz)

On any frequency more than 100%,
up to and including 250% of the 35
authorized bandwidth (20-50 kHz)

On any frequency removed from
the assigned frequency by more $43 + 10 \log P = 46$
than 250% of the authorized (P = 2.0W)
bandwidth (over 50 kHz)

OCCUPIED BANDWIDTH
FCC ID: 09GGMRS480

FIGURE 4

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E. SPURIOUS EMISSIONS AT THE ANTENNA TERMINALS
(Paragraph 2.991 of the Rules)

The GMRS480 transmitter was tested for spurious emissions at the antenna terminals while the equipment was modulated with a 2500 Hz signal, 16 dB above minimum input signal for 50% (2.5 kHz deviation)

modulation at 2462 Hz, the frequency of highest sensitivity.

Measurements were made with Tektronix 494P spectrum analyzer coupled to the transmitter output terminal through Narda 765-20 microwave power attenuator.

During the tests, the transmitter was terminated in the 50 ohm attenuator. Power was monitored on a Bird 43 Thru-Line wattmeter; dc supply was 6.0 volts throughout the tests.

Spurious emissions were measured throughout the RF spectrum from 12.8 MHz (lowest frequency generated in the transmitter) to 4.7 GHz. Any emissions that were between the required attenuation and the noise floor of the spectrum analyzer were recorded. Data are shown in Table 1.

TABLE 1

TRANSMITTER CONDUCTED SPURIOUS
462.5625 MHz, 6.0 Vdc, 2.0 W

<u>Spurious Frequency</u> <u>MHz</u>	<u>dB Below</u> <u>Carrier Reference</u>
925.126	71
1387.689	80
1850.252	96
2312.815	>100
2775.378	>100
3237.941	>100
3700.504	>100
4163.067	>100
4625.630	>100
Required: $43+10\log(P)$	46

All other emissions from 12.8 MHz to 4.7 GHz were 20 dB or more below FCC limit.

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F. DESCRIPTION OF MEASUREMENT FACILITIES

A description of the Hyak Laboratories' radiation test facility is a matter of record with the FCC. The facility was approved for radiation measurements from 25 to 2000WX MHz on October 1, 1976 and is currently listed as an acceptable site.

G. MEASUREMENTS OF SPURIOUS RADIATION

Measurement of radiated spurious emissions from the GMRS480 were made by substitution with a Tektronix 494P spectrum analyzer

using Singer DM-105A calibrated test antennae for the measurements to 1 GHz, Polarad CA-L, CA-S, CA-M and/or EMCO 3115. The transmitter and dummy load were located in an open field 3 meters from the test antenna. Supply voltage was a power supply with a terminal voltage under load of 6 Vdc. Output power was 2.0 watts (conducted) at the 462.5625 MHz operating frequency. The transmitter and test antennae were arranged to maximize pickup. Both vertical and horizontal test antenna polarization were employed.

TABLE 2

TRANSMITTER CABINET RADIATED SPURIOUS
462.5625 MHz, 6.0 Vdc, 1.2 watts ERP (dipole)

<u>Frequency</u> <u>MHz</u>	<u>dB Below</u> <u>Carrier</u> <u>Reference</u> ¹
462.563	0
925.127	48
1387.688	49
3237.932	56
3700.496	55

$$\text{Required: } 43 + 10\text{Log}(1.2) = 44$$

¹Worst-case polarization, H-Horizontal, V-Vertical.

All other spurious from 12.8 MHz to 4.7 GHz were 20 dB or more below FCC limit.

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H. FREQUENCY STABILITY (Paragraph 2.995(a)(2) and 95.621(b) of the Rules)

Measurement of frequency stability versus temperature was made at temperatures from -30°C to +50°C. At each temperature, the unit was exposed to test chamber ambient a minimum of 60 minutes after indicated chamber temperature ambient had stabilized to within $\pm 2^\circ$ of the desired test temperature. Following the 1 hour soak at each temperature, the unit was turned on, keyed and frequency measured within 2 minutes. Test temperature was sequenced in the order shown in Table 3, starting with -30°C.

A Thermotron S1.2 temperature chamber was used. Temperature was monitored with a Keithley 871 digital temperature probe. The transmitter output stage was terminated in a dummy load. Primary

supply was 6.0 volts. Frequency was measured with a HP 5385A digital frequency counter connected to the transmitter through a power attenuator. Measurements were made at 462.5625 MHz. No transient keying effects were observed.

TABLE 3

462.5625 MHz, 6.0 V Nominal, 2.0 watts

<u>Temperature, °C</u>	<u>Output_Frequency, _MHz</u>	<u>p.p.m.</u>
-29.6	462.561368	-2.4
-20.0	462.562533	0.1
- 9.9	462.563095	1.3
0.0	462.563117	1.3
10.2	462.563010	1.1
20.0	462.562841	0.7
29.7	462.562508	0.0
39.9	462.562408	-0.2
50.2	462.562521	0.0

Maximum frequency error: 462.561368
462.562500

- .001132 MHz

FCC Rule 95.621(b) specifies .0005% or a maximum of $\pm .002313$ MHz, which corresponds to:

High Limit 462.564813 MHz
Low Limit 462.560187 MHz

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I. FREQUENCY STABILITY AS A FUNCTION OF SUPPLY VOLTAGE
(Paragraph 2.995(d)(2) of the Rules)

Oscillator frequency as a function of power supply voltage was measured with a HP 5385A digital frequency counter as supply voltage provided by an HP 6264B variable dc power supply was varied from $\pm 15\%$ above the nominal 6.0 volt rating to below the battery end point. A Keithley 197 digital voltmeter was used to measure supply voltage at transmitter primary input terminals. Measurements were made at 20 °C ambient.

TABLE 4

462.5625 MHz, 20°C, 6.0 V Nominal, 2.0 watts

<u>%</u>	<u>Supply_Voltage</u>	<u>Output_Frequency,_MHz</u>	<u>p.p.m.</u>
115	6.9	462.562972	1.0
110	6.6	462.562926	0.9
105	6.3	462.562884	0.8
100	6.0	462.562841	0.7
95	5.7	462.562801	0.7
90	5.4	462.562768	0.6
85	5.1	462.562744	0.5
*	4.8	462.562623	0.3

Maximum frequency error: 462.562972
462.562500

*MFR rated battery endpoint. + .000472 MHz

FCC Rule 95.621(b) specifies .0005% or a maximum of ± 0.002313 MHz, corresponding to:

High Limit 462.564813 MHz
Low Limit 462.560187 MHz

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FUNCTION OF DEVICES

Designator	Description	Function
U300	Dual PLL Synthesizer	Frequency synthesizing
U30	3V Regulator	3V Regulator Circuit
U150 A/C/D	Operational Amplifier	CTCSS low pass (250Hz) filter
U150-B	Operational Amplifier	Receive high pass (300Hz) audio filter
U200-C	Operational Amplifier	Transmit high pass (300Hz) audio filter / mic amp
U200-B	Operational Amplifier	Transmit limiter amp
U200-A	Operational Amplifier	Transmit low pass (3.5Khz) audio filter
U200-D	Operational Amplifier	Receive high pass (300Hz) audio filter
U160	Audio Amplifier	Final stage audio amplifier for 200mW output &

U130	Narrowband FM IF	low pass (3Khz) audio filter
U400	8 Bit Microcontroller	2 nd IF amplifier, 2 nd LO mixing, audio detector
D100	PIN Diode	Transmit/Receive control, key decode, power control
D51	PIN Diode	Transmit/Receive antenna switch
D300	Varactor Diode	Transmit/Receive band switch
D400	General Purpose Diodes	TCXO compensation circuit
D50	Varactor Diode	TCXO compensation circuit
D200	PIN Diode	VCO tuning
D232	PIN Diode	Transmit/Receive antenna switch
D233	PIN Diode	Transmit audio limiter
Q100	Bias Transistor	Transmit audio limiter
Q50/Q51	RF Transistor	Transmit/Receive antenna switch
Q52	Bias Transistor	VCO – fundamental transmit and LO
Q203	RF Power Transistor	Receive/Transmit band switch for VCO
Q200	RF Power Transistor	PA final stage amplifier – class A
Q201	RF Transistor	PA 3 rd stage amplifier – class C
Q202	RF Transistor	PA 2 nd stage amplifier – class A
		PA 1 st stage amplifier – class A

APPENDIX 2

CIRCUITS AND DEVICES TO STABILIZE FREQUENCY, SUPPRESS SPURIOUS EMISSIONS AND LIMIT MODULATION

FREQUENCY DETERMINING CIRCUITS

The fundamental frequency for both the transmitter and the receiver local oscillators are controlled by a phase lock loop (PLL) circuit U300 (Toshiba TB31202). The frequency of operation of the voltage controlled oscillator (VCO), composed of Q50 and Q51 operating in cascode, is phase locked to a voltage controlled crystal reference (VCXO) operating at 10.475 MHz (X300). Compensation for temperature variations on the crystal reference is accomplished by measuring the ambient temperature through an analog to digital converter (ADC) circuit. Compensation for voltage variations on the crystal reference is accomplished through a supply voltage regulator. The micro-controller (U400) then converts these measurements to a correction voltage output through a PWM to maintain the frequency of the VCXO within the +/-5 ppm requirement.

The VCO is locked to the fundamental of the transmit signal in the transmit mode and is locked to the receive 1st LO (Fundamental channel frequency minus 21.4 MHz) in the receive mode. The crystal reference frequency is fed through a doubler circuit to generate the 2nd LO of 20.950 MHz.

TRANSMITTER CIRCUITS

The transmitter amplifies the 0 dBm signal from the VCO to approximately 33dBm that is fed to the antenna. The transmitter is a four stage amplifier composed of Q200, Q201, Q202, and Q203. The first two stages are operated class A, the driver stage as class C, and the final is operated class A. The fundamental transmit signal is fed through an elliptical low pass filter (5-pole, 2 zero) in order to suppress the harmonics to below -60 dBc. The desired frequency modulation of the carrier is accomplished by modulating the current in the VCO directly with the microphone audio signal. The microphone audio is conditioned with a three-pole high pass filter at 300 Hz (U200-C), a hard clipper circuit (U200-B) to limit maximum deviation to +/- 2.5 kHz and a three-pole low pass or splatter filter at 2.8 kHz (U200-A). The low pass filter insures that the occupied bandwidth of the FM modulated signal meets FCC requirements under all input conditions.

RECEIVER CIRCUITS

The received signal from the antenna is band limited to 600 Mhz by the transmitter harmonic filter. The desired signal is fed to a low noise amplifier (LNA – Q101) centered from 460 to 470 MHz that provides approximately 15 dB of gain. The output of the LNA is filtered with a SAW filter (SF1) with passband of 460 to 470 MHz and stopband attenuation of 50 dB. The filtered receive signal is one input to the 1st mixer, the other mixer input (1st LO) is the output of the VCO at the desired channel frequency minus 21.4 MHz. The output of the mixer is tuned to the 1st IF of 21.4 MHz. The 1st IF is transformer coupled for impedance matching to a crystal filter centered at 21.4 MHz with a bandwidth of 15 kHz. The filtered 1st IF is then amplified by Q103 and fed to the 2nd mixer input of the multi-function receiver IC (U130). The 2nd LO (20.950 MHz) is generated by frequency doubling the output of the 10.475 MHz VCXO that is the reference frequency for the PLL. The 2nd mixer output of 450 kHz is filtered through a 4 section ceramic filter that in combination with the 21.4 MHz crystal filter provides approximately 55 dB of adjacent channel attenuation. The 450 kHz 2nd IF is then amplified, limited and fed to a quadrature detector for FM demodulation. The resulting audio output signal is bandpass filtered from 300 to 3 kHz (U200-D, U150-B) and amplified to provide 200 mW of audio power (U160) which differentially drives the 32 ohm speaker. A squelch circuit is provided (U130 pins 10 through 14) to mute the receiver noise under low signal conditions. The squelch circuit amplifies and detects noise in a narrow bandwidth at approximately 5 kHz. When the detected noise exceeds a threshold set to trigger at approximately 12 dB SINAD receive signal strength, the audio output is muted.

TRANSMIT/RECEIVE SWITCH

When the radio is in the transmit mode, pin diode switches D200 and D100 are both turned on (representing less than 0.7 ohms). D200 allows the transmit signal to pass to the antenna and D100 shorts one leg of a T matching network (L100, L101 and C100) to ground in the receive path. This results in a parallel tuned circuit high impedance being presented to the transmit signal so that the receive path does not load the transmit signal. In the receive mode, both D200 and D100 are off, resulting in the antenna signal being coupled into the receive LNA through the 50 ohm T matching network and the unwanted load of the transmit final amplifier is reduced to less than 1 pF by D200.

RADIO CONTROL CIRCUIT

A microprocessor (U400) is used to control the transceiver. User stimuli is provided through a tack switch for PTT (push to talk), along with the keypad for channel selection, channel monitor, and page. Pressing the PTT switch instructs U400 to switch to the transmit mode. This is accomplished by loading the proper channel counter information through a 3-wire serial link to the PLL IC (U300), turning on power to the PLL and VCO, microphone and transmit audio circuits and the transmit RF amplifiers. Pressing the channel Up/Down buttons instructs U400 to increment or decrement respectively the channel frequency by one channel from the channel previously selected.

In receive mode the microcontroller periodically switches on the VCO and receiver power and checks for a valid received signal by monitoring the squelch circuit output. If a valid signal is present, the audio output is turned on and receive power is maintained for the duration of the valid signal. If the valid signal is removed or no valid signal was present, the microcontroller removes power from the VCO and receiver, waits for approximately 100 ms and then checks again. This periodic cycling of the power to the receiver circuits results in a much longer battery life vs. leaving power on continuously. The total period of the cycling is selected such that the worst case delay in 'seeing' a valid receive signal is not disruptive to normal two-way voice communications.

CIRCUITS AND DEVICES TO
STABILIZE FREQUENCY, etc.
FCC ID: 09GGMRS480

APPENDIX 2