SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

TRANSCEIVER

Model 9975J
FCC ID: LLB9975J

August 25, 2008

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TEST REPORT

INTRODUCTION

The Hexagram Model 9975J is a transceiver module currently designated for use in the companies Data Collector Units (DCU). The transceiver can be powered by a DC source between about 3 V and 13.8 V. For these tests a nominal 12 VDC sealed lead-acid battery was used.

The external antenna supplied with the transmitter will not exceed the ERP limits of 90.267(d)(2). One 9975J was tested and this report presents the worst case data obtained in support of an application for a grant of certification for a modular unit as required by 2.1043(a).

MEASUREMENTS PERFORMED

The receiver/digital device 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 receiver/digital device portion is presented in a separate report.

POWER OUTPUT AND SPURIOUS EMISSIONS

Measurements of the RF power output and spurious emissions were made at the antenna terminal per 2.1046 and 2.1051.

The output of the transmitter was connected to the spectrum analyzer through a 20 dB attenuator and 2 ft. of RG-214U coaxial cable. When activated, the transmitter was set to transmit continuously. When a reading was obtained, the transmitter was shut off and restarted before the next reading. The fundamental and harmonic emissions were observed and the signal strengths recorded for three test frequencies covering the tuning range of the transmitter. One spurious signal other than harmonics was noted at about 2.51 GHz.

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 maximum signal level observed was 32.5 dBm. This level would require attenuation of 52.5 dBm or more. The signal level of all harmonics greater than the fourth were in the noise of the analyzer and may be less than the reported values. The non-harmonic spurious signals were above the noise floor and are reported in the tables.

The determined power outputs, the required harmonic attenuation as well as the attenuation for each harmonic are found in Table 1.

TABLE 1a
HEXAGRAM MODEL 9975J TRANSMITTER OUTPUT POWER AND SPURIOUS EMISSIONS DIRECT MEASUREMENT 450 MHz

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Dipole Eq. Power (dBm)	Difference (dB)
450.0	32.4	0.1	32.5	**(52.5 Req.)**
900.0	-27.5	0.1	-27.4	-59.9
1350.0	-31.9	0.2	-31.7	-64.2
1800.0	-34.3	0.2	-34.1	-66.6
2250.0	-36.0	0.2	-35.8	-68.3
2515.8	-24.6	0.3	-24.3	-56.8
2700.0	-36.9	0.3	-36.6	-69.1
3150.0	-34.3	0.3	-34.0	-66.5
3600.0	-34.0	0.3	-33.7	-66.2
4050.0	-33.5	0.3	-33.2	-65.7
4500.0	-33.4	0.4	-33.0	-65.5

32.5 dBm = 1.778W
Required Attenuation = 50 + log(1.778) = 52.5 dB

TABLE 1b
HEXAGRAM MODEL 9975J TRANSMITTER OUTPUT POWER AND SPURIOUS EMISSIONS DIRECT MEASUREMENT

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Dipole Eq. Power (dBm)	Difference (dB)
460.0	32.2	0.1	32.3	**(52.3Req.)**
920.0	-27.3	0.1	-27.2	-59.5
1380.0	-31.0	0.2	-30.8	-63.1
1840.0	-34.8	0.2	-34.6	-66.9
2300.0	-36.2	0.2	-36.0	-68.3
2510.8	-25.3	0.3	-25.0	-57.3
2760.0	-36.7	0.3	-36.4	-68.7
3220.0	-34.5	0.3	-34.2	-66.5
3680.0	-34.6	0.3	-34.3	-66.6
4140.0	-34.3	0.3	-34.0	-66.3
4600.0	-34.4	0.4	-34.0	-66.3

32.3 dBm = 1.698W
Required Attenuation = 50 + log(1.698) = 52.3 dB

TABLE 1c
HEXAGRAM MODEL 9975J TRANSMITTER OUTPUT POWER AND SPURIOUS EMISSIONS DIRECT MEASUREMENT

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Dipole Eq. Power (dBm)	Difference (dB)
470.0	31.5	0.1	31.6	**(51.6 Req.)**
940.0	-28.3	0.1	-28.2	-59.8
1410.0	-30.5	0.2	-30.3	-61.9
1880.0	-36.8	0.2	-36.6	-68.2
2350.0	-36.7	0.2	-36.5	-68.8
2505.8	-25.7	0.3	-25.4	-57.7
2820.0	-35.0	0.3	-34.7	-67.0
3290.0	-34.0	0.3	-33.7	-66.0
3760.0	-34.4	0.3	-34.1	-66.4
4230.0	-32.5	0.4	-32.1	-64.4
4700.0	-35.2	0.4	-34.8	-67.1

31.6 dBm = 1.445W
Required Attenuation = 50 + log(1.445) = 51.6 dB

EQUIVALENT POWER OF SPURIOUS EMISSIONS

Using the power measurements of the fundamental described in the previous section as the reference, measurement of the harmonic emissions was made using the substitution method of TIA/EIA 603. These measurements were made with a 50 Ohm dummy load connected to the transmitter output.

All measurements below 1 GHz were made on the Smith Electronics open area test site located at 8200 Snowville Road, Brecksville, OH. Data pertinent to this site is on file with the FCC (90938) and Industry Canada (4541A-1).

Measurements below 1000 MHz were made at a three-meter test distance with frequencies above 1000 MHz being measured at 1 meter over a suitable ground plane. A tuned dipole was used for receiving below 1000 MHz and a wave guide antenna was used above 1000 MHz. A spectrum analyzer was used as a receiver.

The transmitter was placed on a remotely rotatable, non-conducting test stand. This general set up is shown in Pictorial 1. Under normal operation, transmissions from the 9975J will be less than 1 second. Due to the firmware available and in order to optimize the measurement process, the transmitter was instructed to transmit continuous signal until shut off.

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. After the position for the maximum signal was determined, the transmitter was shut off and allowed to cool. After a suitable time, the transmitter was re-started and the signal strength measurement made. Measurements were made with the antennas positioned both vertically and horizontally and the maximum signal recorded.

Peak detection with some video filtering was used for all measurements of this test. The video filtering reduces the effect of noise and permits more accurate measurements of the lower level signals.

After the maximum received meter readings were obtained for each frequency and polarity, the transmitter 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 and the receive antenna positioned for maximum reception. The signal generator output was then adjusted until the received signal from the antenna was equal to the previously received signal from the unit under test. These measurements were repeated for each frequency and antenna orientation.

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

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

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. Cable loss refers to the cable between the generator and its antenna.

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 2a – 2c.

Pictorial 1
Test Set-Up

TABLE 2a
HEXAGRAM MODEL 9975J TRANSMITTER
SPURIOUS EMISSIONS
SUBSTITUTION METHOD
450 MHz

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
450.0	32.4	0.1	n/a	32.5*	**(52.5 Req.)**
900.0	-26.0	3.0	-0.7	-29.7	-62.2

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1350.0	-53.3	1.7	5.5	-49.5	-82.0
1800.0	-41.0	2.1	5.9	-37.2	-69.7
2250.0	-57.5	2.4	6.8	-53.1	-85.6

* Direct measurement from antenna terminal

32.5 dBm = 1.78 W
Required attenuation for harmonics is 50 + 10log (1.78) = 52.5 dB

All harmonic emissions not shown (up to the tenth) are more than 30 dB below the required attenuation.

TABLE 2b
HEXAGRAM MODEL 9975J TRANSMITTER
SPURIOUS EMISSIONS
SUBSTITUTION METHOD
460 MHz

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
460.0	32.2	0.1	N/A	32.3*	**(52.3 Req).**
920.0	-30.0	3.0	-0.6	-33.6	-65.9

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
1380.0	-56.9	1.8	5.6	-53.1	-85.4
1840.0	-38.6	2.1	5.9	-34.8	-67.1
2300.0	-58.0	2.4	7.0	-53.4	-85.7
2760.0	-60.3	2.7	7.7	-55.3	-87.6
3220.0	-43.8	3.0	7.8	-39.0	-71.3

* Direct measurement from antenna terminal

32.3 dBm = 1.70 W
Required attenuation for harmonics is 50 + 10log (1.70) = 52.3 dB

All harmonic emissions not shown (up to the tenth) are more than 30 dB below the required attenuation.

TABLE 2c
HEXAGRAM MODEL 9975J TRANSMITTER
SPURIOUS EMISSIONS
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)
470.0	31.5	0.1	N/A	31.6*	**(51.6 Req)**
940.0	-33.0	3.1	-0.6	-36.7	-68.3

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
1410.0	-57.6	1.8	5.7	-53.7	-85.3
1880.0	-33.5	2.1	5.9	-29.7	-61.3
2350.0	-61.0	2.4	7.2	-56.2	-87.8
2820.0	-65.0	2.7	7.7	-60.0	-91.6
3290.0	-54.5	3.0	7.8	-49.7	-81.3

* Direct measurement from antenna terminal

31.6 dBm = 1.45
Required attenuation for harmonics is 50 + 10log (1.45) = 51.6 dB

All harmonic emissions not shown (up to the tenth) are more than 30 dB below the required attenuation.

TEST EQUIPMENT USED
(Power, Spurious and Conducted Emissions)

Spectrum Analyzer	Rohde & Schwarz FSL6 Spectrum Analyzer SN: 100602 Calibration Due:: 3-11-09
Antennas	(2x) ETS-Lindgren Tuned Dipole 3121D-4 Frequency Range 400 – 1000 MHz
	(2x)ETS-Lindgren 3115 Double Ridged Guide Horn Frequency Range 1 – 18 GHz
Signal Generator	Hewlett-Packard Model 8340B, S/N 3010A01889 Calibration Due 5/09
Miscellaneous	12.2 m RG-214/U coaxial cable
	6.1 m RG-214/U coaxial cable
	22.5 m LMR-400 coaxial cable
	0.6 m RG-214/U coaxial cable
	1.8 m RG-214/U coaxial cable
	Bird Model 25-A-MFN-20 20 db attenuator
	Bird 50 Ohm dummy load

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 9975J 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 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 the maximum P was determined to be 1.78 W, 50 + 10 log(1.78) equals 52.5 dB.

Both modulated and unmodulated transmissions were stored on the spectrum analyzer display. The plot of Fig. 4 shows both signals with Mask D superimposed on the plot. The plot indicates that the modulated emission does comply with the requirement for occupied bandwidth as found in 90.210.

For purposes of this test, the modulated signal was FSK modulated with a PN9 sequence at the specified 1200 bits per second data rate.

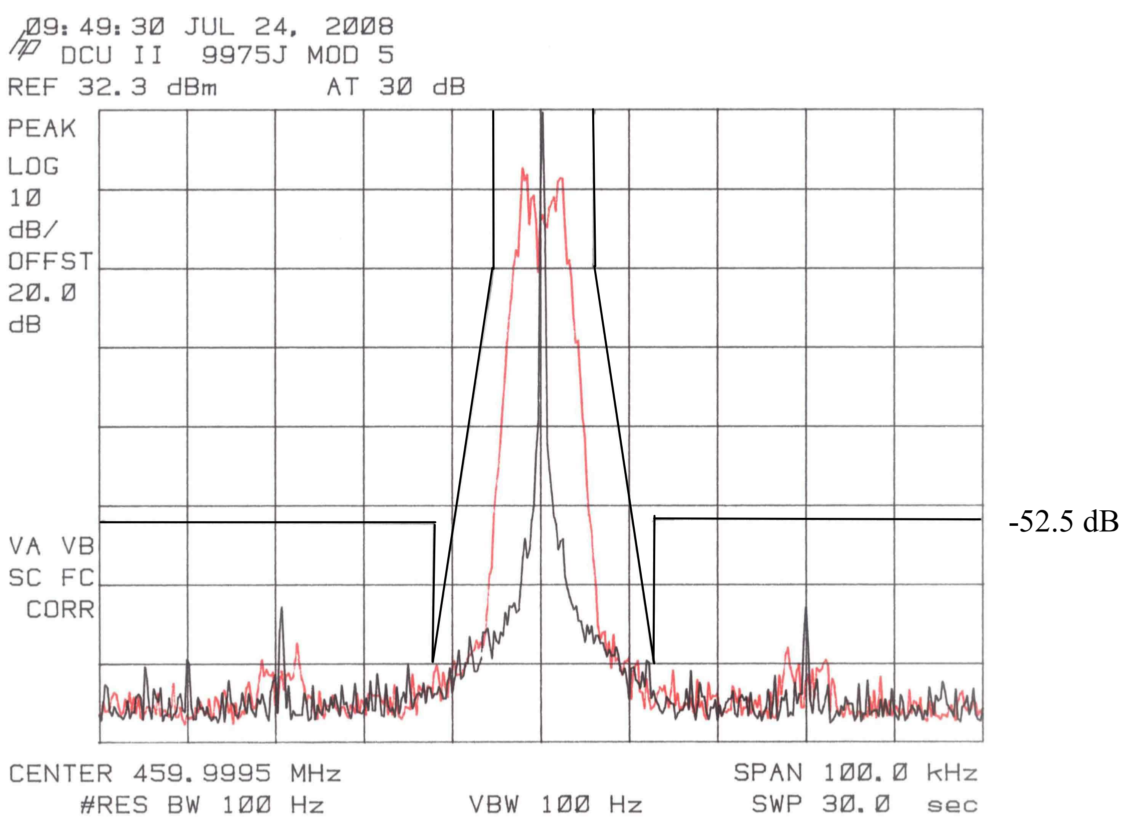

Fig. 1
Hexagram Model 9975J Transceiver
Emissions Mask

TEST EQUIPMENT USED
(Occupied Bandwidth)

Spectrum Analyzer

Hewlett-Packard 8593EM
Calibration Due: 7/08.

FREQUENCY STABILITY VS. TEMPERATURE

The temperature stability of the frequency generating components of the transmitter was observed. The DCU II was placed in a temperature chamber with the RF output connected to a spectrum analyzer through an attenuator and coaxial cable.. The transmitter was turned on when a frequency reading was desired.

With the transmitter programmed to transmit at 460 MHz, the chamber temperature was set to 20° C. After reaching the set temperature, the transmitter was allowed to stabilize for about 15 minutes or more. The transmission signal was captured by the spectrum analyzer and the frequency was determined. The "reference" frequency is considered the tuned frequency of 460.000000MHz. The temperature in the chamber was then decreased to -30° C. At each new temperature, time was allowed for stabilization of the transmitter, a transmission was made and the frequency determined. The temperature was then increased in 10°C increments up to 70°C, checking the frequency at each 10° point. The frequency at each temperature was recorded, compared to the "reference" frequency, and is recorded in Table 4 It can be seen from the table that all readings are within the deviation limit of ±2.5 ppm

TABLE 3
9975J FREQUENCY STABILITY
VS. TEMPERATURE

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	459.999906	-94	-0.204
-30	459.999906	-94	-0.204
-20	459.999944	-56	-0.122
-10	459.999844	-156	-0.339
0	459.999813	-187	-0.407
+10	459.999813	-187	-0.407
+20	459.999844	-156	-0.339
+30	459.999844	-156	-0.339
+40	460.000031	+31	+0.067
+50	459.999969	-31	-0.067
+60	459.999906	-94	-0.204
+70	459.999906	-94	-0.204

Reference frequency= 460.000000 MHz

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 charging voltage of 13.8 VDC. Measurements were made at 11.7 VDC, 13.8 VDC and 15.9 VDC. With the voltage set to a measurement point, the transmitted signal was captured by the spectrum analyzer and the frequency value determined. The frequencies are compared to the "reference" tuned frequency of 460.000000 MHz. All data for these measurements are found in Table 5. Again, it can be seen that all values obtained are within the deviation limit of ±2.5 ppm.

TABLE 4
9975J FREQUENCY STABILITY
VS. SUPPLY VOLTAGE

INPUT DC Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
11.7	459.999880	-120	-0.26
13.8	459.999880	-120	-0.26
15.9	459.999880	-120	-0.26

"Reference Frequency" = 460.000000 MHz

TEST EQUIPMENT USED
(Frequency Stability)

Spectrum Analyzer	.Tektronix WC2A Comm. Analyzer S/N: J300168 Calibration Due: 7/09. Rohde & Schwarz FSL6 Spectrum Analyzer SN: 100602 Calibration Due:: 3-11-09
Antennas	None, signal sent directly by cable
DC Power Supply	RSR Model 1410-SP-503E DC Supply
Thermometer	Chamber temperature sensor
Digital Volt Meter	Fluke Model 75
Temperature Chamber	Test Equity Model 1007H Calibration Due: 2/10 .

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 at the end of the transmission.

The Model 9975J transmitter was tested for transient frequency behavior using the test method of TIA/EIA-603. A block diagram of the test setup is seen in Fig. 2. 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 test signal was at least 50 dB below the received signal level from the 9975J.

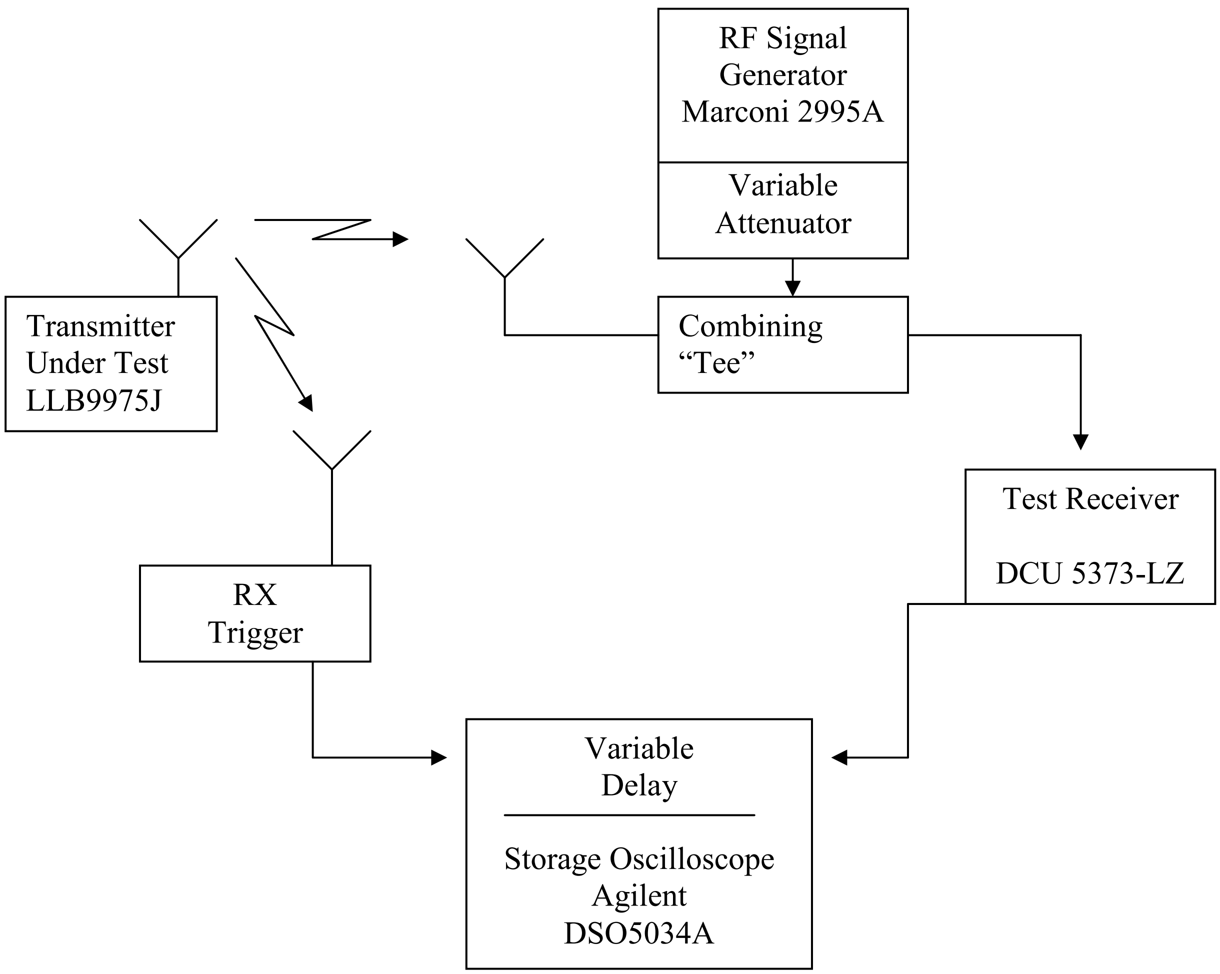

Fig. 2
Transient Frequency Behavior
Test Setup

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.

Test Data

Figures 3 through 7 show the Model 9975J's transient frequency characteristics. The limit masks are indicated on each of the figures.

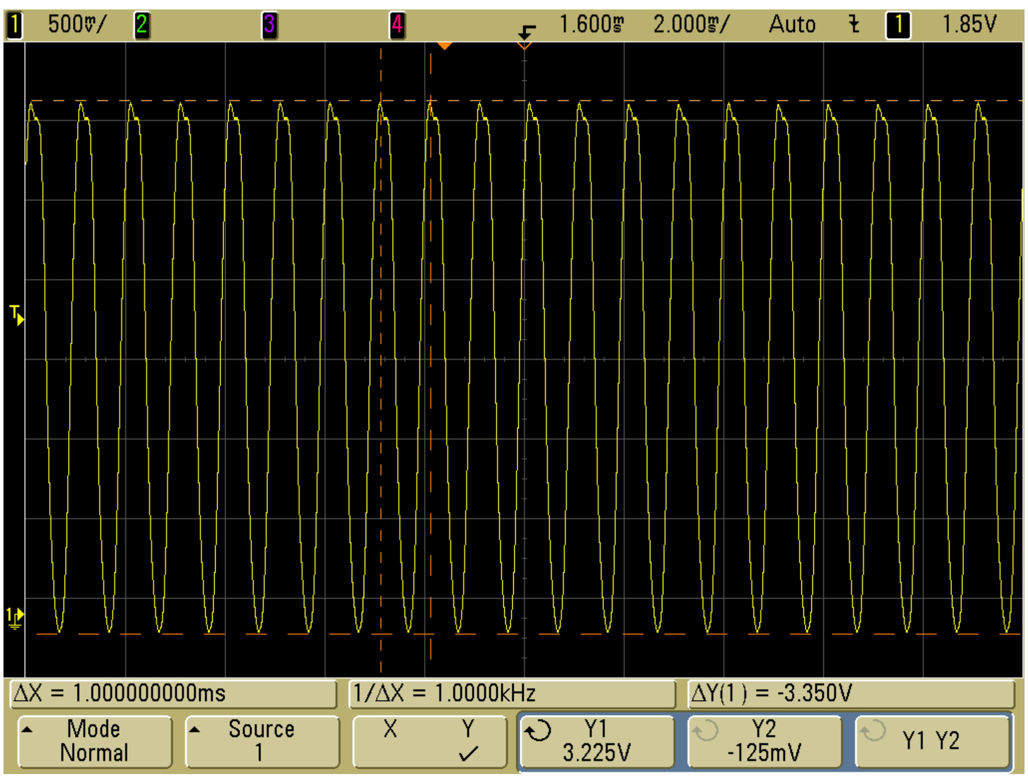

Fig. 3 ±12.5 kHz modulated test signal 25 kHz = 3.35 V.

6.25 kHz = 838 mV
1.15 kHz = 154 mV

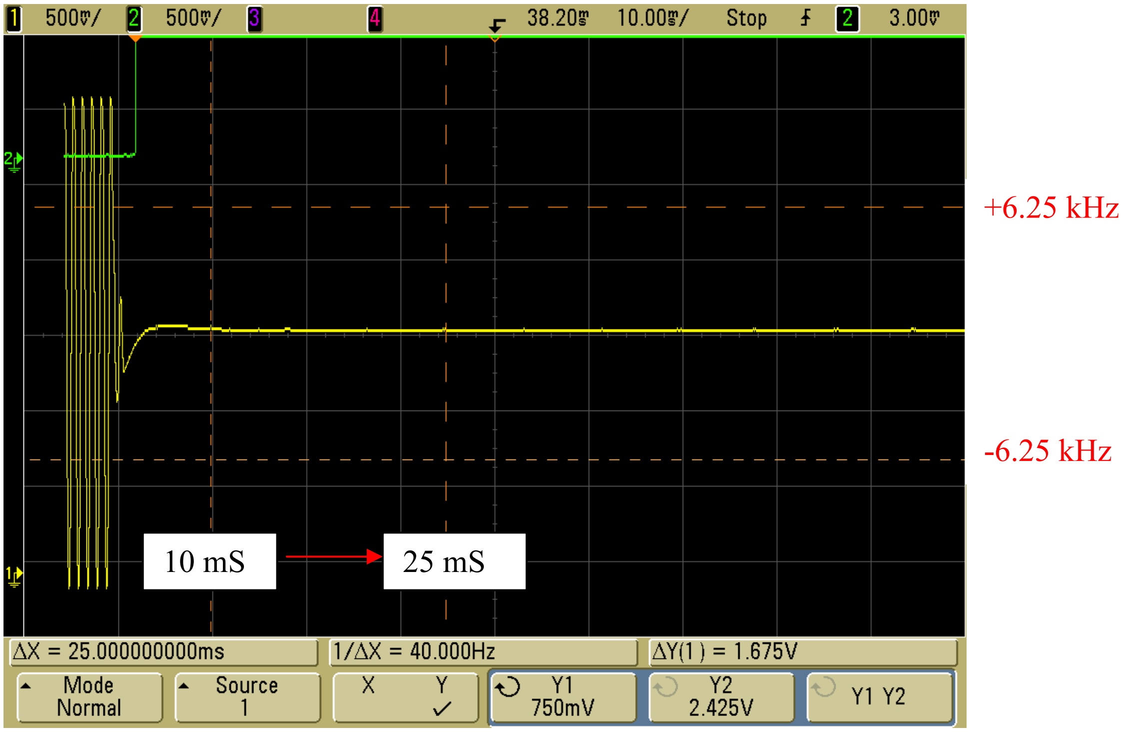

Fig. 4 Start of Transmission

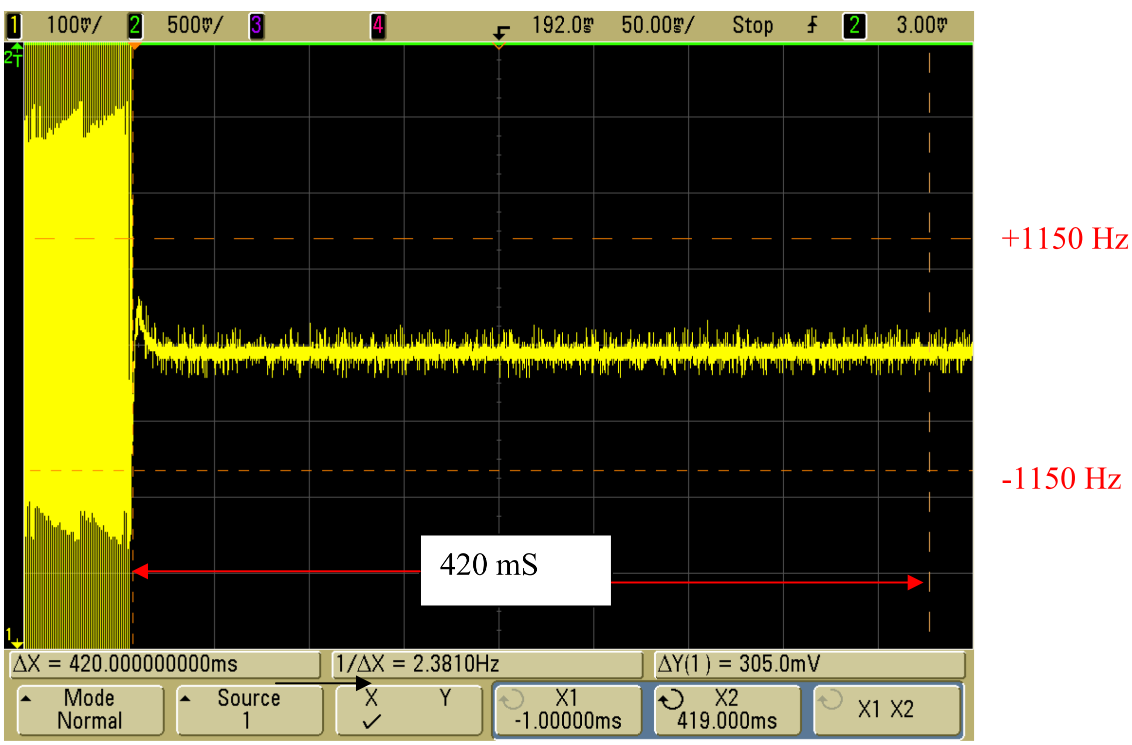

Fig. 5 Full Transmission*

* Available software did not permit a typical, short, unmodulated signal. Transmissions would normally have a length of no more than 200 – 300 ms. This figure indicates that the signal remains within the ±1150 Hz limitation for at least 420 ms.

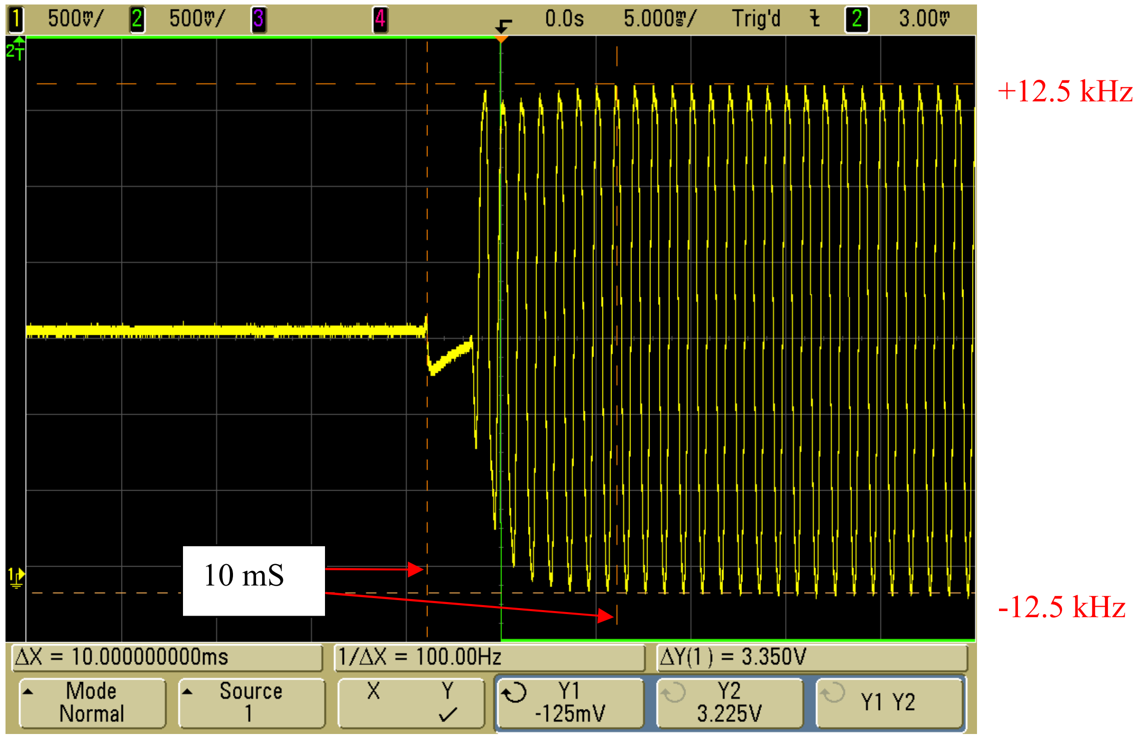

Fig. 6   Turn Off Transient

The modulated signal appears well within the allowed 10 ms and does not exceed ±12.5 kHz within or beyond 10 ms.

TEST EQUIPMENT USED
(Transient Performance)

Signal Generator	Marconi Model 2955A Calibration Due: 3/09
Test Receiver	Hexagram DCU-1 (Modified)
Oscilloscope	Agilent Model DSO5034A S/N MY47150518 Calibration Due: 3/09
RF Trigger	Hexagram Detector Circuit

TEST INFORMATION

SUMMARY

The Hexagram Meter Transmitting Unit transmitter, Model 9975J has been shown to be capable of complying with those requirements of the Federal Communications Commission for a Part 90 transmitter module that are covered by this report.

EQUIPMENT UNDER TEST	Transceiver, Model 9975J
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Cleveland, OH 44122
TEST DATES	July 24 – August 25, 2008
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (440)526-4386 Mail Address: 2730 Old Mill Rd. Hudson, OH 44236