HEXAGRAM INC.
An ESCO Technologies Company
30400 Solon Road
Solon OH 44139
(440) 528-7200

ENGINEERING TEST REPORT

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

METER TRANSMITTING UNIT

Model 2009-002
FCC ID: LLB09002

September 15, 2009

Report Prepared by

James R. Pollock

James R. Pollock
Agency Certification Control Technician

TEST REPORT

INTRODUCTION

The Hexagram Model 2009-002 transceiver is a “Meter Transmitting Unit” (MTU) designed to provide remote reading capability for water leakage when connected to an acoustic sensor. This MTU is designed to be mounted at ground level, under the cap of a vertical pipe accessing the water line being monitored. The transceiver is self-powered with an on-board battery pack and connects to the sensor output with an electrical cable. The transmitter provides a short, intermittent radio frequency transmission to send data logged by the sensor. 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 section can be used for upgrading firmware, requests for meter reads or other options available in the system. 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 FCC 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 of the Model 2009-002 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 (Reg. #90938) and Industry Canada (File #4541A-1). 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. A ferrite bead was placed on the battery leads to minimize emissions that might come from the leads.

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 signals 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 vertically 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.

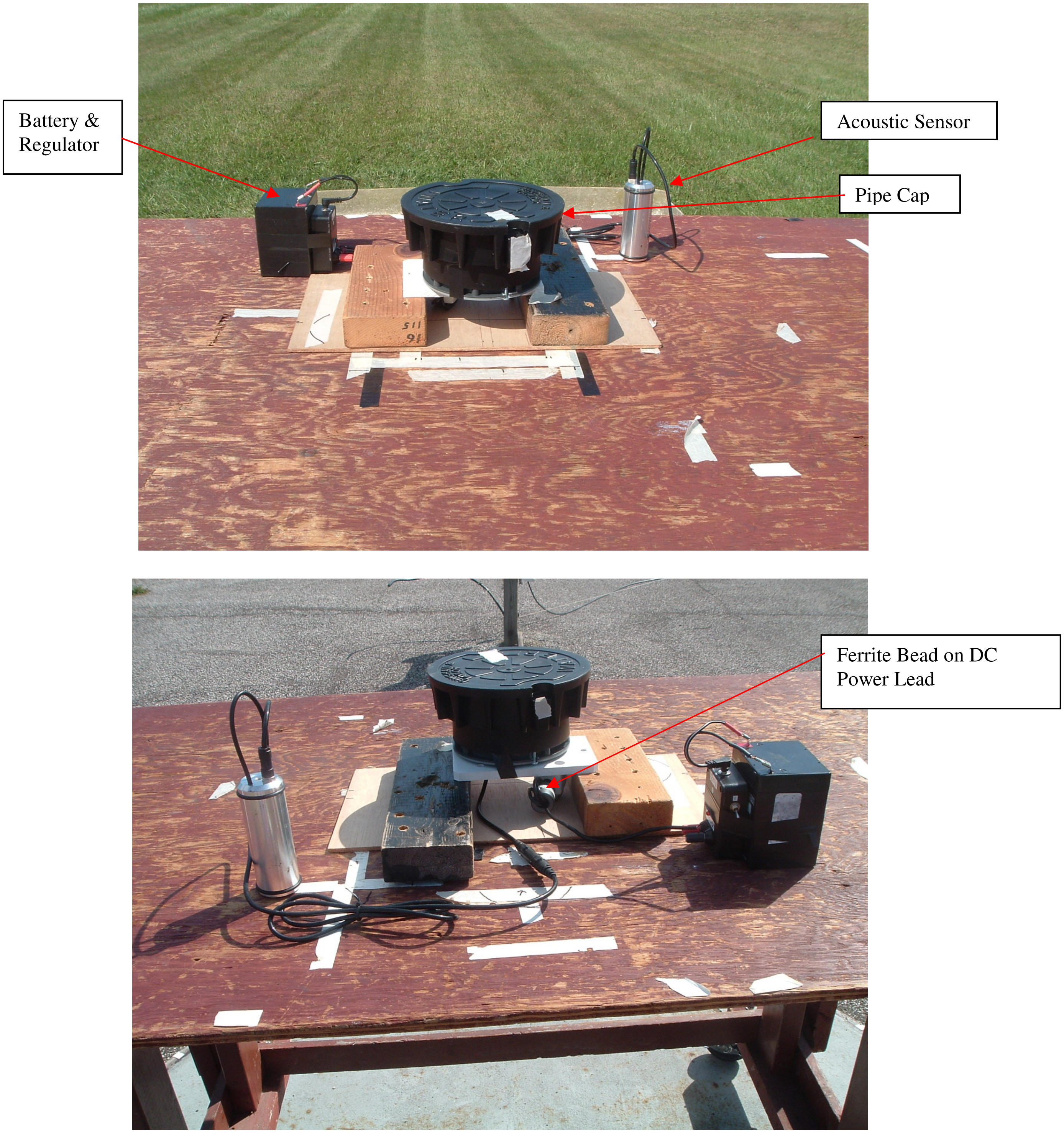
In order to convert the signal generator output value to equivalent radiated power from a dipole, the following equation is used:

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

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 theoretical 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 2009-002 MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 1a
HEXAGRAM MODEL 2009-002 TRANSMITTER
SUBSTITUTION METHOD
450 MHz

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	14.4	2.0	-0.4	12.0	
900	-27.8	2.9	-0.7	-31.4	-43.4

Output = 12.0 dBm
= 0.016 W
Req. Att.= 32.0 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)
1350	-32.7	0.8	5.5	-28.0	-40.0
1800	-39.0	1.0	5.9	-34.1	-46.1
2250	-59.1	1.2	6.8	-53.5	-65.5
2700	-55.7	1.3	7.7	-49.3	-61.3
3150	-52.6	1.4	7.8	-46.2	-58.2
3600	-36.4	1.6	7.8	-30.2	-42.2
4050	-41.1	1.7	7.7	-35.1	-47.1
4500	-63.9	1.8	8.3	-57.4	-69.4

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	21.9	2.0	-0.4	19.5	
900	-23.1	2.9	-0.7	-26.7	-46.2

Output = 19.5dBm
= 0.089 W
Req. Att.= 39.5 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	-30.6	0.8	5.5	-25.9	-45.4
1800	-42.5	1.0	5.9	-37.6	-57.1
2250	-56.1	1.2	6.8	-50.5	-70.0
2700	-61.7	1.3	7.7	-55.3	-74.8
3150	-54.5	1.4	7.8	-48.1	-67.6
3600	-38.7	1.6	7.8	-32.5	-52.0
4050	-48.7	1.7	7.7	-42.7	-62.2
4500	-60.5	1.8	8.3	-54.0	-73.5

TABLE 1b
HEXAGRAM MODEL 2009-002 TRANSMITTER
SUBSTITUTION METHOD
460 MHz

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	13.5	2.1	-0.4	11.0	
920	-27.7	3.0	-0.6	-31.3	-42.3

Output = 11.0 dBm
= 0.013 W
Req. Att.= 31.0 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	-33.0	0.9	5.6	-28.3	-39.3
1840	-40.3	1.0	5.9	-35.4	-46.4
2300	-58.7	1.2	7.0	-52.9	-63.9
2760	-56.8	1.3	7.7	-37.8	-61.4
3220	-53.5	1.4	7.8	-46.9	-57.9
3680	-42.5	1.6	7.7	-36.4	-47.4
4140	-40.6	1.7	7.8	-34.5	-45.5
4600	-52.2	1.8	8.4	-45.6	-56.6

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)
460	19.9	2.1	-0.4	17.4	
920	-22.2	3.0	-0.6	-25.8	-43.2

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)
1380	-31.0	0.9	5.6	-26.3	-43.7
1840	-46.2	1.0	5.9	-41.3	-58.7
2300	-57.0	1.2	7.0	-51.2	-68.6
2760	-61.7	1.3	7.7	-55.3	-72.7
3220	-54.5	1.4	7.8	-48.1	-65.5
3680	-42.6	1.6	7.7	-36.5	-53.9
4140	-44.2	1.7	7.8	-38.1	-55.5
4600	-51.8	1.8	8.4	-45.2	-62.6

TABLE 1c
HEXAGRAM MODEL 2009-003 TRANSMITTER
SUBSTITUTION METHOD
470 MHz

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)
470	14.7	2.1	-0.4	12.2	
940	-26.9	3.0	-0.6	-30.5	-42.7

Output = 12.2 dBm
= 0.017 W
Req. Att.= 32.2 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)
1410	-31.6	0.9	5.7	-26.8	-39.0
1880	-37.7	1.0	5.9	-32.8	-45.0
2350	-59.1	1.2	7.2	-53.1	-65.3
2820	-55.7	1.3	7.7	-49.3	-61.5
3290	-47.3	1.5	7.8	-41.0	-53.2
3760	-37.3	1.6	7.7	-31.2	-43.4
4230	-42.7	1.7	7.9	-36.5	-48.7
4700	-52.6	1.8	8.4	-46.0	-58.2

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)
470	21.8	2.1	-0.4	19.3	
940	-20.1	3.0	-0.6	-23.7	-43.0

Output = 19.3 dBm
= 0.085W
Req. Att.= 39.3 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)
1410	-28.5	0.9	4.4	-25.0	-44.3
1880	-43.6	1.0	4.7	-39.9	-59.2
2350	-57.6	1.2	6.7	-52.1	-71.4
2820	-60.4	1.3	7.9	-53.8	-73.1
3290	-50.1	1.5	8.1	-43.5	-62.8
3760	-38.2	1.6	7.9	-31.9	-51.2
4230	-39.1	1.7	8.5	-32.3	-51.6
4700	-52.9	1.8	9.6	-45.1	-64.4

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Model 8593EM Spectrum Analyzer SN: 3536AO0147 Cal Due: 8/2010
Antennas	(2x) ETS-Lindgren Model DB-4 Tuned Dipole Frequency Range 400 – 1000 MHz
	(2x) ETS-Lindgren Model 3115 Double Ridged Guide Horn Frequency Range 0.75 – 18 GHz
Signal Generator	Hewlett-Packard Model 8340B, S/N 3010A01889 Cal Due: 6/2010
Miscellaneous	12.2 m RG-213/U coaxial cable
	22.5 m LMR-400 coaxial cable
	3.0 m RG-213/U coaxial cable
	3.0 m RG-213/U coaxial cable
Tests Performed	September 3 – 4, 2009

Unit Tested: 2009-002 Rev D MTU ID: 303

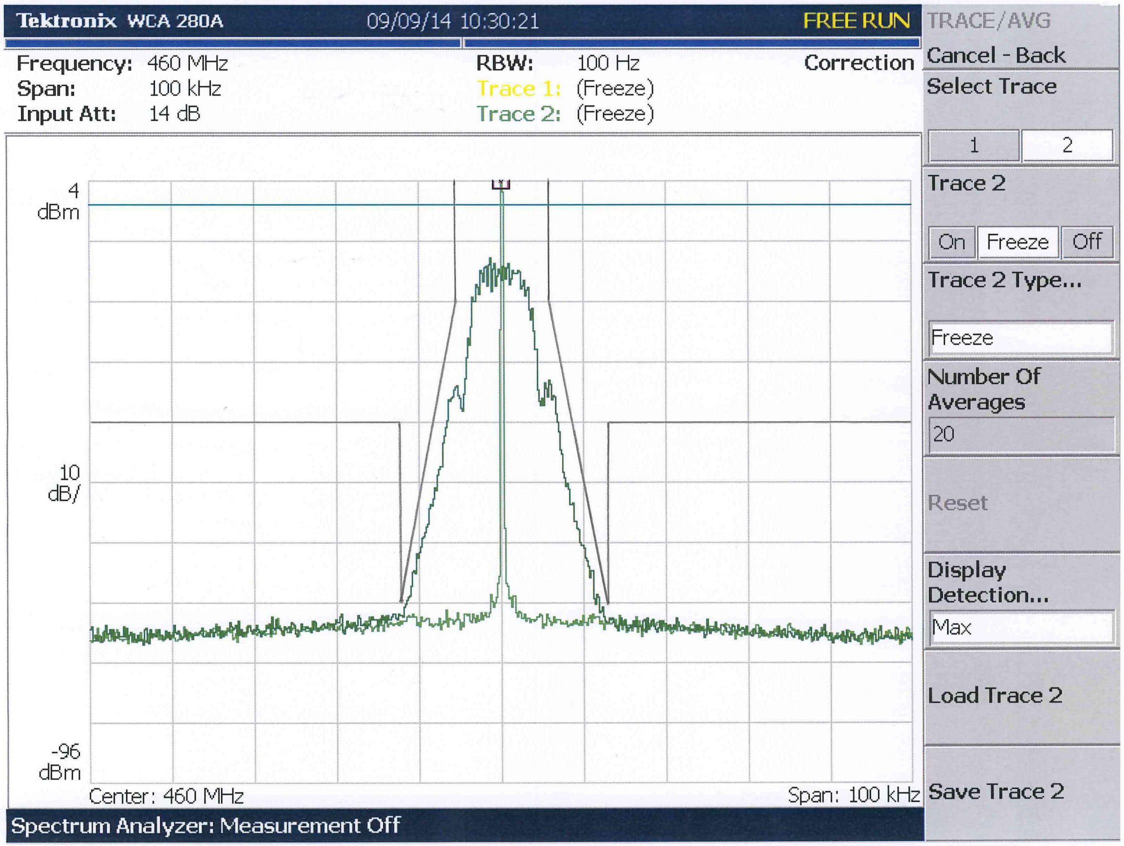
OCCUPIED BANDWIDTH

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 2009-002 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 0.089 W, 50 + 10 log(0.089) equals 39.5 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 PN9 modulated at the specified 7200 bits per second data rate.



Tektronix WCA 280A 09/09/14 10:30:21 FREE RUN

Frequency: 460 MHz
Span: 100 kHz
Input Att: 14 dB
RBW: 100 Hz
Trace 1: (Freeze)
Trace 2: (Freeze)
Correction

Center: 460 MHz
Span: 100 kHz

Trace 2 Type... Freeze
Number Of Averages 20
Display Detection... Max

Spectrum Analyzer: Measurement Off

Fig. 1
Hexagram Model 2009-002
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Tektronix Model WCA 280A SN: J300168 Cal Due: 7/2010
Antenna	Maxrad Model MUF4505 Whip antenna 450 – 470 MHz
Test Performed	September 14, 2009

Unit Tested: 2009-002 Rev D MTU ID: 303

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 a programming coil that allows a transmission to be requested from outside the chamber. 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 MHz, the chamber temperature was set to 20° C. After reaching the set temperature, the transmitter was allowed to stabilize. The transmitted signal was captured by the spectrum analyzer and the frequency was determined. The temperature in the chamber was then increased to 30° C. At each temperature, at least 20 minutes were allowed for stabilization of the transmitter, a transmission was made and the frequency determined. The temperature was increased in 10° C intervals to 80° C and then to 85° C. The temperature was then returned to 20° C. stabilized and the decreased to -30° C in 10° intervals. The temperature was stabilized at each 10° interval before a reading was made. The frequency at each temperature was recorded, compared to the 460 MHz tuned 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 1150 Hz at 460 MHz.

TABLE 2
FREQUENCY STABILITY
VS. TEMPERATURE
460 MHz

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	460.000156	156	+0.34
+30	460.000156	156	+0.34
+40	460.000156	156	+0.34
+50	460.000156	156	+0.34
+60	460.000156	156	+0.34
+70	460.000156	156	+0.34
+80	460.000156	156	+0.34
+85	460.000313	313	+0.68
+20	460.000156	156	+0.34
+10	460.000156	156	+0.34
0	460.000156	156	+0.34
-10	460.000313	313	+0.68
-20	460.000156	156	+0.34
-30	460.000000	0	+0.00
+20	460.000156	156	+0.34

Reference frequency = 460.000000 MHz

FREQUENCY STABILITY VS. SUPPLY VOLTAGE

To vary the DC test voltage, a variable DC source was connected to the transmitter, bypassing the battery. The frequency was measured at the TIA default standard of 7.50 V (2x3.75 V)of the Lithium Ion battery pack, and at, or below, the 85% level of 6.37 V.

With the voltage set to a measurement point, the transmitted signal was captured by a spectrum analyzer and the frequency value determined. The frequencies are compared to the tuned frequency. The 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
460 MHz

INPUT Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
7.5 VDC	460.000118	+118	+0.26
7.0 VDC	460.000098	+98	+0.21
6.5 VDC	460.000088	+88	+0.19
5.5 VDC	460.000078	+78	+0.17
5.0 VDC	460.000078	+78	+0.17
4.5 VDC	460.000078	+78	+0.17
4.0 VDC	460.000078	+78	+0.17
3.5 VDC	460.000029	+29	+0.06

Reference frequency = 460.000000 MHz

TEST EQUIPMENT USED

Spectrum Analyzer	Tektronix Model WCA 280 (Voltage) S/N J300168 Cal Due: 7/2010
	Sony/Tektronix Model 3086 (Temperature) Real time analyzer SN: J300195 Cal Due 6/2010
Antenna	Maxrad Model MUF4505 Whip 450 – 47- MHz
DC Power Supply	Mastech Model HY1503D SN: 0036790
Digital Multi-Meter	Fluke Model 179 Cal. Due: 5/2010
Thermometer	Cooper Model SRH77A SN: 460525 Cal Due: 6/2010
Temperature Chamber	Test Equity Model 1007H Cal. due: 2/2010
Tests Performed	Temperature September 9, 2009 Voltage September 8, 2009

Unit Tested: 2009-002 Rev D MTU ID: 303

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 2009-002 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 2009-002.

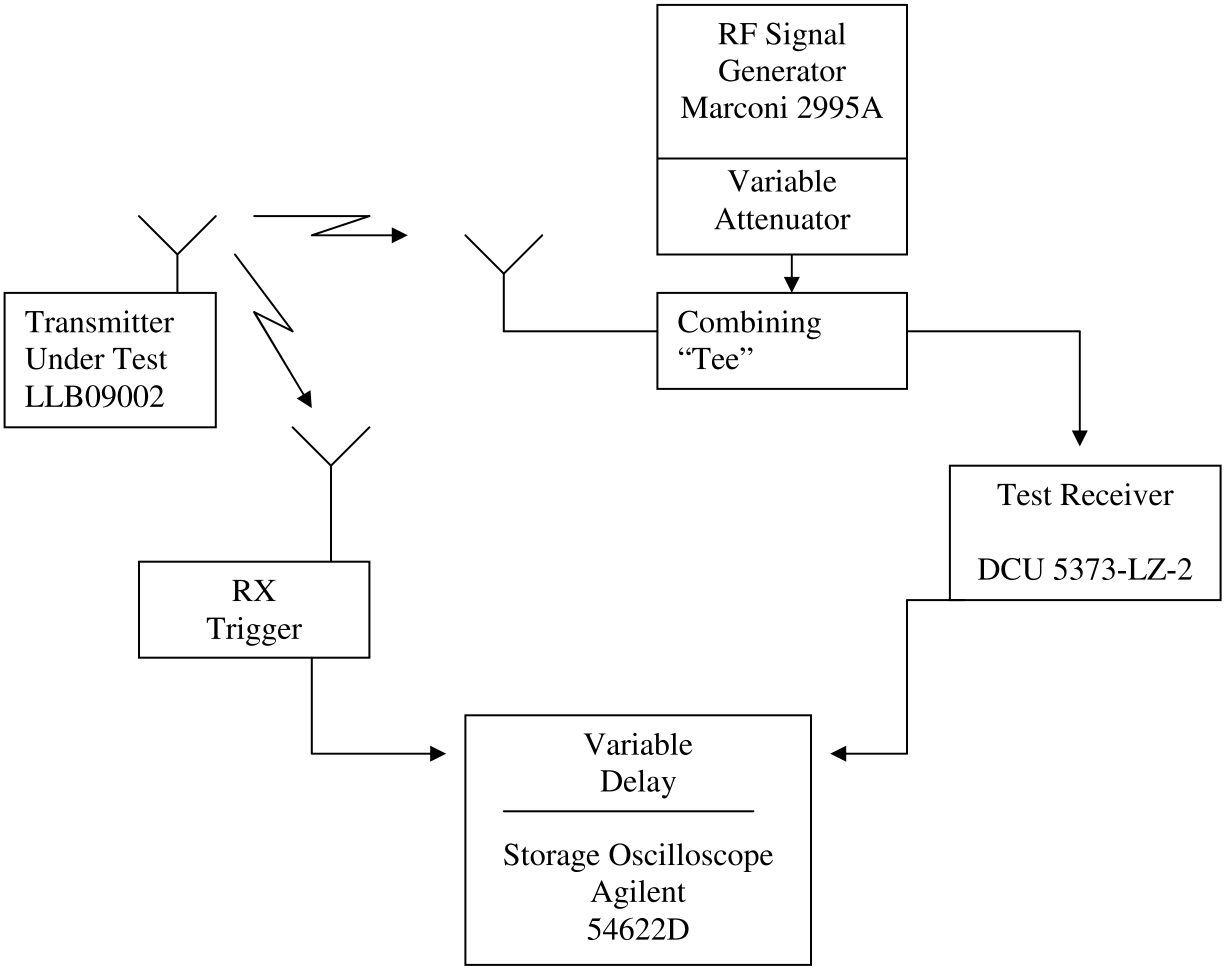


Fig. 2
Transient Frequency Behavior
Test Setup

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 than ±2.5 ppm, or ±1150 Hz at 460 MHz.

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 2009-002's transient frequency characteristics. The limit masks are indicated on each of the figures.

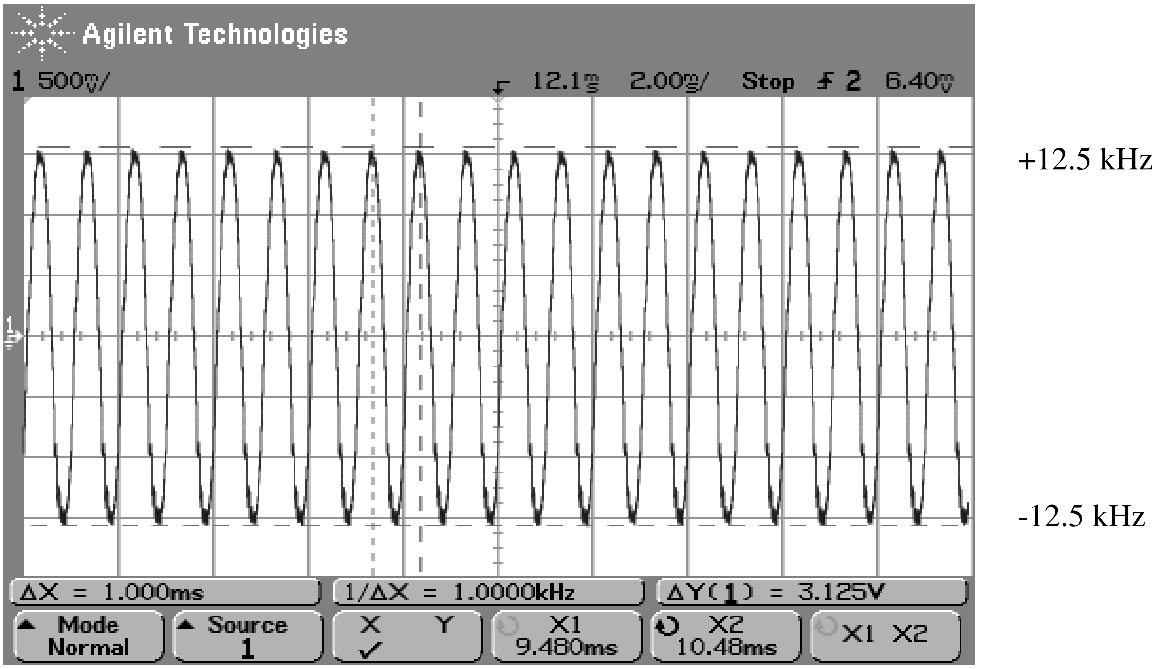


Fig. 3 ±12.5 kHz modulated test signal .

±12.5 kHz = 3.125 V
±6.25 kHz = 1.562 V
±1.15 kHz = 288 mV

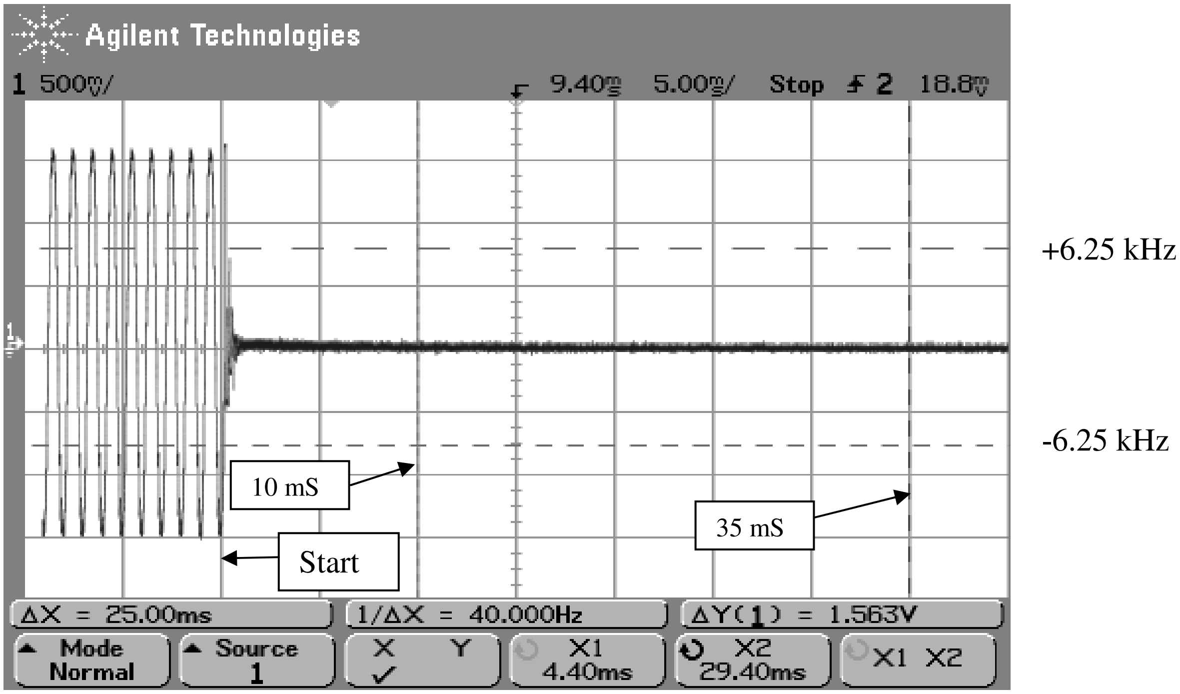


Fig. 4   Start of Transmission

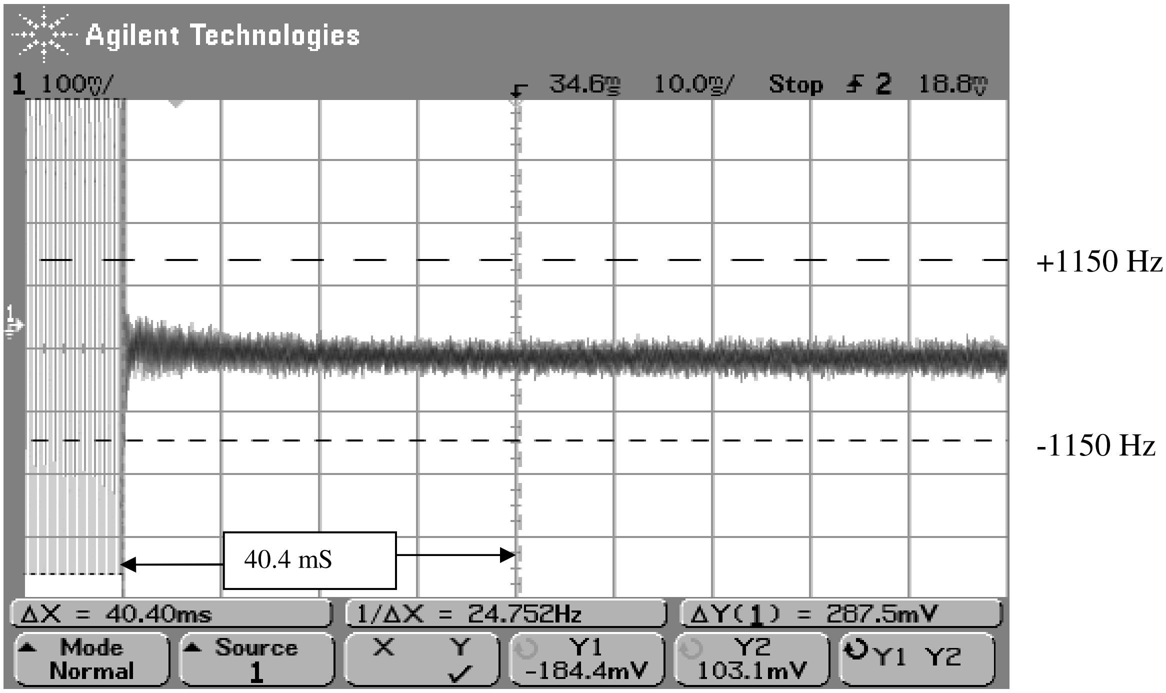


Fig. 5   Full Transmission

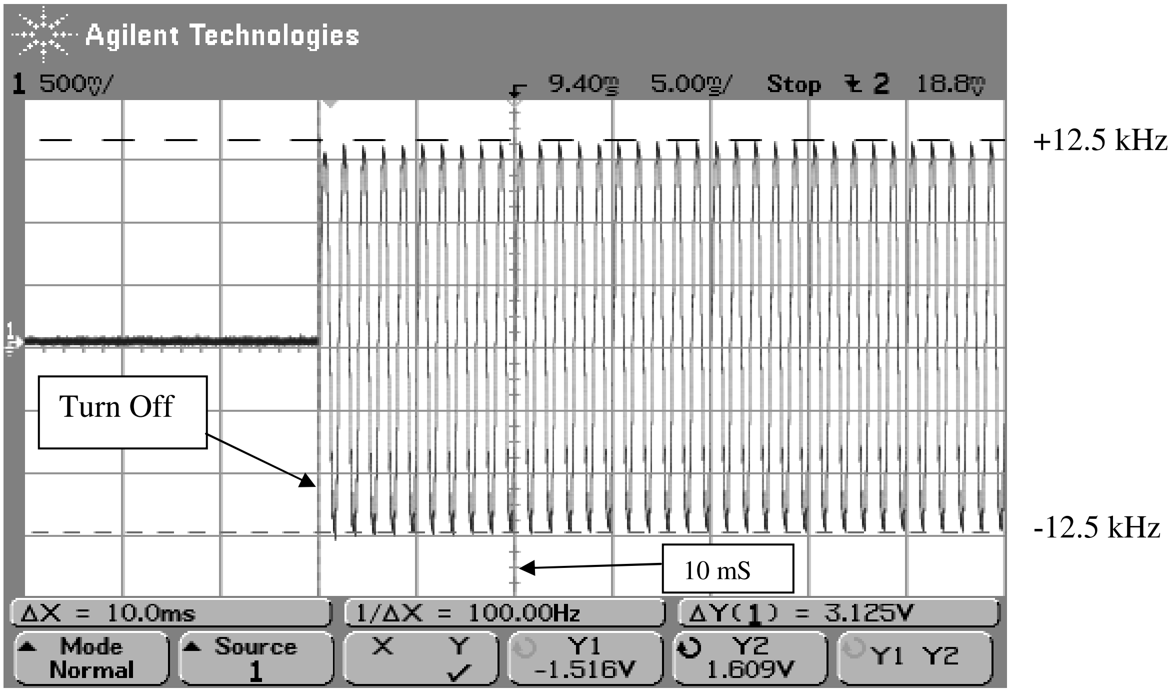


Fig. 6 Turn Off Transient

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 SN: 132061/199 Cal. Due: 10/2009
Test Receiver	Hexagram Broadband Receiver
Oscilloscope	Agilent Model 54622D SN: MY40003551 Cal Due: 11/20009
RF Trigger	Hexagram Detector Circuit
Test Performed	September 10, 2009

Unit Tested: 2009-002 Rev D MTU ID: 303

TEST INFORMATION

SUMMARY

The Hexagram Model 2009-002 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 2009-002
MANUFACTURER	Hexagram, Inc. 30400 Solon Rd. Solon, OH 44139
TEST DATES	September 3 – 14, 2009
OPEN AREA TEST SITE	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (330) 289-9306 FCC (Reg. #90938) Industry Canada (File #4541A-1).