SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

S-4
METER TRANSMITTING UNIT (MTU)
with RECEIVER

Model 9845
FCC ID: LLB9845

April 19, 2006

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TEST REPORT

INTRODUCTION

The Hexagram Model 9845 transceiver is a designed to provide remote meter reading capability with the Landis & Gyr "S-4" family of electric meters. The transceiver is connected to the meter circuitry and mounts within the meter enclosure. An on-board battery provides power when AC power is not available. 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. The receiver can be used to request a meter reading or other options available in the system. One transmitter was tested and this report presents the data obtained in support of an application for certification.

MEASUREMENTS PERFORMED

The microprocessor and receiver portions of the transceiver were also examined for radiated emissions per Part 15, and have been verified to comply with the appropriate sections of that part. The data used for verification of the microprocessor and receiver is presented in a separate report.

POWER OUTPUT AND SPURIOUS EMISSIONS

Within the tuning range of 450 – 470 MHz, the transmitter portion was examined at three fundamental frequencies and their harmonics. All measurements below 1 GHz were made at a 3-meter distance 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 and Industry Canada. The harmonic measurements above 1 GHz were made at a distance of 1 meter over a suitable ground plane. The measurements were made using the substitution method described in TIA/EIA-603-A.

Tuned dipoles were used for measurements 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. 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 these 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.

Peak detection 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 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. With the signal detected, the receiving antenna was positioned for maximum reception. The signal generator output was then adjusted until the received signal was equal to the previously 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.

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 in dBm, P_g is the generator output into the substitution antenna, also in dBm, 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.

PICTORIAL 1
HEXAGRAM MODEL 9845 MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 1a
HEXAGRAM MODEL 9845 TRANSMITTER
SUBSTITUTION METHOD

Horizontal 3 meter measurement using tuned dipole antenna

Freq. (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
450	28.7	1.1	0	27.6	
900	-25.0	1.7	0	-26.7	-54.3

Output = 27.6Bm
= 0.575 W
Req. Att.= 47.6Bm

Horizontal 1 meter measurement using horn antenna

Freq. (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1350	-38.9	0.8	3.1	-36.6	-64.2
1800	-42.1	1.0	4.9	-38.2	-65.8
2250	-44.8	1.2	5.6	-40.4	-68.0
2700	-50.6	1.3	6.2	-45.7	-73.3
3150	-43.4	1.5	6.7	-38.2	-65.8
3600	-53.0	1.7	6.6	-48.1	-75.7
4050	-45.7	1.9	6.5	-41.1	-68.7
4500	-44.7	2.1	7.2	-39.6	-67.2

Vertical 3 meter measurement using tuned dipole antenna

Freq. (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
450	18.5	1.1	0	17.4	
900	-34.0	1.7	0	-35.7	-53.1

Output = 17.4 dBm
= 0.055 W
Req. Att.= 37.4 dBm

Vertical 1 meter measurement using horn antenna

Freq. (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1350	-43.5	0.8	3.1	-41.2	-58.6
1800	-43.5	1.0	4.9	-39.6	-57.0
2250	-41.7	1.2	5.6	-37.3	-54.7
2700	-48.8	1.3	6.2	-43.9	-61.3
3150	-38.0	1.5	6.7	-32.8	-50.2
3600	-47.1	1.7	6.6	-42.2	-59.6
4050	-45.0	1.9	6.5	-40.4	-57.8
4500	-45.3	2.1	7.2	-40.2	-57.6

TABLE 1b
HEXAGRAM MODEL 9845 TRANSMITTER
SUBSTITUTION METHOD

Horizontal 3 meter measurement using tuned dipole antenna

Freq. (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
460	26.8	1.1	0	25.7	
920	-27.0	1.7	0	-28.7	-54.4

Output = 25.7 dBm
= 0.372 W
Req. Att.= 45.7 dBm

Horizontal 1 meter measurement using horn antenna

Freq. (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1380	-35.6	0.8	3.1	-33.3	-59.0
1840	-33.9	1.0	4.9	-30.0	-55.7
2300	-43.9	1.2	5.6	-39.5	-65.2
2760	-57.0	1.4	6.2	-52.2	-77.9
3220	-41.5	1.6	6.7	-36.4	-62.1
3680	-53.8	1.7	6.6	-48.9	-74.6
4140	-53.8	1.9	6.5	-49.2	-74.9
4600	-44.4	2.1	7.2	-39.3	-65.0

Vertical 3 meter measurement using tuned dipole antenna

Freq. (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
460	16.5	1.1	0	15.4	
920	-37.9	1.7	0	-39.6	-55.0

Output = 15.4 dBm
= 0.035W
Req. Att.= 35.4 dBm

Vertical 1 meter measurement using horn antenna

Freq. (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1380	-38.4	0.8	3.1	-36.1	-51.5
1840	-35.8	1.0	4.9	-31.9	-47.3
2300	-41.2	1.2	5.6	-36.8	-52.2
2760	-55.0	1.4	6.2	-50.2	-65.6
3220	-39.2	1.6	6.7	-34.1	-49.5
3680-	-50.5	1.7	6.6	-45.6	-61.0
4140	-48.6	1.9	6.5	-44.0	-59.4
4600	-44.5	2.1	7.2	-39.4	-54.8

TABLE 1c
HEXAGRAM MODEL 9845 TRANSMITTER
SUBSTITUTION METHOD

Horizontal 3 meter measurement using tuned dipole antenna

Freq. (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
469	25.5	1.1	0	24.4	
938	-27.1	1.7	0	-28.8	-53.2

Output = 24.4 dBm
= 0.2754 W
Req. Att.= 44.4 dBm

Horizontal 1 meter measurement using horn antenna

Freq. (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1407	-38.8	0.8	3.1	-36.5	-60.9
1876	-33.6	1.0	4.9	-29.7	-54.1
2345	-40.6	1.2	5.6	-36.2	-60.6
2814	-50.2	1.4	6.2	-45.4	-69.8
3283	-41.0	1.6	6.7	-35.9	-60.3
3752	-56.0	1.8	6.6	-51.2	-75.6
4221	-46.9	1.9	6.5	-42.3	-66.7
4690	-44.3	2.1	7.2	-39.2	-63.6

Vertical 3 meter measurement using tuned dipole antenna

Freq. (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
469	16.9	1.1	0	15.8	
938	-38.1	1.7	0	-39.8	-55.6

Output = 15.8 dBm
= 0.038 W
Req. Att.= 35.8 dBm

Vertical 1 meter measurement using horn antenna

Freq. (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1407	-45.4	0.8	3.1	-43.1	-58.9
1876	-34.3	1.0	4.9	-30.4	-46.2
2345	-38.2	1.2	5.6	-33.8	-49.6
2814	-52.2	1.4	6.2	-47.4	-63.2
3283	-36.1	1.6	6.7	-31.0	-46.8
3752	-51.4	1.8	6.6	-46.6	-62.4
4221	-48.2	1.9	6.5	-43.6	-59.4
4690	-42.7	2.1	7.2	-37.6	-53.4

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Spectrum Analyzer Model 8563A S/N 3020A00248 Calibrated 12/05
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 12/05
Miscellaneous	12.2 m RG-214/U coaxial cable
	6.1 m RG-214/U coaxial cable
	2.4 m RG-8/U coaxial cable
	1.8 m RG-/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 9845 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 the maximum P was determined to be 0.575 W, 50 + 10 log(0.575) equals 47.6 dB.

Both modulated and unmodulated transmissions were stored on the spectrum analyzer display. The plot of Fig. 1 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 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.

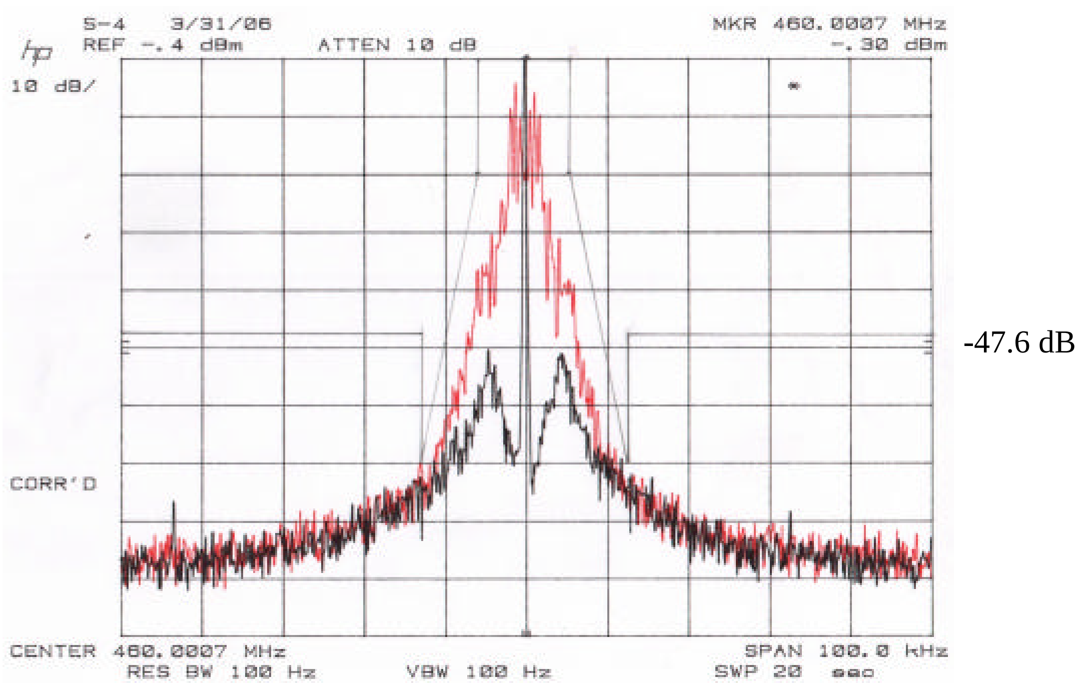

Fig. 1
Hexagram Model 9845 MTU
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard 8568B with 85680A RF Section S/N: 2216A02120 85662A Display Section SN: 2152A03683 Calibration 11/05
Antenna	EMCO Model 3146 Log Periodic Frequency Range 200 MHz – 1000 MHz

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 with the battery-powered transmitter set to transmit at intervals of about 2 minutes. 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 462 MHz, the chamber temperature was set to 20° 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 considered the "reference" frequency. The temperature in the chamber was then increased 85° C. At each temperature, time was allowed for stabilization of the transmitter, a transmission was made and the frequency determined. The temperature was decreased to 80° C, and then in 10° steps to -30° C, again stabilizing at each 10° interval before a reading was made. The frequency at each temperature was recorded, compared to the "reference" frequency, and is recorded in Table 2. It can be seen from the table that all readings are within the deviation limit of ±2.5 ppm or 1155 Hz at 462 MHz.

TABLE 2
FREQUENCY STABILITY
VS. TEMPERATURE

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	462.001875*	0	0
+85	462.002188	+313	+0.68
+80	462.001875	0	0
+70	462.001875	0	0
+60	462.001875	0	0
+50	462.001875	0	0
+40	462.001875	0	0
+30	462.001875	-0	0
+20	462.001875	0	0
+10	462.002188	+313	0
-0-	462.002188	+313	0.68
-10	462.002313	+438	++0.95
-20	462.002000	+125	+0.27
-30	462.002313	+438	+0.68

* = "reference frequency"

FREQUENCY STABILITY VS. SUPPLY VOLTAGE

As the primary power source for the transmitter is the AC line that powers the electric meter, the frequency stability of the transmitted signal was measured at the nominal 115 Volt level as well as at 115% and 85% of that level. In the event of a power outage, the on-board battery provides power to the transmitter. Because of this, the transmitter was also checked with no AC applied and the DC voltage at a nominal 3.6 V as well as at 85% of that value.

For the AC frequency stability test, a variable voltage AC supply was connected to the AC input of the transmitter. The transmitted frequency was checked at the nominal 115 V level. The frequency was also measured at 115% (132.3 V) and at 85% (97.8 V) of the nominal value.

For the DC test, the AC power was removed and the battery replaced by a variable DC supply. The frequency was measured at both the nominal 3.60 V of the battery and at the 85% level or 3.06 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 frequencies are compared to the “reference” frequency obtained at the nominal operating voltage. All data for these measurements are found in Table 3. Again, it can be seen that all values obtained are within the deviation limit of ±2.5 ppm or 1150 Hz at the 460 MHz test frequency.

TABLE 3
FREQUENCY STABILITY
VS. SUPPLY VOLTAGE

INPUT Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
97.8 VAC	460.002344	0	0
115 VAC	460.002344*	0	0
132.3 VAC	460.002344	0	0
3.60 VDC	460.002344*	0	0
3.06 VDC	460.002344	0	0

* = “reference frequency”

Note: Transmitter tuned to 460 MHz.

TEST EQUIPMENT USED

Real-Time Spectrum Analyzer	Tektronix/Sony Model 3086 S/N J300195 Calibration 5/05
Antenna	EMCO 3146 LPA
DC Power Supply	Harrison Laboratories, Inc. Model 8028 Twin Low Voltage Power Supply
Thermometer	Cooper Instrument Corp. Model SRH 77A Calibration 1/06
AC Power Supply	Superior Electric Type 1226 Powerstat
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 at the end of the transmission.

The Model 9845 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 9845.

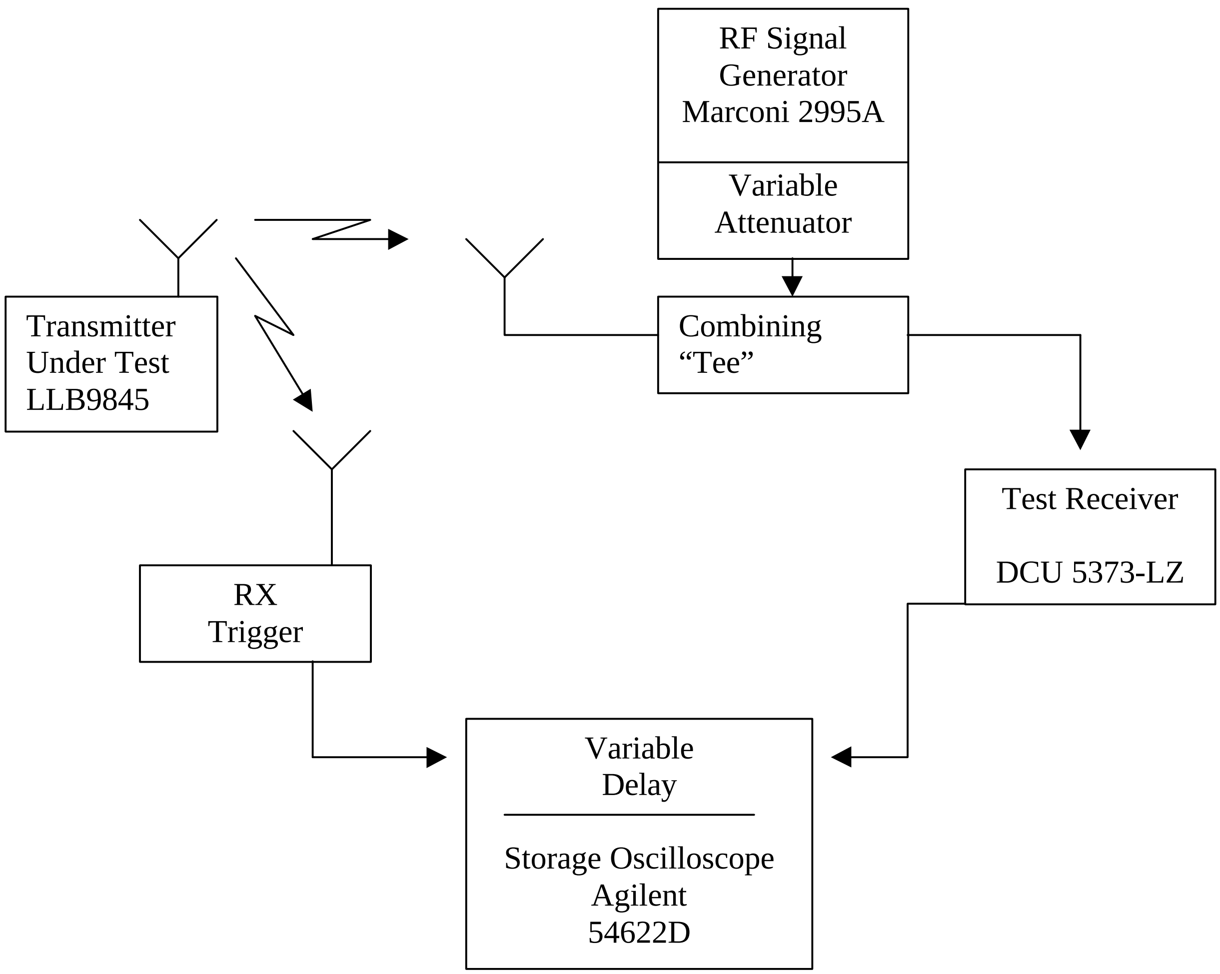

Fig. 2
Transient Frequency Behavior
Test Setup

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 9845's transient frequency characteristics. The limit masks are indicated on each of the figures.

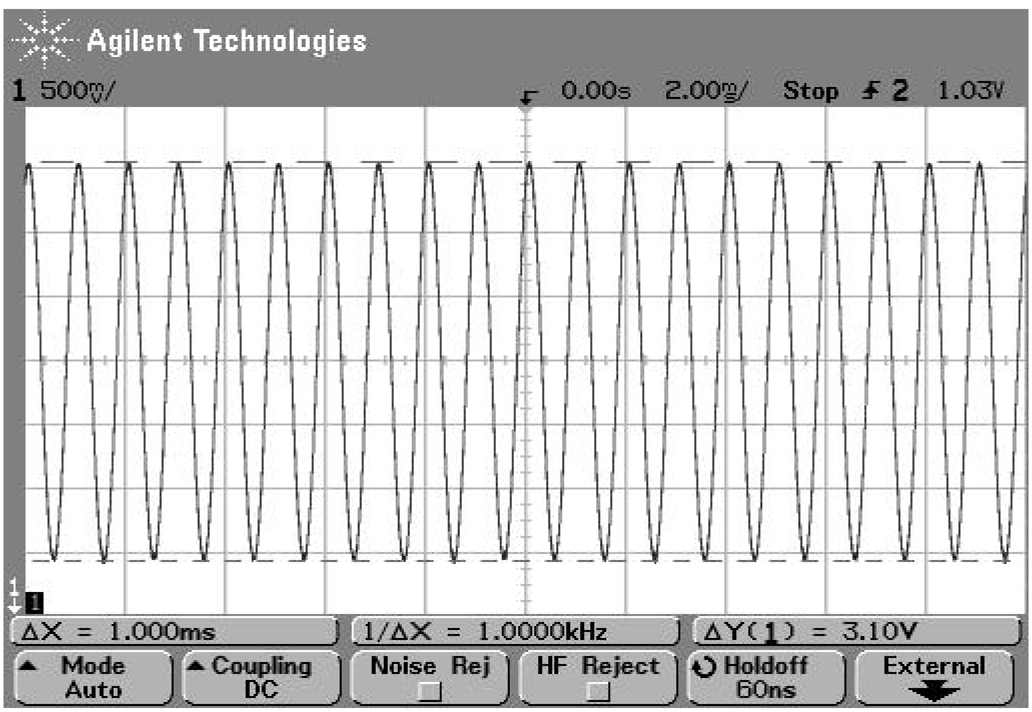

Fig. 3   ±12.5 kHz modulated test signal   25 kHz = 3.10 V.

6.25 kHz = 775 mV
1.15 kHz = 143 mV

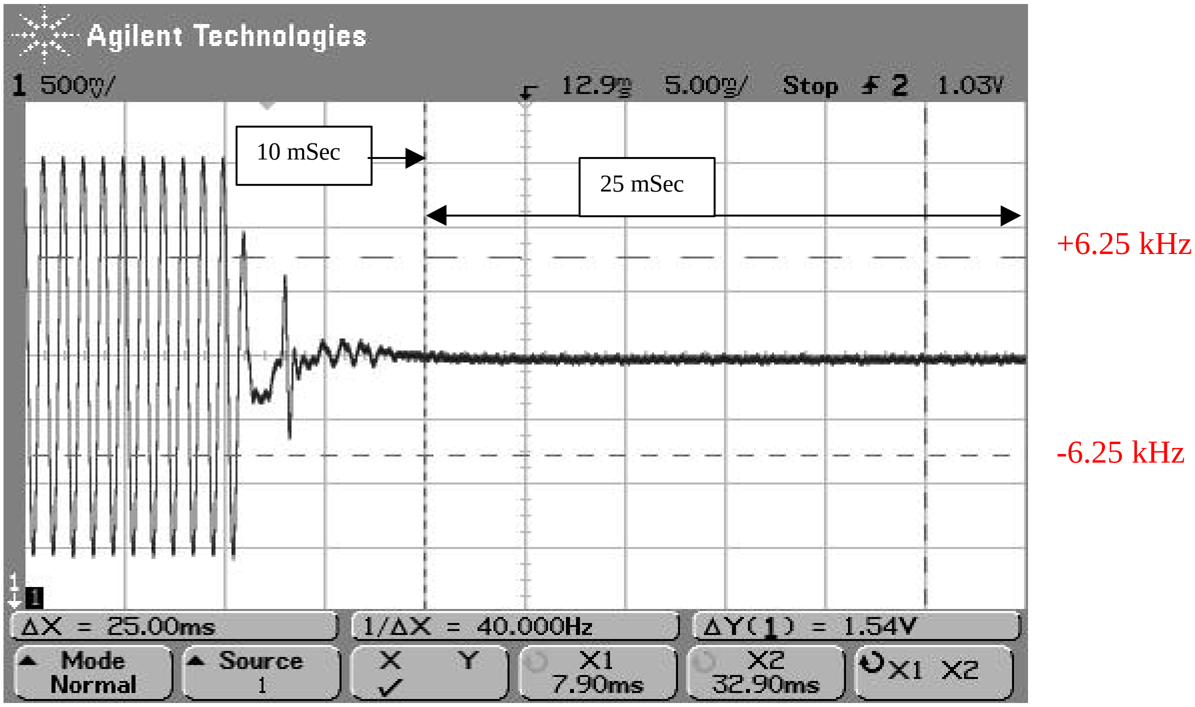

Fig. 4 Start of Transmission

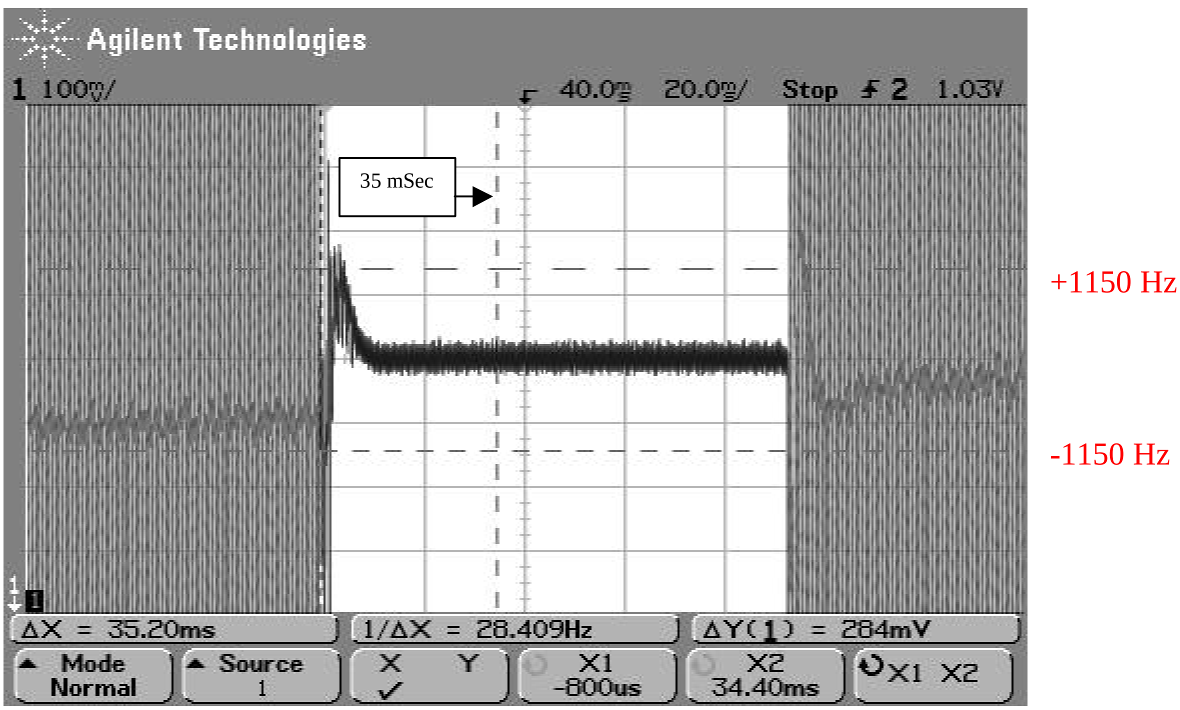

Fig. 5 Full Transmission

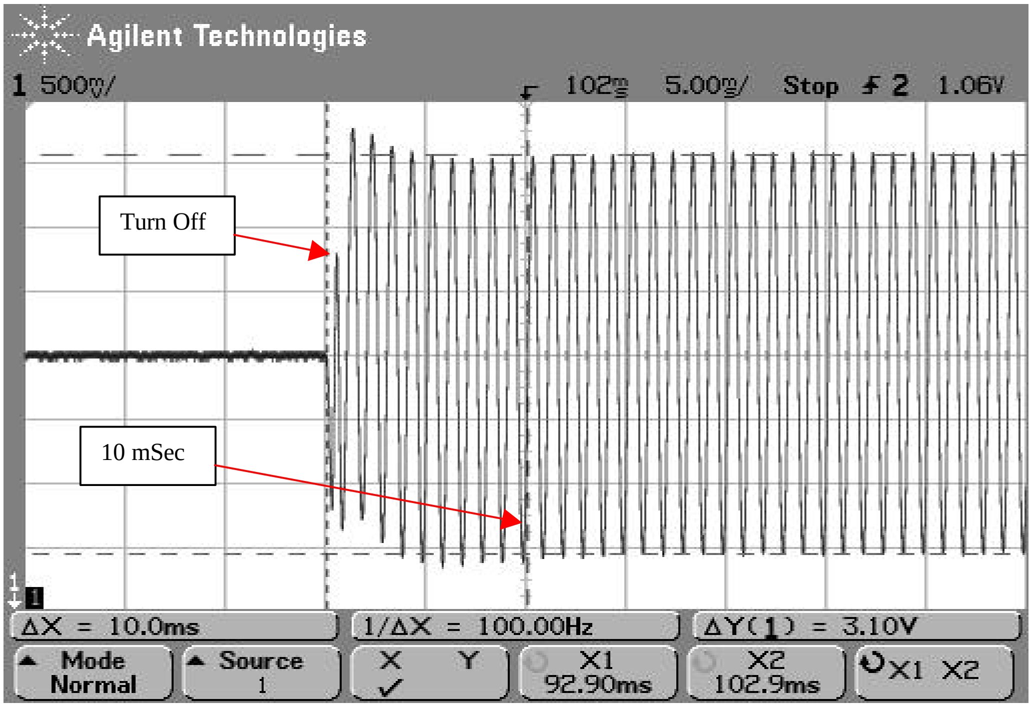

Fig. 6   Turn Off Transient

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

TEST EQUIPMENT USED

Signal Generator	Marconi Model 2955A Calibration 12/05
Test Receiver	Hexagram DCU-1 (Modified)
Oscilloscope	Agilent Model 54622D S/N MY40006228 Calibration 12/05
RF Trigger	Hexagram Detector Circuit

TEST INFORMATION

SUMMARY

The Hexagram Model 9845 transmitter 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, Model 9845
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Cleveland, OH 44122
TEST DATES	March 29 – April 14, 2006
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (440)526-4386