ENGINEERING STATEMENT

For Type Certification of

SHAKESPEARE COMPANY

Model No: SE700

FCC ID: I40SE700

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 Shakespeare Company to make type certification measurements on the SE700 transceiver. These tests made by me or under my supervision in our Springfield laboratory.

Test data required by the FCC for type certification are included in this report. It is submitted that the above mentioned transceiver meets FCC requirements and type Certification is requested.

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Rowland S. Johnson

Dated: October 7, 1999

A. INTRODUCTION

The following data are submitted in connection with this request for type certification of the SE700 transceiver in accordance with Part 2, Subpart J of the FCC Rules.

The SE700 is a portable, 1 or 5 watt, VHF, frequency modulated transmitter/receiver combination intended for applications in the 156-163 MHz band.

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

1. Name of applicant: Shakespeare Company

2. Identification of equipment: FCC ID: I40SE700

   a. The equipment identification label is submitted as a separate exhibit.
   b. Photographs of the equipment are submitted as a separate exhibit.

3. Quantity production is planned.

4. Technical description:

   a. 16k0F3E emission
      Frequency range: 156-162.6 MHz.
   b. Operating power of transmitter is fixed at the factory at 5 watts, with provisions for reduction to one watt.
   d. Maximum power permitted under Part 80 of the FCC Rules is 25 watts, with capability to reduce, readily, to one watt maximum. The SE700 meets both these requirements.
   e. The dc voltage and dc currents at final amplifier:

      Collector voltage: 6.4 Vdc
      Collector current: 1.1 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.
   j. A description of circuits for stabilizing frequency is included in Appendix 2.

B. GENERAL INFORMATION (continued)

k. A description of circuits and devices employed for suppression of spurious radiation and for limiting modulation is included in Appendix 3.

l. Not applicable.

5. Data for 2.985 through 2.997 follow this section.

6. The equipment identification label is submitted as a separate exhibit.

7. Photographs of the equipment are submitted as separate exhibits.

8. RF Power Output (Paragraph 2.987(a) of the Rules)

RF power output was measured with a Bird 4421 RF power meter and a Narda 765-20 power attenuator as a 50-ohm dummy load. (The transmitter was tuned by the factory according to the procedure of Appendix 4.) A power output of 5.2 watts was measured on Channel 16 with a supply voltage of 6.5 volts at 68^{o}F ambient temperature, and in the lower power position, 1.2 watts.

Automatic power reduction to 1 nominal watt on Channels 13 and 67 was confirmed. A manual over-ride is provided.

C. 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 a 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 a Audio Precision System One TRMS voltmeter. The curves show compliance with paragraphs 2.987(b).

3. Figure 3 is a graph of the post-limiter low pass filter which meets the requirements of paragraph 80.211(e) in providing a roll-off of 60Logf/3 dB where f is audio frequency in kHz. Measurements were made following EIA RS-152B with an Audio Precision System One tracking generator and selective voltmeter on the Boonton 8220

C. MODULATION CHARACTERISTICS (continued)

modulation meter audio output.

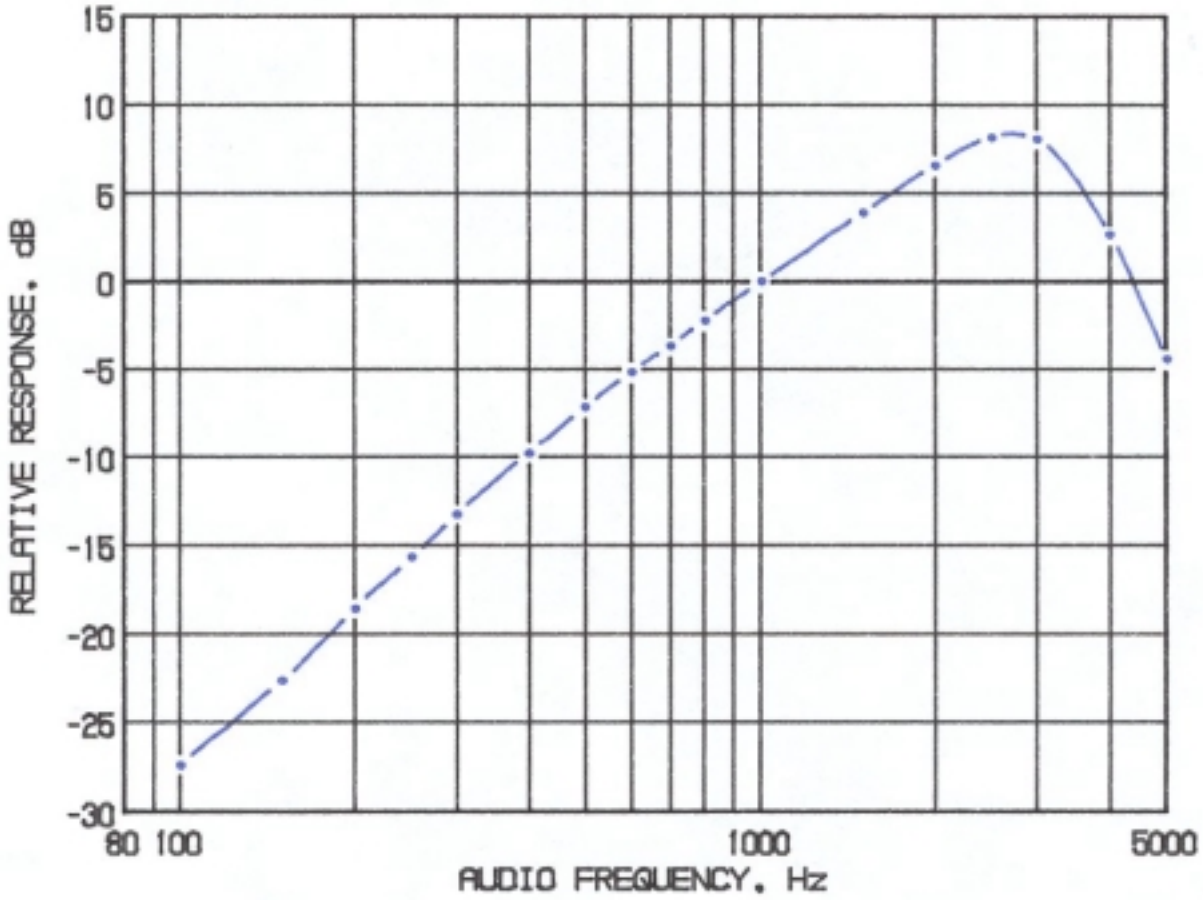
4. Occupied Bandwidth

(Paragraphs 2.989(c), and 80.211(f) of the Rules) Figures 4a and 4b are plots of the sideband envelope of the transmitter taken from the display unit of a Tektronix 494P spectrum analyzer. Modulation corresponded to conditions of 2.989(1) and consisted of 2500 Hz tone at an input level 16 dB greater than that necessary to produce 50% modulation at 2996 Hz, the frequency of maximum response. Measured modulation under these conditions was 4.2 kHz.

The plots are within the limits imposed by Part 80 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.

FIGURE 1

MODULATION FREQUENCY RESPONSE

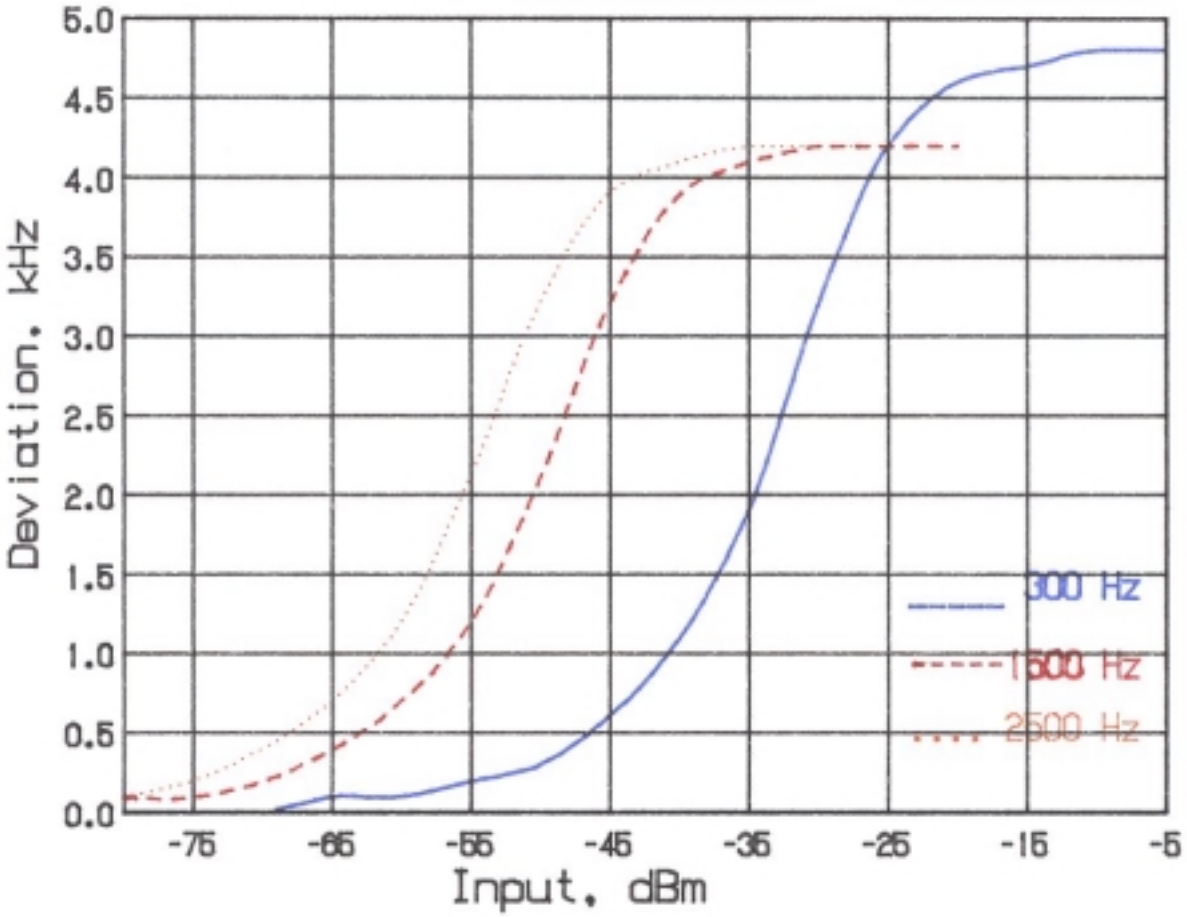


MODULATION FREQUENCY RESPONSE
FCC ID: I40SE700

FIGURE 1

FIGURE 2

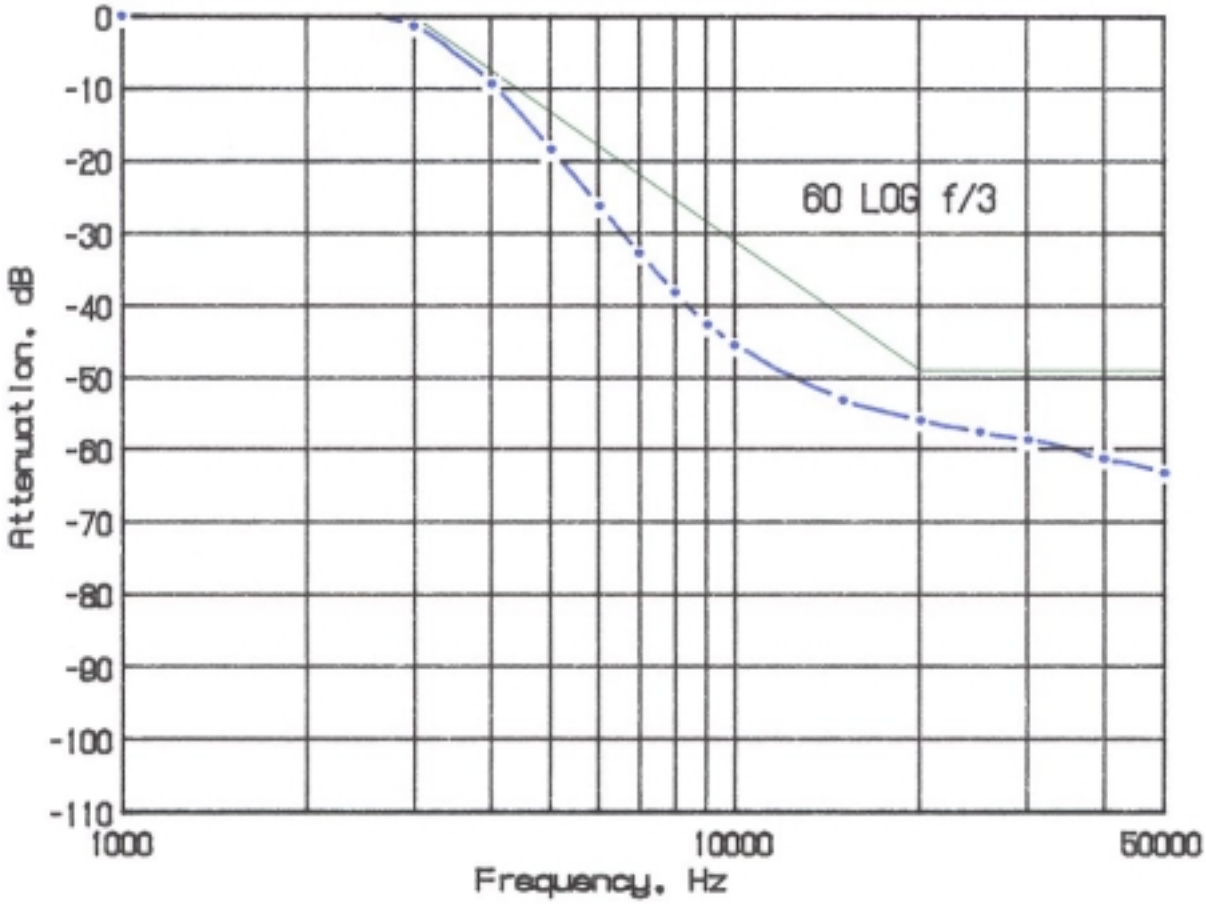
AUDIO LIMITER CHARACTERISTICS



AUDIO LIMITER CHARACTERISTICS
FCC ID: I40SE700

FIGURE 2
FIGURE 3

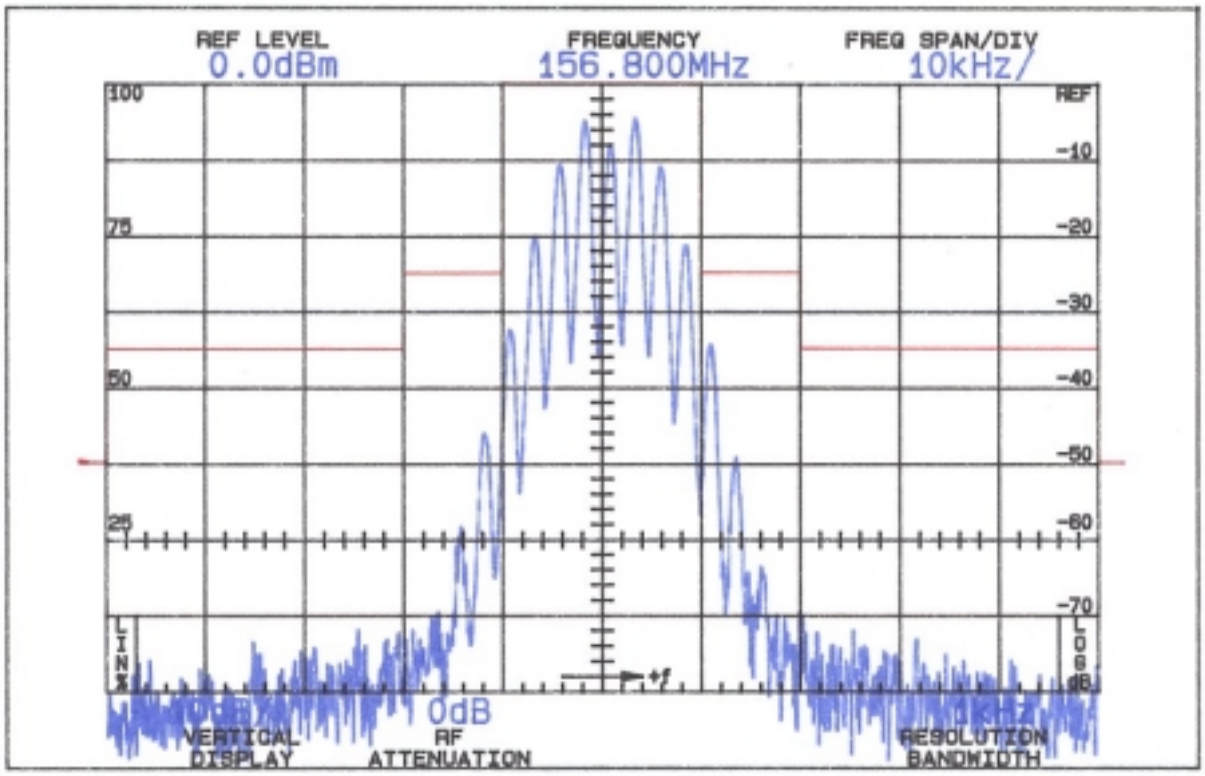
AUDIO LOW PASS FILTER RESPONSE



AUDIO LOW PASS FILTER RESPONSE
FCC ID: I40SE700

FIGURE 3
FIGURE 4a

OCCUPIED BANDWIDTH



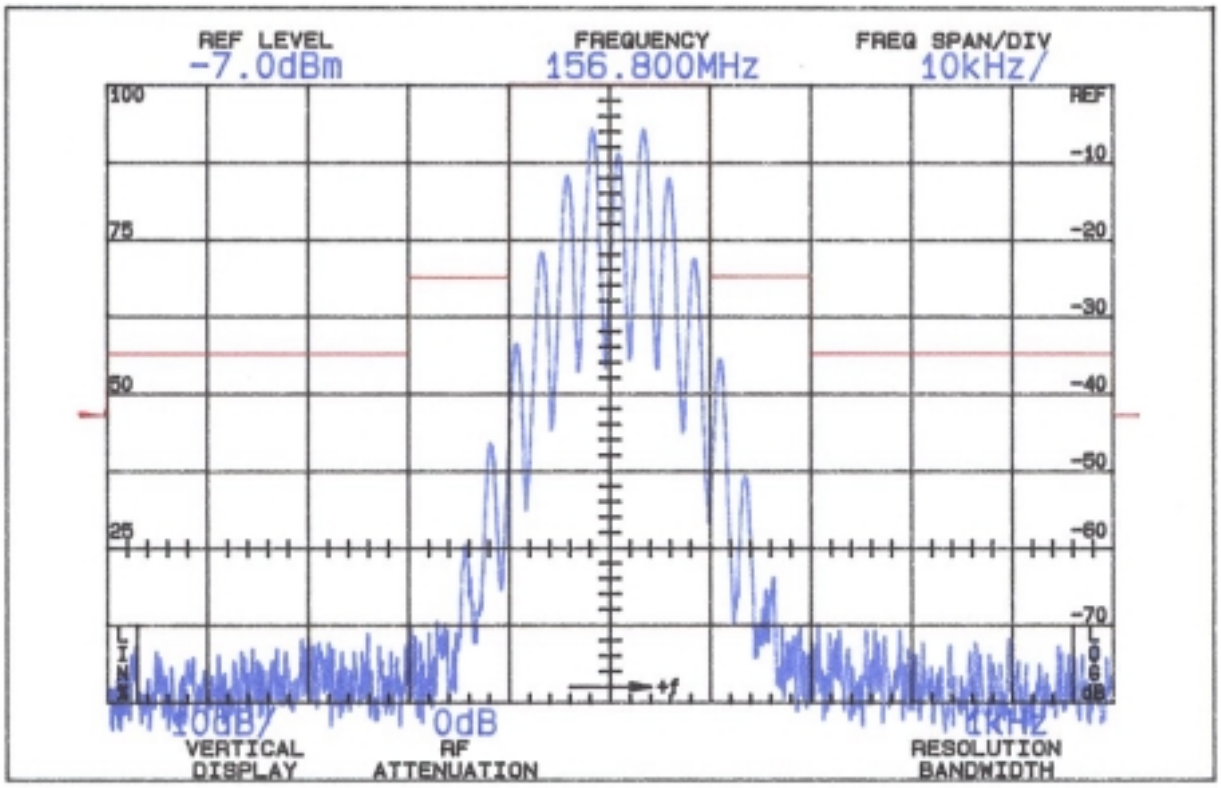
	Attenuation in dB Below Mean Output Power Required
On any frequency more than 50% up to and including 100% of the authorized bandwidth, 20 kHz (10-20 kHz)	25
On any frequency more than 100%, up to and including 250% of the authorized bandwidth (20-50 kHz)	35
On any frequency removed from the assigned frequency by more than 250% of the authorized bandwidth (over 50 kHz)	43+10LogP=50 (P=5.2W)

OCCUPIED BANDWIDTH
FCC ID: I40SE700

FIGURE 4a

FIGURE 4b

OCCUPIED BANDWIDTH



	Attenuation in dB Below Mean Output Power Required
On any frequency more than 50% up to and including 100% of the authorized bandwidth, 20 kHz (10-20 kHz)	25
On any frequency more than 100%, up to and including 250% of the authorized bandwidth (20-50 kHz)	35
On any frequency removed from the assigned frequency by more than 250% of the authorized bandwidth (over 50 kHz)	43+10LogP=44 (P=1.2W)

OCCUPIED BANDWIDTH
FCC ID: I40SE700

FIGURE 4b

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

The SE700 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 2996 Hz, the frequency of highest sensitivity.

Measurements were made with a Tektronix 494P spectrum analyzer coupled to the transmitter output terminals through a Narda 765-20 50 ohm power attenuator. A notch filter attenuated the carrier.

During the tests, the transmitter was terminated in the Narda attenuator. Power was monitored on a Bird 43 Thru-Line wattmeter; dc supply was 6.5 volts throughout the tests.

Spurious emissions were measured throughout the RF spectrum from 12 (lowest frequency generated in the transmitter is 12.8 MHz) to 1.6 GHz. Any emissions that were between the required attenuation and the 90 dB noise floor of the spectrum analyzer were recorded. Data are shown in Table 1.

TABLE 1

TRANSMITTER CONDUCTED SPURIOUS
156.80 MHz, 6.5 Vdc

Spurious Frequency, MHz	dB Below Carrier Reference	
	1.2 watt	5.2 watts
313.600	51	59
470.400	76	88
627.200	83	94
784.000	58	67
940.800	80	91
1097.600	88	95
1254.400	>100	>100
1411.200	>100	>100
1568.000	>100	>100
Required:43+10Log(P)	44	50

All other spurious were 20 dB or more below carrier reference on both power levels from 12 MHz to 1.6 GHz.

E. FIELD STRENGTH MEASUREMENTS OF SPURIOUS RADIATION
(Paragraph 2.993(a) (b) (2) of the Rules)

Field intensity measurements of radiated spurious emissions from the SE700 were made with a Tektronix 494P spectrum analyzer using Singer DM-105A calibrated test antennas below a GHz, and Polarad calibrated Horn CA-L from 1-2.4 GHz. 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 6.5 Vdc. Output power was 5.2 watts at the 156.80 MHz operating frequency. The transmitter and test antennas were arranged to maximize pickup. Both vertical and horizontal test antenna polarization were employed.

Reference level for the spurious radiation was taken as an ideal dipole excited by 5.2 watts, the output power of the transmitter according to the following relationship:*

$$E = \frac{(46.5P_t)^{1/2}}{R}$$

Where E = electric field intensity in volts/meter

P_t = transmitter power in watts

R = distance in meters

for the case $E = \frac{(46.5 \times 5.2)^{1/2}}{3} = 5.3$ V/m

Since the spectrum analyzer is calibrated in decibels above one milliwatt (dBm), a conversion, for convenience, was made from dBu to dBm:

$$5.3 \text{ volts/meter} = 5.3 \times 10^6 \text{ uV/m}$$

$$\text{dBu/m} = 20\text{Log}_{10}(5.3 \times 10^6)$$

$$= 135 \text{ dBu/m}$$

Since 1 uV/m = -107 dBm, the reference becomes

$$135 - 107 = 28 \text{ dBm}$$

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*Reference_Data_For_Radio_Engineers, Fourth Edition, International Telephone and Telegraph Corporation, p. 676.

E. FIELD STRENGTH MEASUREMENTS...(Continued)

The measurement system was capable of detecting signals 100

dB or more below the reference level. Measurements were made from the lowest frequency generated within the unit, or 12 MHz, to 10 times operating frequency, 1.6 GHz. Data after application of antenna factors and line loss corrections are shown in Table 2.

TABLE 2

TRANSMITTER RADIATED SPURIOUS
156.80 MHz; 5.2 watts; 6.5 Vdc

Spurious Frequency, MHz	dB Below Carrier Reference
313.600	58H
470.400	84V*
627.200	78V*
784.000	69V*
940.800	87H*
1097.600	84H*
1254.400	88V*
1411.200	85V*
1568.000	92H*

Required: 43+10Log(5.2) = 50

1. Worst-case polarization, H-horizontal, V-vertical.

2. Includes transmission line losses. Horn antenna factors from FCC Project 3235-18.

All other spurious from 12 - 1600 MHz were 20 dB or more below FCC limit.

F. FREQUENCY STABILITY
(Paragraph 2.995(2) and 80.209 of the Rules)

Measurement of frequency stability versus temperature was made at temperatures from -20°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 ±2°C 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.

A Thermotron S1.2 temperature chamber was used. Temperature was monitored with a Keithley 871 digital thermometer. The transmitter output stage was terminated in a dummy load. Primary supply was 6.5 volts. Frequency was measured with a HP5385A digital frequency counter connected to the transmitter through a power attenuator. Measurements were made at 156.80 MHz. No transient keying effects were observed.

Test temperature was sequenced in the order shown in Table 3, starting with -20°C.

TABLE 3

FREQUENCY AS A FUNCTION OF TEMPERATURE
156.800 MHz; 5.2 W, 6.5 Vdc

Temperature, °C	Output Frequency, MHz	p.p.m.
-19.8	156.800448	2.9
-10.0	156.800480	3.1
0.1	156.800516	3.3
10.4	156.800423	2.7
20.5	156.800118	0.7
30.0	156.799827	-1.1
40.5	156.799825	-1.1
49.7	156.799924	-0.5

Maximum frequency error: 156.800516
156.800000

+ 0.000516 MHz

FCC Rule 80.209(a)(5) (ship station) specifies .001% or a maximum of ±. 001568 MHz, which corresponds to:

High Limit 156.001568 MHz
Low Limit 156.798432 MHz

G. 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 an HP 62648 variable dc power supply was varied ±15% from the nominal 6.5 volt rating. A Keithley 197 digital voltmeter was used to measure supply voltage at transmitter primary input terminals. Measurements were made at 20°C ambient.

Test voltage was sequenced in the order shown in Table 4, starting with 7.47 V.

TABLE 4

FREQUENCY AS A FUNCTION OF SUPPLY VOLTAGE
156.800 MHZ; 5.2 W; Nominal 6.5 Vdc

Supply Voltage	Output Frequency, Hz	p.p.m.
7.47	156.800291	1.9
7.15	156.800253	1.6
6.83	156.800184	1.2
6.50	156.800112	0.7
6.18	156.800048	0.3
5.85	156.799994	0.0
5.53	156.799954	-0.3
5.20*	no rf output	
Maximum frequency error:	156.800291	
	156.800000	
	+ 0.000291 MHz	

FCC Rule 80.209(a)(5) (ship station) specifies .001% or a maximum of ±.001568 MHz, corresponding to:

High Limit	156.001568 MHz
Low Limit	156.798432 MHz

*Mfg. rated battery end-point.

APPENDIX 1

FUNCTIONS OF SEMICONDUCTOR DEVICES

SE700 Board for function of active device

SYMBOL	ARTICLE	MFGR'S DESIGN	DESCRIPTION
D1	PLANAR PIN DIODE	1SV307	TX/RX SW
D2	PLANAR PIN DIODE	1SV307	TX/RX SW
D3	SI SCHOTTKY DIODE	1SS383	RF POWER DETECTOR
D4	CHIP VARI-CAP DIODE	1SV276	VCO OSCILLATER CIRCUIT
D5	CHIP VARI-CAP DIODE	1SV276	VCO OSCILLATER CIRCUIT
D6	CHIP VARI-CAP DIODE	1SV276	VCO MODURATION CIRCUIT
D7	SILICON DIODE	DAP202U	MODURATED LIMITER
D8	SILICON DIODE	DA204U	MIC AMP MOD LIMITER
D9	SILICON DIODE	DAN202U	POWER SUPPLY TEMP. SW
D11	SI SCHOTTKY DIODE	MA728	RX RF AMP LIMITER
D12	SI SCHOTTKY DIODE	MA728	UNLOCK DETECTOR
D201	ZENER DIODE	02CZ8.2Y	BATTERY VOLTAGE DETECTOR
D202	LED	MAA3362X	LCD BACKLIGHT
D203	LED	MAA3362X	LCD BACKLIGHT
D204	SI SCHOTTKY DIODE	RB461F	DC JACK SERIES SW
D205	SILICON DIODE	DAN202U	CONTROL CIRCUIT SW
IC1	IC	M68731H-21	TX RF POWER AMP MODULE
IC2	IC	TA4101F	1ST MIXER IC
IC3	IC	TB31213FN	PLL IC
IC4	IC	TA31136FN	IF IC
IC5	IC	TC75S51F	RF POWER CONTROL
IC6	IC	NJM3403AV	MIC AMP,LIMITER,LPF
IC7	IC	NJM2904V	DEEMPHASIS FILTER
IC8	IC	TK11240AM	DC4V REGULATOR
IC10	IC	NJM2070M	AUDIO AMPLIFIER
IC201	IC	uPD753036GK	CPU
IC202	IC	BR93LC46AF	EEPROM
IC204	IC	TK11240AM	DC4V REGULATOR
IC205	IC	LMC567C	TONE DETECTOR
Q1	TRANSISTOR	2SC4226R24	RX RF AMP
Q2	TRANSISTOR	2SC4226R24	IF AMP
Q3	TRANSISTOR	2SC4116GR	UNLOCK SW
Q4	TRANSISTOR	DTC144EUA	UNLOCK SW
Q5	TRANSISTOR	2SC3357RF	TX RF DRIVER AMP
Q6	TRANSISTOR	2SC4226R24	TX RF BUFFER AMP
Q7	TRANSISTOR	2SC4116GR	TX POWER DETECTOR SW
Q8	TRANSISTOR	DTC144EUA	TX HI/LOW-POWER SW
Q9	TRANSISTOR	2SA1586GR	TX4V REGULATED SW
Q10	TRANSISTOR	2SA1586GR	RX4V REGULATED SW
Q12	TRANSISTOR	DTC343TK	RX AUDIO MUTE SW
Q201	TRANSISTOR	DTC343TK	BEEP CONTROL SW
Q202	TRANSISTOR	2SA1298Y	LED REGULATED SW
Q203	TRANSISTOR	2SA1298Y	IC205 CONTOROL SW
Q204	TRANSISTOR	UMD3N	CONTROL CIRCUIT SW

APPENDIX 2

CIRCUITS AND DEVICES TO DETERMINE AND STABILIZE FREQUENCY

Frequency stabilization is accomplished through PLL technology.

FREQUENCY CONTROL
FCC ID: I40SE700

APPENDIX 2

APPENDIX 3

CIRCUITS TO SUPPRESS SPURIOUS EMISSIONS,

CONTROL MODULATION, AND POWER

A) Circuits to Suppress Spurious Emissions:

Circuit employed for suppression of spurious radiation is band-pass filter, L1, L2, L3, C1, C2, C3, C4, C5, L11, and C29.

B) Modulation Limiting:

Integrated circuit IC6 forms a microphone amplifier, limiter and low pass filter.

SUPPRESSION, AND LIMITING
FCC ID: I40SE700

APPENDIX 3