SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

UTILITY METER TRANSMITTING UNIT (MTU)
Model: 6327W
FCC ID: LLB 6327W

October 20, 2003

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TEST REPORT

INTRODUCTION

The Hexagram Model 6327W transmitter is a battery-powered transmitter designed to be a) mounted directly on a typical gas meter; b) connected with a utility meter by an external 12 ft wire. The transmitter provides a very short, intermittent radio frequency transmission to provide a remote reading of the meter. A microprocessor provides timing, control and data processing functions. The built in antenna is inaccessible to the user and no provision is made for an external antenna. This report describes the tests performed on the transmitter in support of both applications for certification.

MEASUREMENTS PERFORMED

The microprocessor portion of the transmitter was also examined for radiated emissions per Part 15, and has been verified to comply with the appropriate sections of that part. The data used for verification of the microprocessor portion is presented in a separate report.

POWER OUTPUT AND SPURIOUS EMISSIONS

A series of measurements of three tuned frequencies and their harmonic emissions was made on the Smith Electronics, open field test site located at 8200 Snowville Road, Brecksville, OH. Data pertinent to this site is on file with the FCC. A scan of the transmitter emissions made in the shielded room showed no significant emissions other than the fundamental and its harmonics. The measurements were made using the substitution method described in TIA/EIA-603-A.

Measurements below 1000 MHz were made at a three-meter test distance with frequencies above 1000 MHz being measured at one meter. A receiver and a tuned dipole were used for receiving below 1000 MHz and a spectrum analyzer and a wave guide antenna were used above 1000 MHz.

The transmitter was placed on a remotely rotatable, non-conducting test stand. This general set up is shown in Pictorial 1. Because of the intermittent nature of the normally operating transmitter a larger, external battery pack was connected directly to the transmitter and the transmitter was forced to continually transmit for the measurements.

With the test receiver tuned to the unmodulated signal, the transmitter under test was rotated to the position of maximum signal. The receiving antenna was then varied between 1 and 4 meters in height to again maximize the signal. Measurements were made with the antennas positioned both vertically and horizontally and the maximum signal recorded.

No differences were observed with different signal detectors, so a quasi-peak detector was used for the signals below 1000 MHz and average detection above 1000 MHz.

After the maximum received meter readings were obtained for each frequency and polarity, the meter under test was removed from the area and replaced by a signal generator and transmitting antenna. With the transmit antenna placed as close as possible to the position of the test unit, the signal generator was activated at a test frequency. With the signal detected, the transmit antenna was rotated slightly to maximize the reading. The receive antenna was also positioned for maximum reception. The signal generator output was then adjusted until the received signal was equal to the received signal from the unit under test. These measurements were repeated for each frequency and antenna orientation and the maximum values obtained are noted in Tables 1a – 1c. Transmitting antenna gain and coax loss figures are also included in the tables.

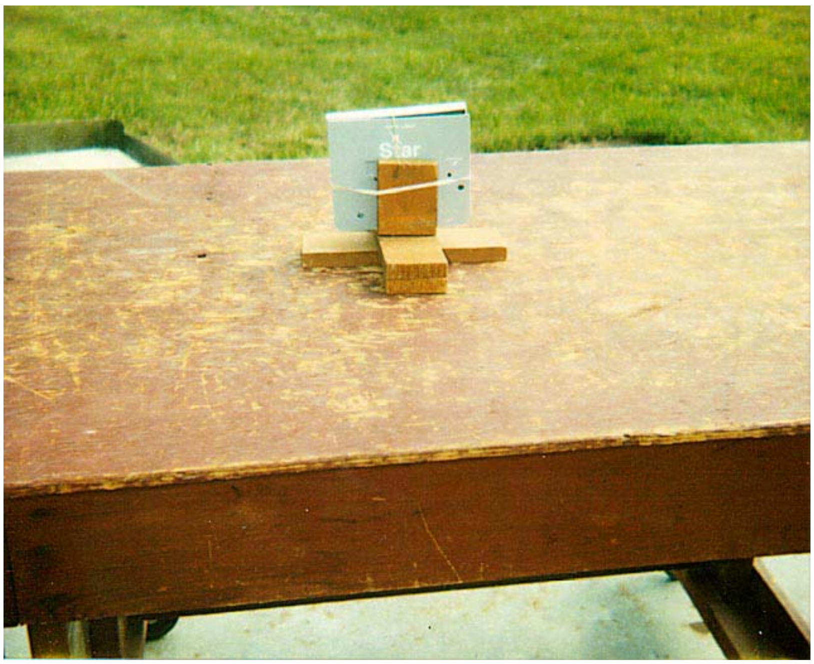
In order to convert the signal generator output value to equivalent radiated power from a dipole, the following equation is used:

$$P_d = P_g - \text{cable loss(dB)} + \text{antenna gain(dB}_d\text{)}$$

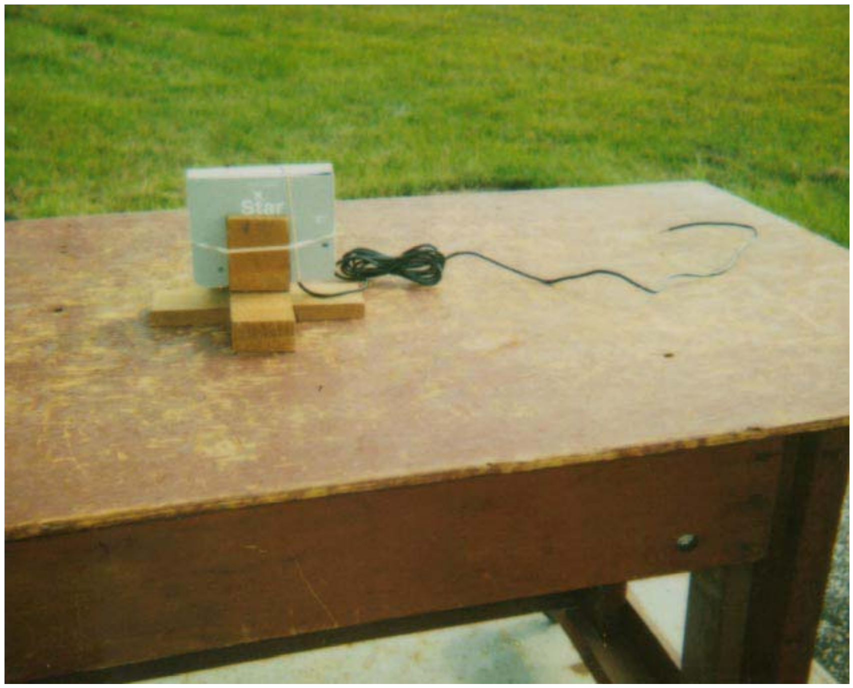
where:

P_d is the dipole equivalent power, P_g is the generator output into the substitution antenna and “antenna gain” is the gain of the substitution antenna with respect to a dipole.

According to 90.210(d)(3) all emissions greater than 12.5 kHz from the center of the authorized band shall be attenuated below the unmodulated carrier by 50 + 10log(P). The determined power outputs, the required harmonic attenuation as well as the attenuation for each harmonic are found in Tables 1a – 1c, and, 2a – 2c.



PICTORIAL 1
HEXAGRAM GAS METER TRANSMITTING UNIT
MODEL 6327W, no external wiring
OUTPUT POWER AND SPURIOUS EMISSIONS
TEST SETUP



PICTORIAL 2
HEXAGRAM GAS METER TRANSMITTING UNIT
MODEL 6327W with external wiring
OUTPUT POWER AND SPURIOUS EMISSIONS
TEST SETUP

TABLE 1a
HEXAGRAM MODEL 6327W TRANSMITTER
WITHOUT EXTERNAL WIRING
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
450	14.8	0.3	0	14.5	-
900	-32.0	0.5	0	-32.5	-47.0

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
1350	-52.3	0.7	3.1	-49.9	-64.4
1800	-51.0	0.8	4.9	-46.9	-61.4
2250	-45.7	0.9	5.6	-41.0	-55.5
2700	-50.0	1.1	6.2	-44.9	-59.4
3150	-46.0	1.2	6.7	-40.5	-55.0
3600	-42.2	1.3	6.6	-36.9	-51.4
4050	-47.0	1.4	6.5	-41.9	-56.4
4500	-54.8	1.5	7.2	-49.1	-63.6

14.5 dBm = 28.2 mW or 0.0282 W
Required attenuation for harmonics is 50 + log (.0282) = 34.5 dBm

LLB 6327W no wires, September 24, 2003

TABLE 1b
HEXAGRAM MODEL 6327W TRANSMITTER
WITHOUT EXTERNAL WIRING
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
460	19.0	0.3	0	18.7	-
920	-28.0	0.5	0	-27.5	-46.2

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
1380	-54.0	0.7	3.1	-51.6	-70.3
1840	-50.8	0.8	4.9	-46.7	-65.4
2300	-49.0	0.9	5.6	-44.3	-63.0
2760	-50.7	1.1	6.2	-45.6	-64.3
3220	-44.7	1.2	6.7	-39.2	-57.9
3680	-44.1	1.3	6.6	-38.8	-57.5
4140	-52.0	1.4	6.5	-46.9	-65.6
4600	-39.7	1.5	7.2	-34.0	-52.7

18.7 dBm = 74.1 mW or 0.0741 W
Required attenuation for harmonics is 50 + log (.0741) = 38.7 dBm

LLB 6327W no wires, August 4, 2003

TABLE 1c
HEXAGRAM MODEL 6327W TRANSMITTER
WITHOUT EXTERNAL WIRING
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
469.15	20.9	0.3	0	20.6	-
938.3	-22.0	0.5	0	-22.5	-43.1

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
1407.45	-55.8	0.7	3.1	-53.4	-72.5
1876.6	-54.8	0.8	4.9	-50.4	-69.5
2345.75	-49.8	0.9	5.6	-45.1	-64.2
2814.9	-52.9	1.1	6.2	-47.8	-66.9
3284.05	-47.0	1.2	6.7	-41.5	-60.6
3753.2	-42.0	1.3	6.6	-36.7	-55.8
4222.35	-51.5	1.4	6.5	-46.4	-65.5
4691.5	-46.3	1.5	7.2	-40.6	-59.7

20.6 dBm = 114.8 mW or 0.1148 W
Required attenuation for harmonics is 50 + log (.1148) = 40.6 dBm

LLB 6327W no wires, September 24, 2003

TABLE 2a
HEXAGRAM MODEL 6327W TRANSMITTER
WITH EXTERNAL WIRING
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
450	21.2	0.3	0	20.9	
900	-37.0	0.5	0	-37.5	-58.4

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1350	-50.0	0.7	3.1	-47.6	-68.5
1800	-58.1	0.8	4.9	-54.0	-74.9
2250	-37.0	0.9	5.6	-32.3	-53.2
2700	-46.0	1.1	6.2	-40.9	-61.8
3150	-46.4	1.2	6.7	-40.9	-61.8
3600	-42.4	1.3	6.6	-37.1	-58.0
4050	-54.8	1.4	6.5	-49.7	-70.6
4500	-45.2	1.5	7.2	-39.5	-60.4

20.9 dBm = 123.0 mW or 0.123 W
Required attenuation for harmonics is 50 + log (.123) = 40.9dB

TABLE 2b
HEXAGRAM MODEL 6327W TRANSMITTER
WITH EXTERNAL WIRING
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
460	20.8	0.3	0	20.5	-
920	-31.2	0.5	0	-31.7	-52.2

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1380	-48.4	0.7	3.1	-46.0	-66.5
1840	-50.2	0.8	4.9	-46.1	-66.6
2300	-41.0	0.9	5.6	-36.3	-56.8
2760	-48.1	1.1	6.2	-43.0	-63.5
3220	-44.5	1.2	6.7	-39.0	-59.5
3680	-39.5	1.3	6.6	-34.2	-54.7
4140	-52.2	1.4	6.5	-47.1	-67.6
4600	-52.8	1.5	7.2	-47.1	-67.6

20.5dBm = 112.2 mW or 0.112 W
Required attenuation for harmonics is 50 + log (.112) = 40.5dB

TABLE 2c
HEXAGRAM MODEL 6327W TRANSMITTER
WITH EXTERNAL WIRING
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
470	20.0	0.3	0	19.7	-
940	-26.0	0.5	0	-26.5	-46.2

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1410	-52.0	0.7	3.1	-49.6	-69.3
1880	-51.9	0.8	4.9	-47.8	-67.5
2350	-48.0	0.9	5.6	-43.3	-63.0
2820	-49.4	1.1	6.2	-44.3	-64.0
3290	-43.8	1.2	6.7	-38.3	-58.0
3760	-42.0	1.3	6.6	-36.7	-56.4
4230	-51.8	1.4	6.5	-46.7	-66.4
4700	-52.8	1.5	7.2	-47.1	-66.8

19.7dBm = 93.3 mW or 0.0933 W.
Required attenuation for harmonics is 50 + log (.0933) = 39.7 dB

TEST EQUIPMENT USED

Meters & Analyzers	Singer-Stoddart EMI Field Intensity Meter Model NM 37/57 S/N 0366-06168 Calibrated 6/03
	Hewlett-Packard Spectrum Analyzer Model 8593EM S/N 3536A00147 Calibrated 6/00
Antennas	(2x) Stoddart 91598-2 Tuned Dipole Frequency Range 400 – 1000 MHz
	EMCO 3115 Double Ridged Guide Horn Frequency Range 1 – 18 GHz (Rcv)
	Eaton Model 96001 Double Ridged Guide Horn Frequency Range 1 – 18 GHz (Xmt)
Signal Generator	Hewlett-Packard Model 8340B, S/N 3010A01889 Calibrated 1/03
Miscellaneous	12.2 m RG-214/U coaxial cable
	6.1 m RG-214/U coaxial cable
	(2x) 1.8 m RG-214/U coaxial cable

OCCUPIED BANDWIDTH

The emissions close to the center of the specified channel are limited by the emissions masks described in 90.210. For the frequency range of the MTU transmitter, Mask D is specified. From the center frequency of the band ±5.625 kHz, 0 dB of attenuation is required. From 5.625 kHz to 12.5 kHz from the center frequency, attenuation must be at least $7.27(f_d - 2.88 \text{ kHz})$ dB, where f_d is the displacement frequency from the center of the band in kHz.

At more than 12.5 kHz from the band center, the attenuation must be 70 dB or 50 + 10 log(P), whichever is less. Since maximum P was determined to be 0.1148 W (application without external wires), and 0.123 W (with external wires), 50 + 10 log(0.1148) equals 40.6 dB (without external wires) and 40.9 dB (at application with external wires).

The short transmission was caught by the Real-Time-Spectrum-Analyzer and stored to disk for evaluation.

The plots of Fig. 3a and 4a shows the unmodulated carrier, while Fig. 3b and 4b shows the modulated signal.
Both Figs. have Mask D superimposed on the plot. The plots indicate that the modulated emission does appear to comply with the requirement for occupied bandwidth as found in 90.210. For clearer view of plots see Appendix 1.

For purposes of this test, the transmitter was FSK modulated with a continuous sequence of Manchester encoded 1's at the specified 1200 bits per second data rate. The Manchester encoding scheme forces a mid-bit transition for an encoded "1". Therefore, the sequence of continuous 1's sends the highest frequency waveform to the modulator circuit.

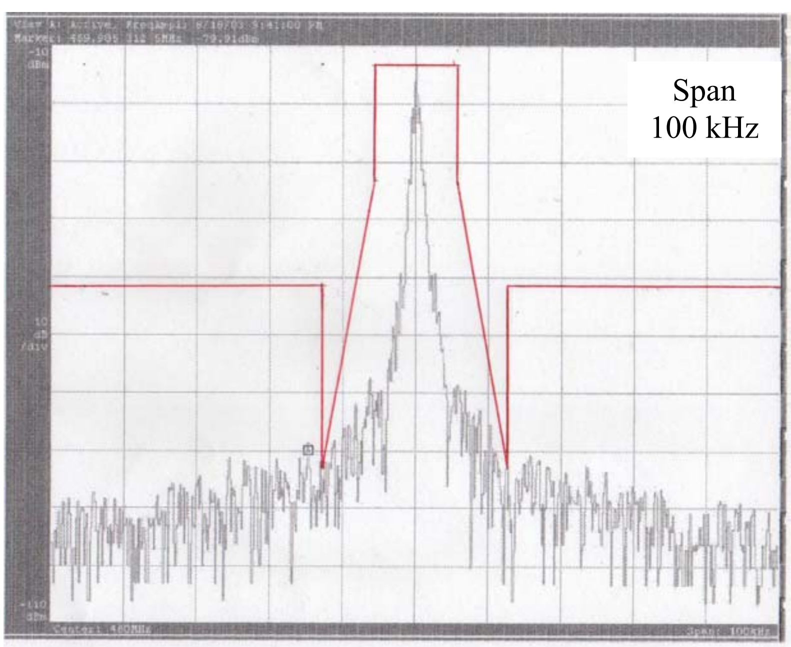


Fig. 3a
Hexagram Model LLB 6327W (w/o external wire)
Unmodulated Emissions Mask

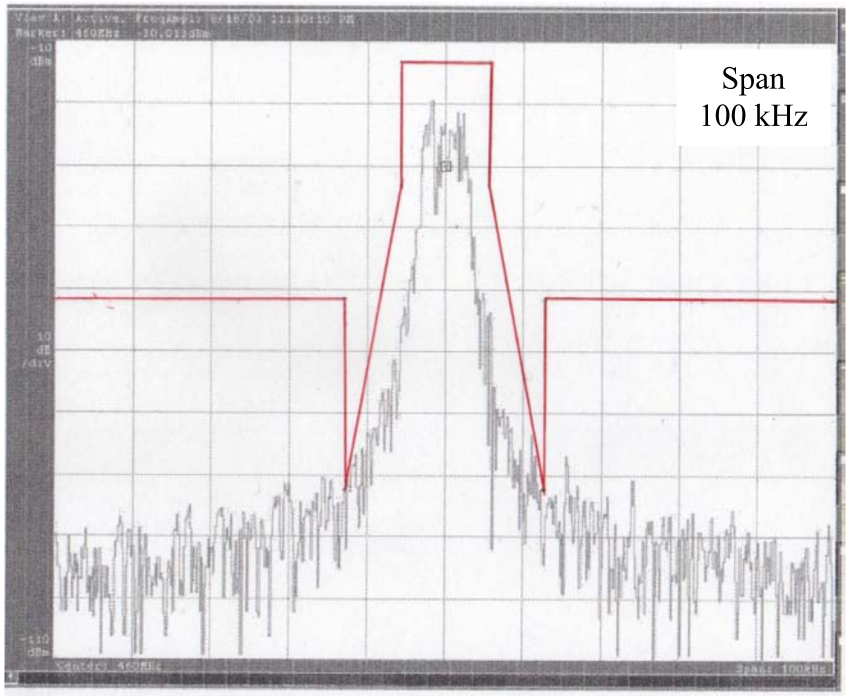


Fig. 3b
Hexagram LLB 6327W w/o external wire
Modulated Emissions Mask

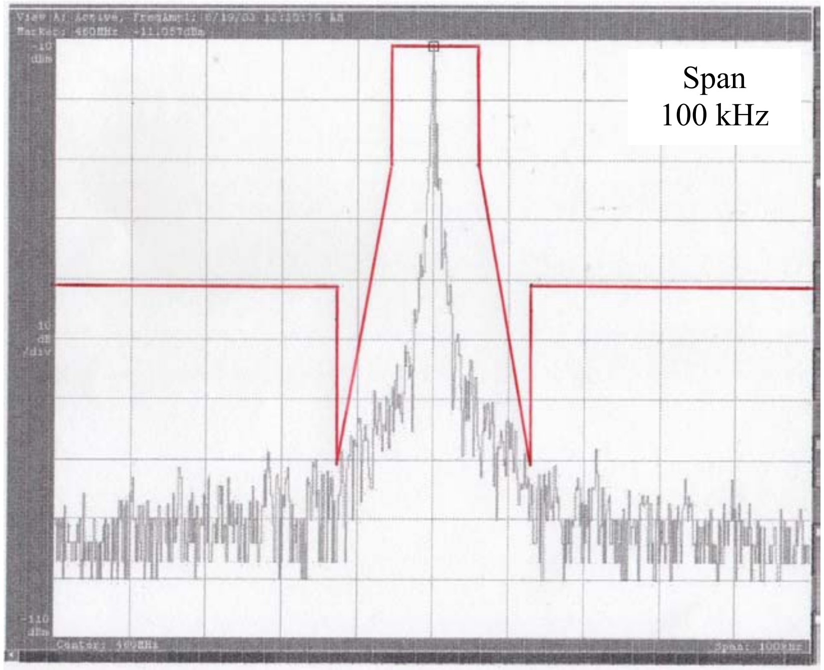


Fig. 4a
Hexagram LLB 6327W MTU with external Wire
Unmodulated Emissions Mask

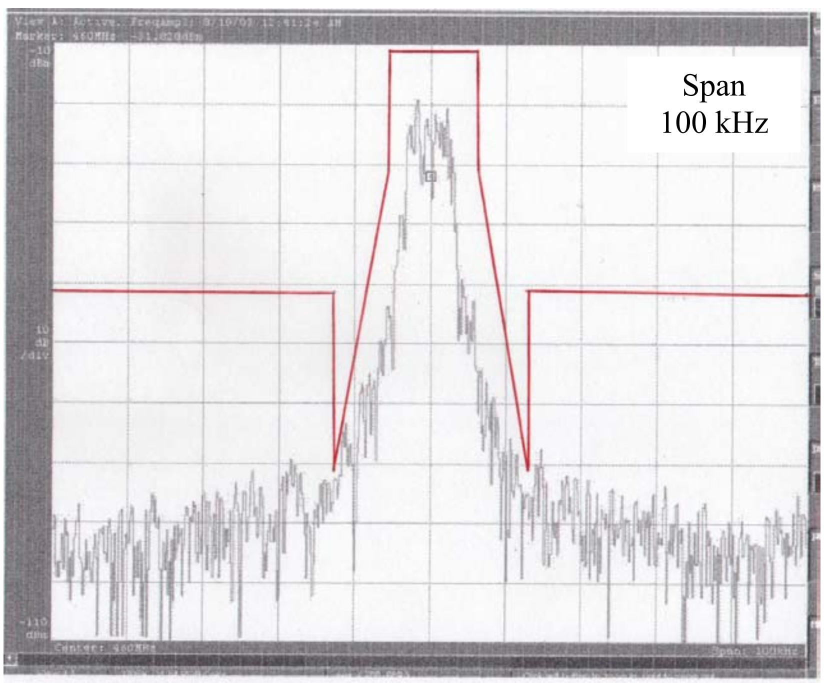


Fig. 4b
Hexagram LLB 6327W MTU with external Wire
Modulated Emissions Mask

TEST EQUIPMENT USED

Real-Time Spectrum Analyzer	Tektronix/Sony Model 3086 S/N J300195 Calibration 12/02
Antenna	EMCO Model 3146 Log Periodic Frequency Range 200 MHz – 1000 MHz

For clearer view of above shown plots see Appendix 1.

FREQUENCY STABILITY VS. TEMPERATURE

The temperature stability of the frequency generating components of the transmitter was observed. The transmitter was placed in a temperature chamber. The battery powered meter was set to transmit at intervals of about 40 seconds. A receiving antenna outside the chamber picked up the transmitted signal which was fed to the real-time spectrum analyzer.

With the transmitter programmed to transmit at 460.025000 MHz, the chamber temperature was set to 70° C. After reaching the set temperature, the transmitter was allowed to stabilize for about 10 minutes or more. The transmission signal was captured by the real-time spectrum analyzer and the frequency was determined and compared to the expected 460.025000 MHz. The temperature in the chamber was then decreased in 10° C increments. At each new temperature, time was allowed for stabilization of the transmitter, a transmission was made and the frequency determined. The temperature was decreased by the 10° C increments, stabilizing and checking the frequency at each point, until a temperature of -30° C was reached. The frequency at each temperature was recorded and is found in Table 3 (this is the worst case for both: MTUs with and without external wires). It can be seen from the table that all readings are exactly on frequency with no deviation.

TABLE 3

FREQUENCY STABILITY VS. TEMPERATURE

Temperature ° C	**Measured Frequency** MHz	Dev. Hz	Dev. ppm
	Expected = 460.025000		
+70	460.025000	0	0
+60	460.025000	0	0
+50	460.025000	0	0
+40	460.025000	0	0
+30	460.025000	0	0
+20	460.025000	0	0
+10	460.025000	0	0
0	460.025000	0	0
-10	460.025000	0	0
-20	460.025000	0	0
-30	460.025000	0	0

FREQUENCY STABILITY VS. SUPPLY VOLTAGE

The frequency stability was also determined as a function of the DC battery voltage. A variable DC power supply was used to set the voltage between about 85% and 115% of the nominal 3.60 VDC input. Measurements were made at 3.60 V, 3.06 V and 4.14 V. With the voltage set to a measurement point, the transmitted signal was captured by the real-time spectrum analyzer and the frequency value determined. The data for these measurements are found in Table 3 (this is the worst case for both: MTUs with and without external wires). Again, it can be seen that all values obtained are exactly on frequency.

TABLE 4

FREQUENCY STABILITY

VS. SUPPLY VOLTAGE

INPUT DC Volts	**Measured Frequency** MHz	Dev. Hz	Dev. ppm
	Expected = 460.028125		
3.06	460.028125	0	0
3.60	460.028125	0	0
4.14	460.028125	0	0

TEST EQUIPMENT USED

Real-Time Spectrum Analyzer	Tektronix/Sony Model 3086 S/N J300195 Calibration 12/02
Antenna	EMCO Model 3146 Log Periodic Frequency Range 200 MHz – 1000 MHz
DC Power Supply	Harrison Laboratories, Inc. Model 8028 Twin Low Voltage Power Supply
Thermometer	Radio Shack 63-1011 Digital Thermometer
Digital Volt Meter	Fluke Model 23
Temperature Chamber	Standard Environmental Systems, Inc. Model TK/5

TRANSIENT STABILITY

The transient stability measurements indicate the variation in tuned frequency during the brief interval of time during the start of the transmission and the end of the transmission.

The LLB 6327W transmitter was tested for transient frequency behavior using the test method TIA/EIA-603. A block diagram of the test setup is seen in Fig. 5. A model DCU-1 receiver with an audio bandwidth of 16 kHz (low Pass) was used. The storage oscilloscope was triggered by the radiated signal from the transmitter. Appropriate delay was provided by the digital delay circuitry of the oscilloscope. The 1 kHz test signal was provided by the Marconi signal generator. The generator's output control was used to insure that the signal was at least 50 dB below the received signal level from the LLB 6327W.

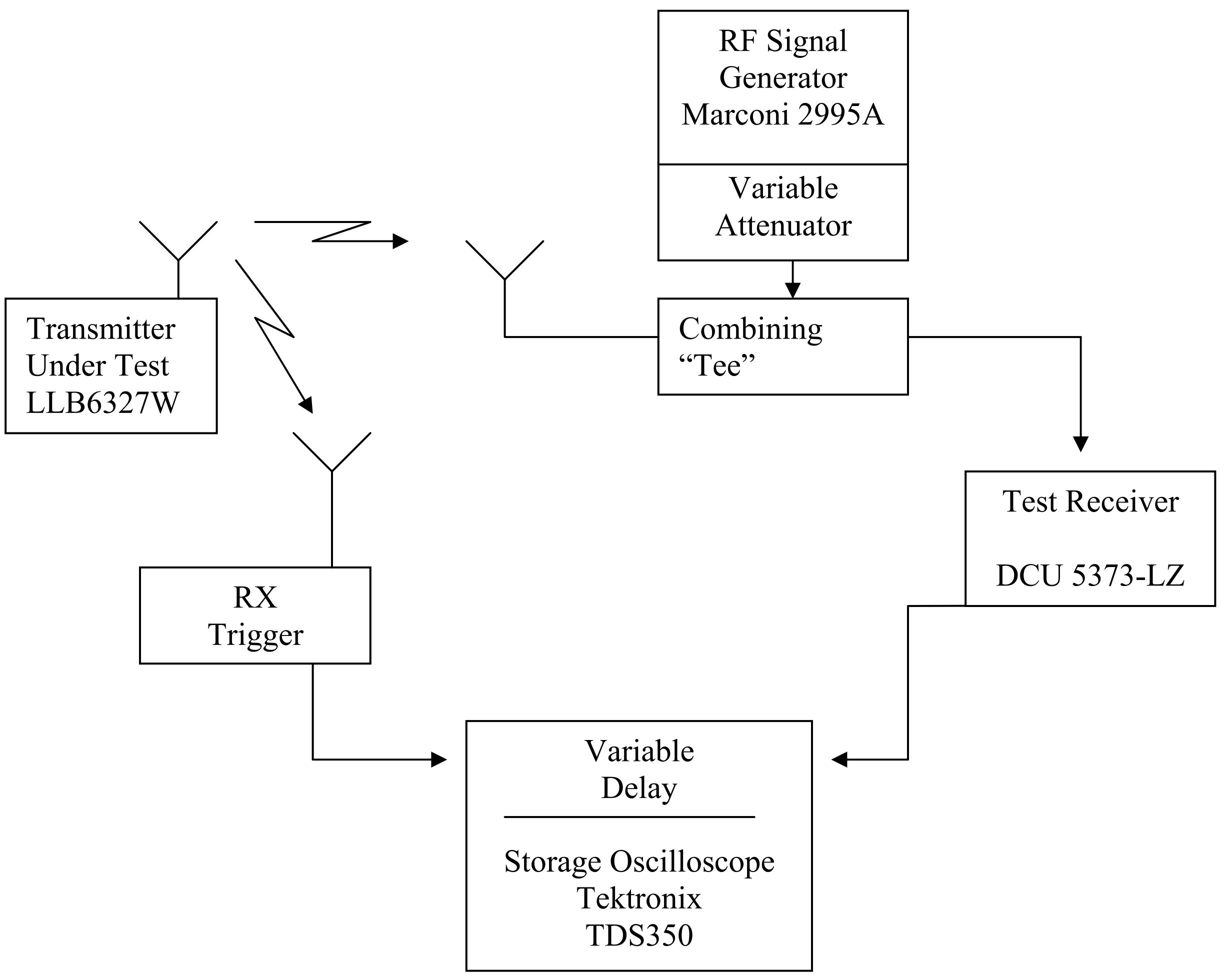


Fig. 5
Transient Frequency Behavior
Test Setup

Test Requirements

The test requirements per 90.214 are:

1. Frequency deviation during t_1 (10 ms duration after t_{on}) may be greater than ±12,5 kHz because the output power is less than 6 Watts.

2. Frequency deviation during t_2 (25 ms duration after t_1) must be less than ±6.25 kHz.

3. Frequency deviation after t_2 must be less the ±2.5 ppm. or ±1150 Hz.

4. Frequency deviation during t_3 (10 ms duration after transmitter is turned off) may exceed ±12.5 kHz because output power is less than 6 Watts.

Both transmitters (with and without external wires) are tested, and, the worst case is represented in the following oscilloscope snaps.

Test Data

Figures 6 through 10 show the LLB 6327W's transient frequency characteristics. The limit masks are overlaid or indicated on each of the figures.

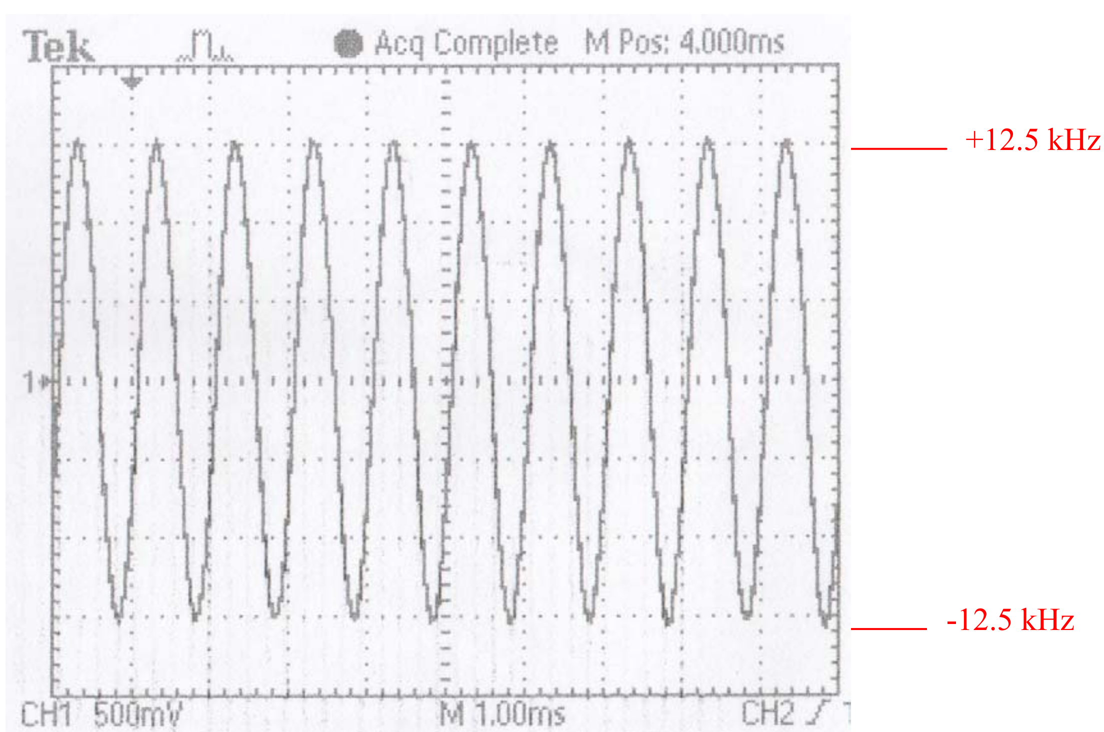


Fig. 6 ±12.5 kHz modulated test signal 25 kHz/6.2 div. = 4 kHz/div.

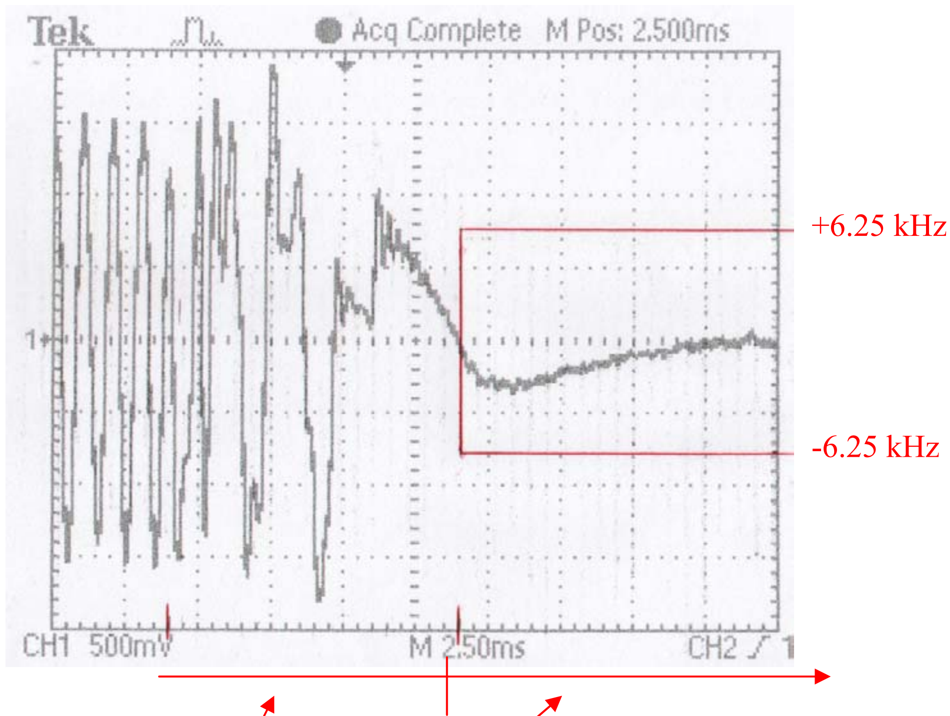


Fig. 7 Start of Transmission
t_1 = 10 ms (Unlimited deviation)
t_2 = 25 ms (±6.25 kHz deviation or ±1.56 div.

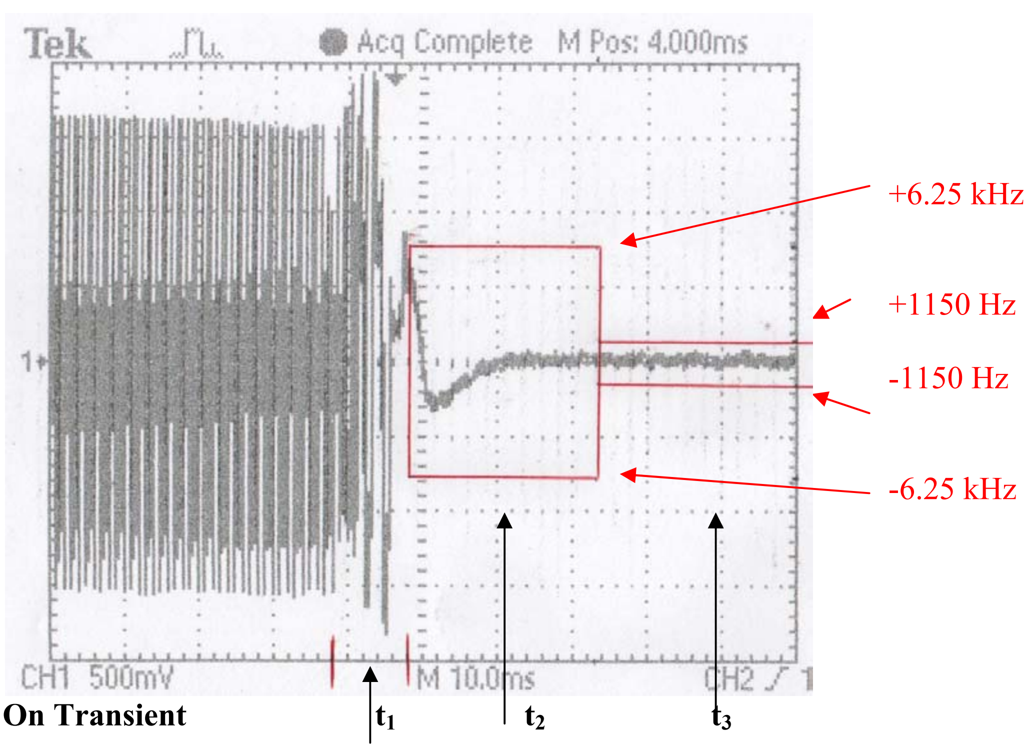


Fig. 8 Turn On Transient

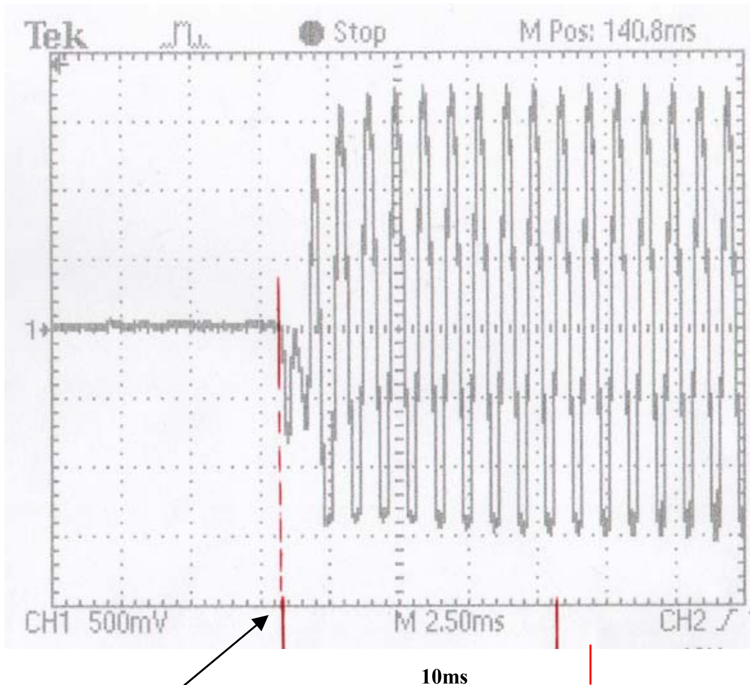


Fig. 9 Turn Off Transient

Turn Off

Modulated signal appears well within the allowed 10 ms and does not exceed ±12.5 kHz.

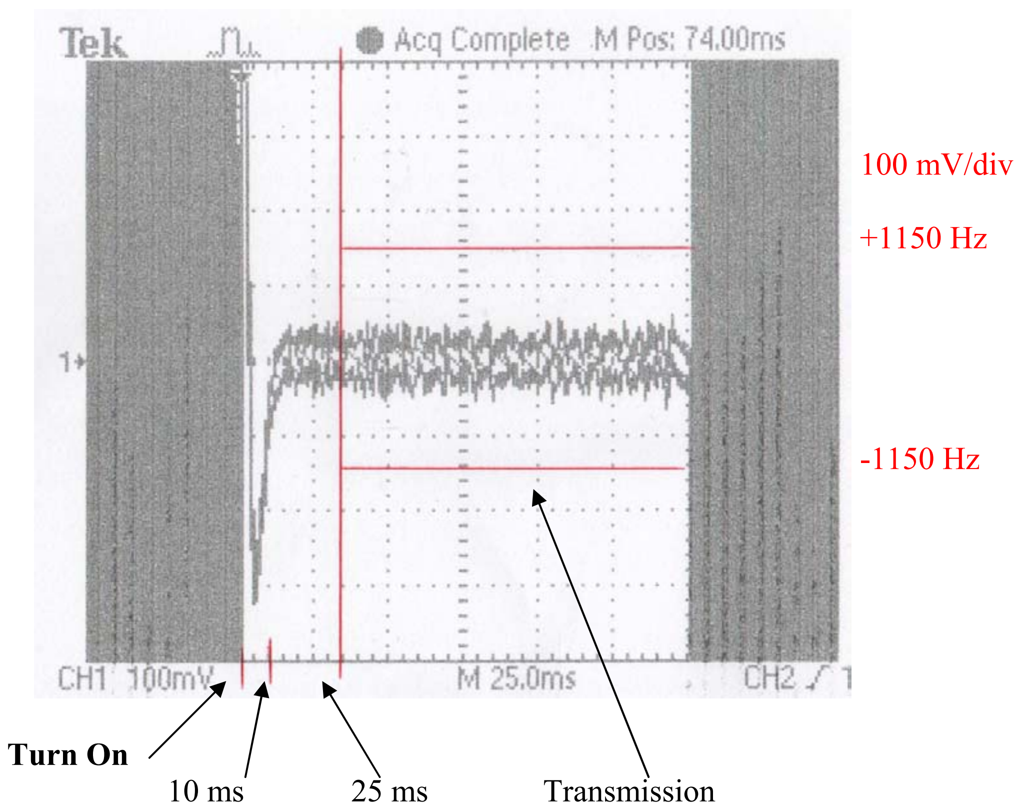


Fig. 10 Complete Transmission

MTU 6327W w/o Wire, August 20, 2003

TEST EQUIPMENT USED

Signal Generator	Marconi Model 2955A Calibration 10/02
Test Receiver	Hexagram DCU-1 (Modified)
Oscilloscope	Tektronix Model TDS 1002 S/N CO15640 Calibration 10/02
Printer	Hewlett-Packard Thinkjet
RF Trigger	Hexagram Detector Circuit

TEST INFORMATION

SUMMARY

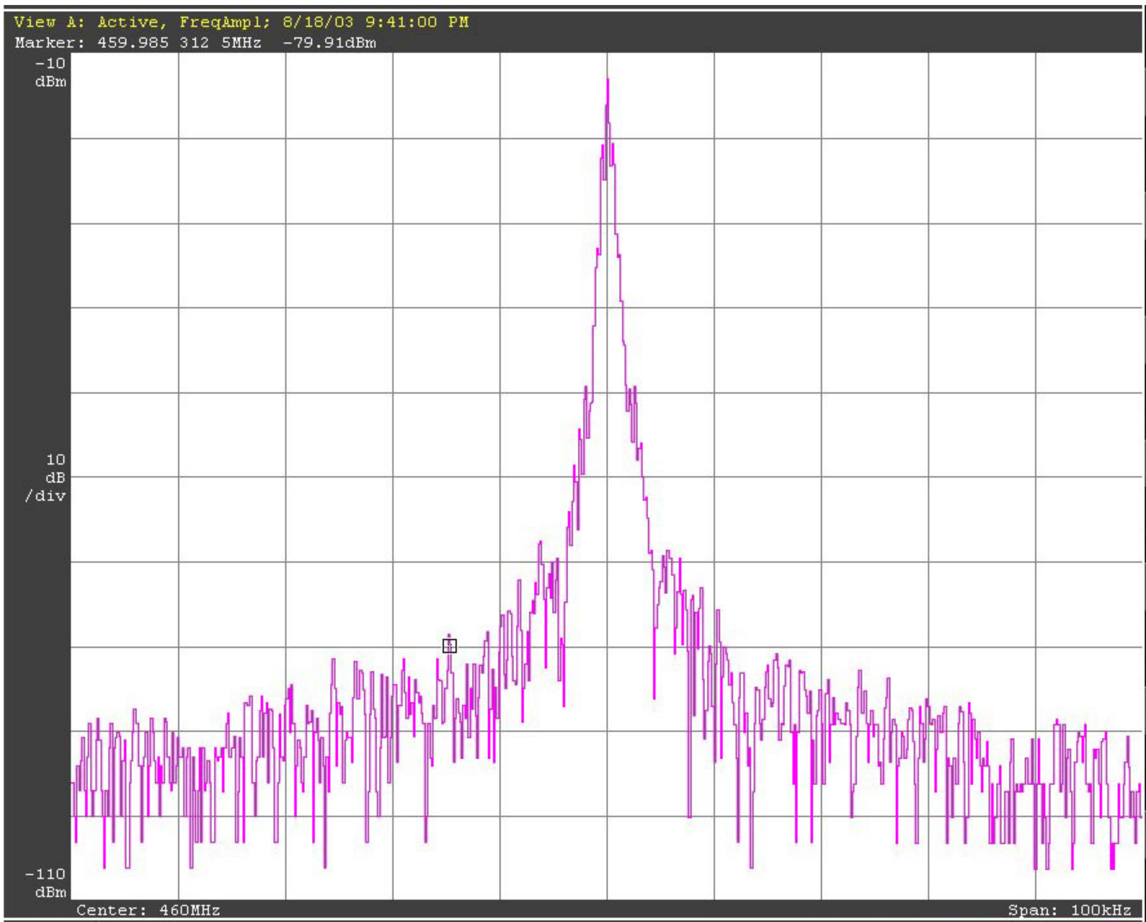
The Hexagram Meter Transmitting Unit transmitter, LLB 6327W, has been shown to be capable of complying with those requirements of the Federal Communications Commission for a Part 90 transmitter that are covered by this report.

EQUIPMENT UNDER TEST	MTU Transmitter, LLB 6327W
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Cleveland, OH 44122
TEST DATES	August 4 – September 24, 2003
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (440)526-4386

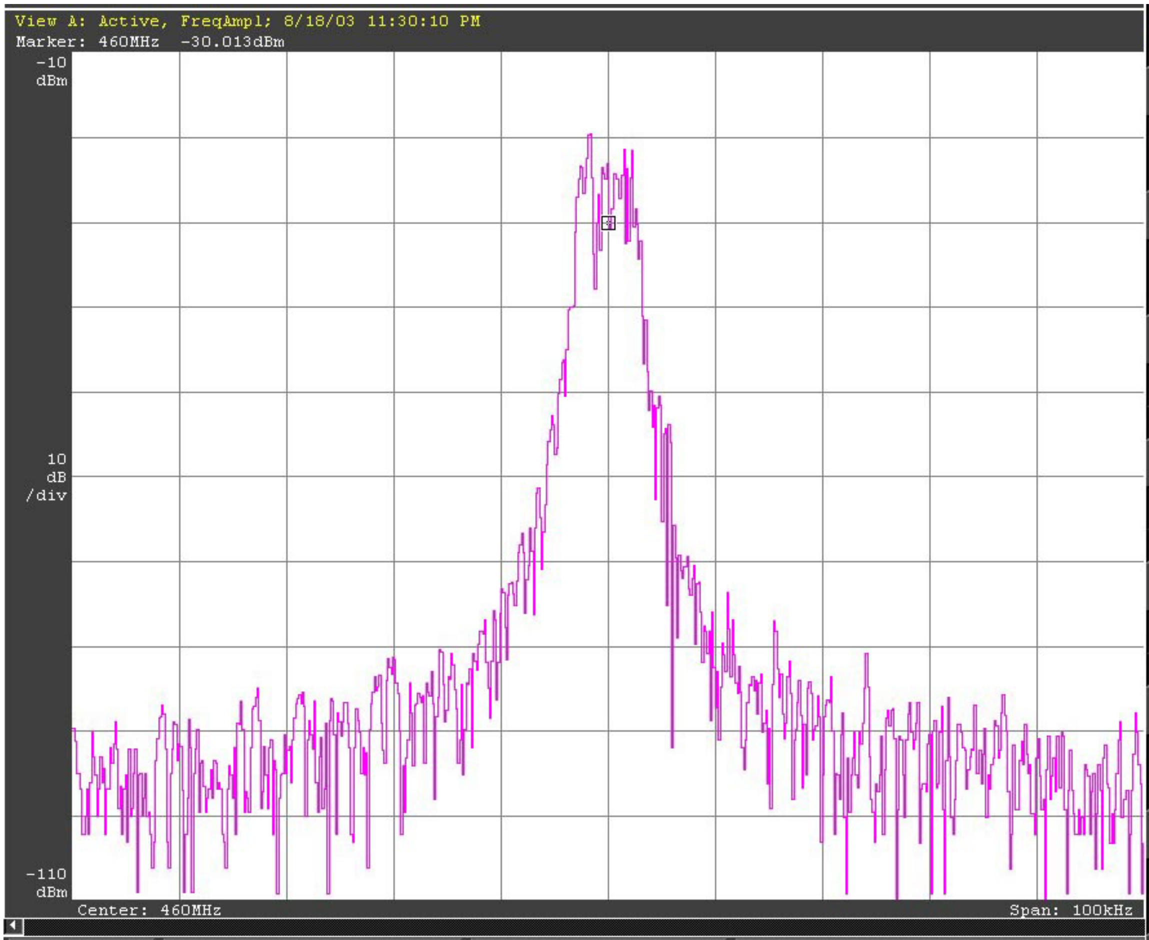
APPENDIX

APPENDIX

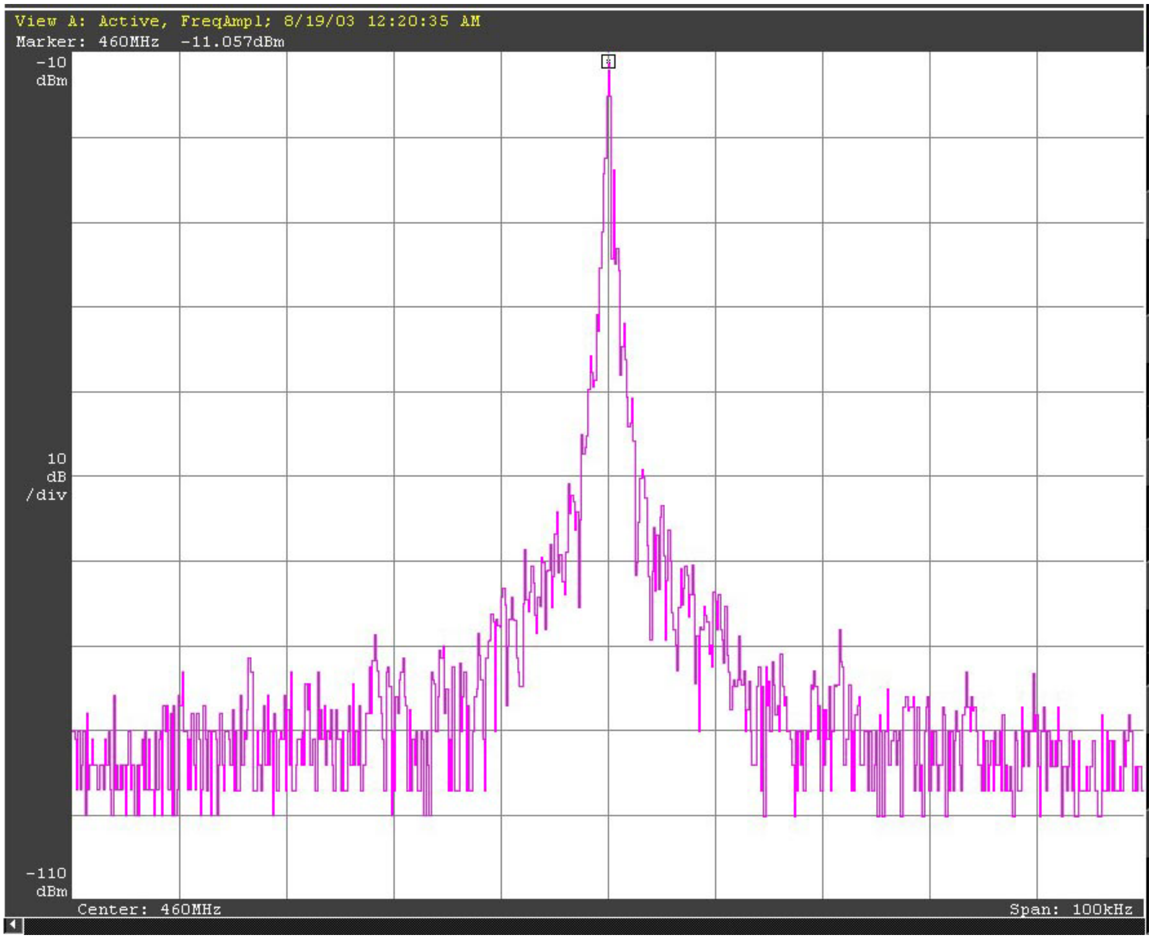
Unmodulated transmission w/o mask (Unit without wires)



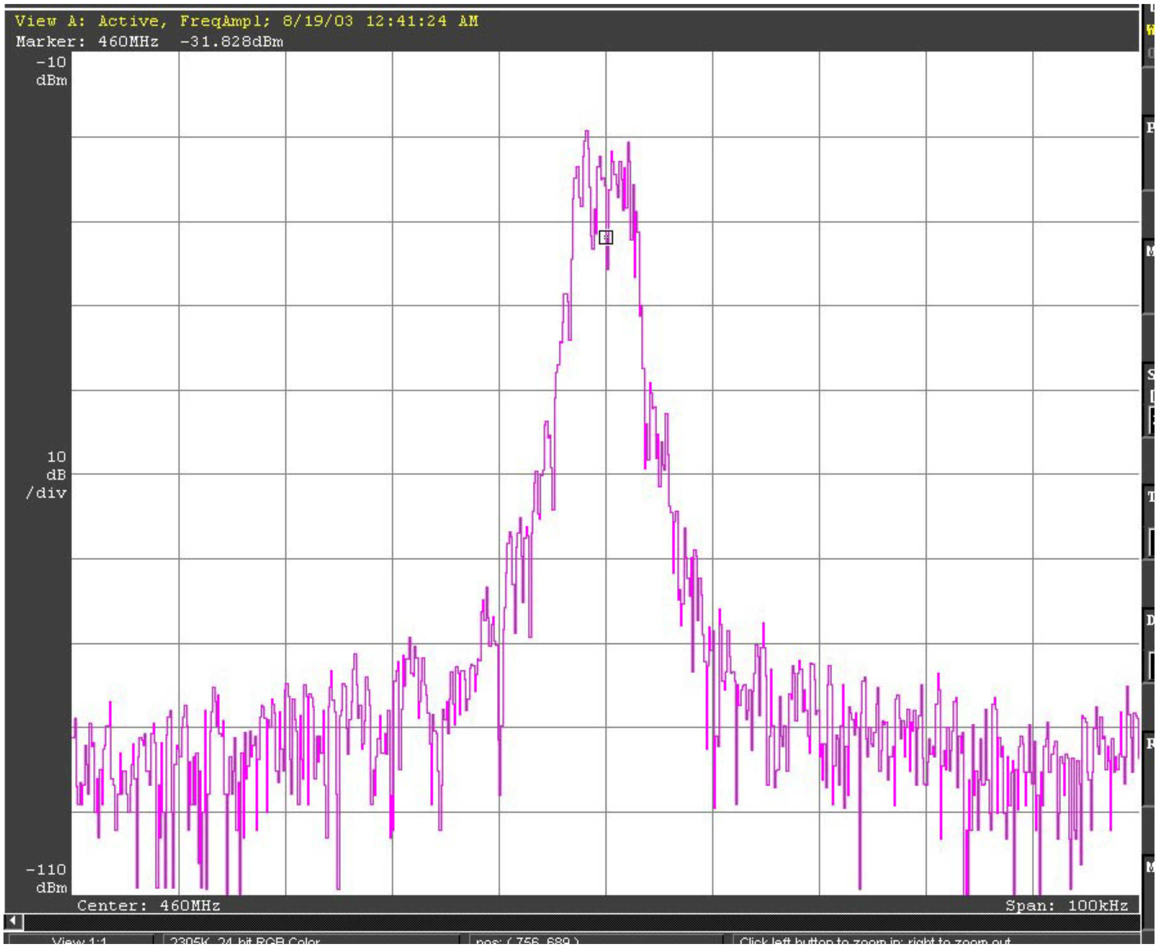
Modulated transmission w/o mask. (Unit without wires)



Unmodulated transmission w/o mask (Unit with external wires).



Modulated transmission w/o mask (Unit with external wires).



END.