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An ESCO Technologies Company

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ENGINEERING TEST REPORT

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

METER TRANSMITTING UNIT

Model 2009-002G

FCC ID: LLB09002G

June 11, 2011

Report Prepared by

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TEST REPORT

INTRODUCTION

The Hexagram Model 2009-002G 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 to receive instructions from the Data Collector. This report presents the data obtained in support of an application for certification.

Two identical units were used for testing. The serial number of the unit used for a particular test is indicated in each test section.

MEASUREMENTS PERFORMED

Power Output and Spurious Emissions with test set up photographs	Page 3
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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 2009-002G 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). 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-C.

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. Ferrite beads were placed on the battery leads to minimize emissions that might come from the leads which would not normally be present.

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.

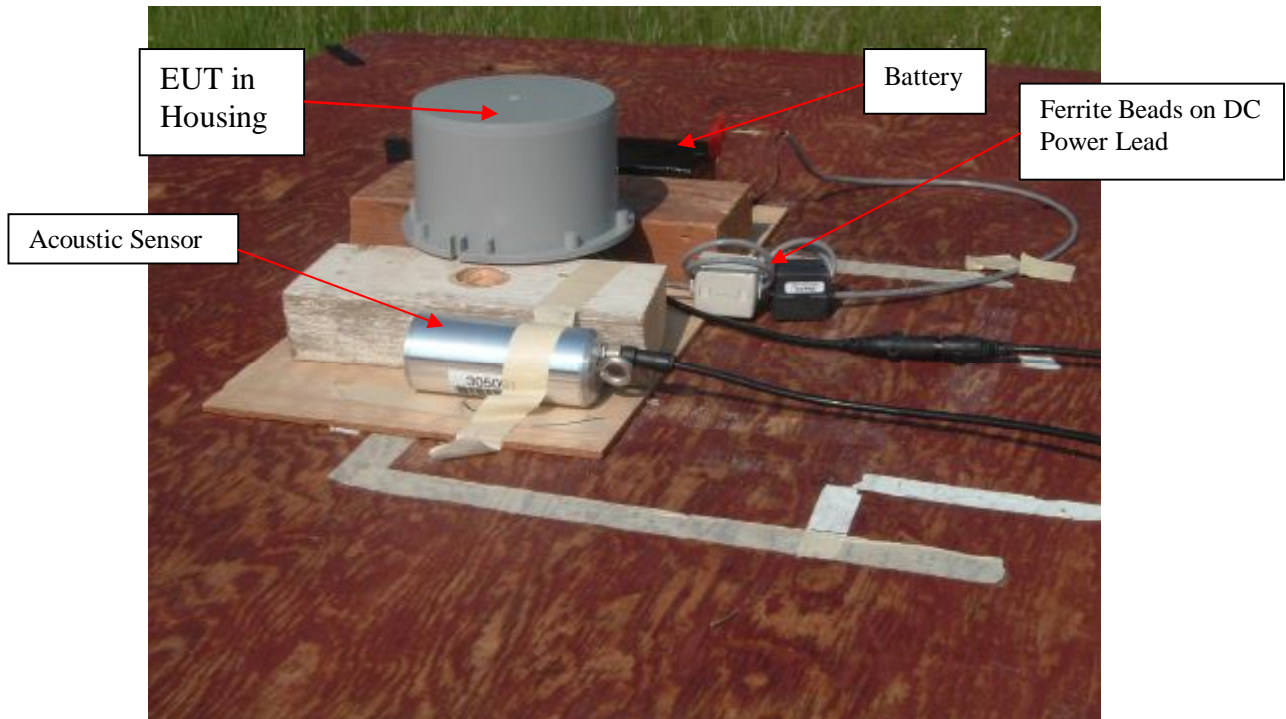
After the maximum received meter readings were obtained for each frequency and polarity, the transmitter under test was removed from the area and replaced by a signal generator and transmitting antenna. With the transmit antenna placed as close as possible to the position of the test unit, the signal 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:

$$P_d = P_g - \text{cable loss(dB)} + \text{antenna gain(dB}_d) \quad (\text{Eq.1})$$

In Eq. 1, 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 $50 + 10\log(P)$. 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 2009-002G MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

**TABLE 1a
HEXAGRAM MODEL 2009-002G 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	18.2	2.0	-0.2	16.	
900	-32.9	2.9	-0.5	-36.3	-52.3

**Output = 16.0 dBm
= 0.040 W
Req. Att.= 36.0 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	-47.2	0.8	5.5	-42.5	-58.5
1800	-52.0	1.0	5.9	-47.1	-63.1
2250	-54.5	1.2	6.8	-48.9	-64.9
2700	-36.8	1.3	7.6	-30.5	-46.5
3150	-47.2	1.4	7.7	-40.9	-56.9
3600	-57.2	1.6	7.7	-51.1	-67.1
4050	-55.5	1.7	7.6	-49.6	-65.6
4500	-63.1	1.8	8.3	-56.6	-72.6

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)
450	25.4	2.0	-0.2	23.2	
900	-33.1	2.9	-0.5	-36.5	-59.7

**Output = 23.2dBm
= 0.209 W
Req. Att.= 43.2 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	-47.4	0.8	5.5	-42.7	-65.9
1800	-55.1	1.0	5.9	-50.2	-73.4
2250	-55.9	1.2	6.8	-50.3	-73.5
2700	-37.0	1.3	7.6	-30.7	-53.9
3150	-47.3	1.4	7.7	-41.0	-64.2
3600	-51.9	1.6	7.7	-45.8	-69.0
4050	-47.2	1.7	7.6	-41.3	-64.5
4500	-59.1	1.8	8.3	-52.6	-75.8

**TABLE 1b
HEXAGRAM MODEL 2009-002G 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	25.7	2.1	-0.2	23.4	
920	-31.0	3.0	-0.4	-34.4	-57.8

**Output = 23.4 dBm
= 0.219 W
Req. Att.= 43.4 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)
1380	-39.8	0.9	5.6	-35.1	-58.5
1840	-56.9	1.0	5.9	-52.0	-75.4
2300	-54.2	1.2	6.9	-48.5	-71.9
2760	-37.2	1.3	7.6	-30.9	-54.3
3220	-52.5	1.4	7.8	-46.1	-69.5
3680	-55.7	1.6	7.7	-49.6	-73.0
4140	-53.6	1.7	7.7	-47.6	-71.0
4600	-63.8	1.8	8.3	-57.3	-80.7

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	27.0	2.1	-0.2	24.7	
920	-28.4	3.0	-0.4	-31.8	-56.5

**Output = 24.7 dBm
= 0.295 W
Req. Att.= 44.7 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	-41.1	0.9	5.6	-36.4	-61.1
1840	-59.7	1.0	5.9	-54.8	-79.5
2300	-55.2	1.2	6.9	-49.5	-74.2
2760	-39.8	1.3	7.6	-33.5	-58.2
3220	-50.5	1.4	7.8	-44.1	-68.8
3680	-50.8	1.6	7.7	-44.7	-69.4
4140	-54.8	1.7	7.7	-48.8	-73.5
4600	-59.9	1.8	8.3	-53.4	-78.1

**TABLE 1c
HEXAGRAM MODEL 2009-002G 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	20.6	2.1	-0.2	18.3	
940	-24.0	3.0	-0.4	-27.4	-45.7

**Output = 18.3 dBm
= 0.068 W
Req. Att.= 38.3 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	-34.8	0.9	5.7	-30.0	-48.3
1880	-61.8	1.0	5.9	-56.9	-75.2
2350	-59.0	1.2	7.1	-53.1	-71.4
2820	-34.3	1.3	7.7	-27.9	-46.2
3290	-52.8	1.5	7.8	-46.5	-64.8
3760	-57.2	1.6	7.6	-51.2	-69.5
4230	-60.4	1.7	7.9	-54.2	-72.5
4700	-67.1	1.8	8.4	-60.5	-78.8

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	26.0	2.1	-0.2	23.7	
940	-27.5	3.0	-0.4	-30.9	-54.6

**Output = 23.7 dBm
= 0.234W
Req. Att.= 43.7 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	-33.3	0.9	5.7	-28.5	-52.2
1880	-60.6	1.0	5.9	-55.7	-79.4
2350	-53.9	1.2	7.1	-48.0	-71.7
2820	-39.0	1.3	7.7	-32.6	-56.3
3290	-51.4	1.5	7.8	-45.1	-68.8
3760	-48.0	1.6	7.6	-42.0	-65.7
4230	-56.1	1.7	7.9	-49.9	-73.6
4700	-59.6	1.8	8.4	-53.0	-76.7

TEST EQUIPMENT USED

Spectrum Analyzer

Hewlett-Packard Model 8593EM Spectrum Analyzer
SN: 3536AO0147 Cal Due: 8/2011

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: 6/2011

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

June 4 – 11, 2011

Unit Tested

Model 2009-002G MTU ID: 312

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 2009-002G 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 (dipole equivalent power) was determined to be 0.295 W, $50 + 10 \log(0.295)$ equals 44.7 dB. (Attenuation of -47 dBc is shown in Fig. 1.)

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.

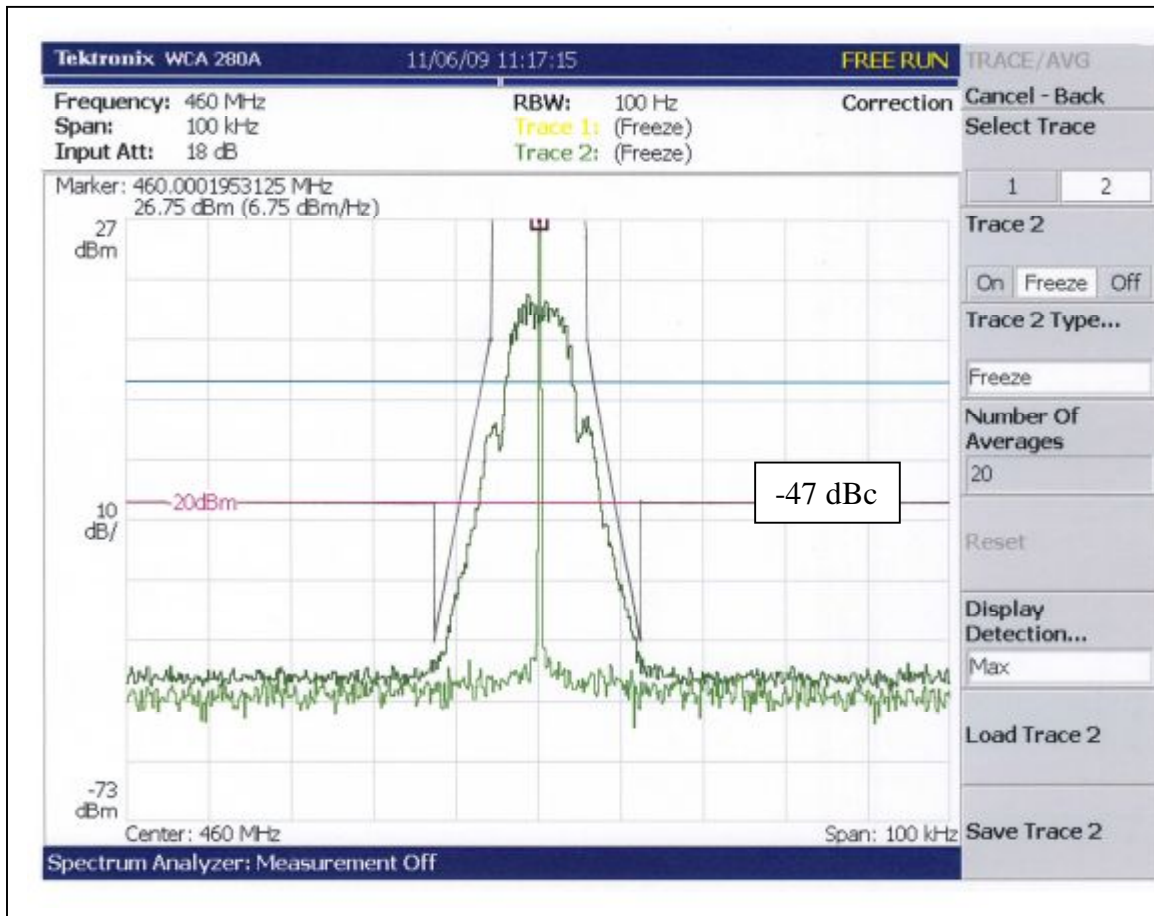


Fig. 1
Hexagram Model 2009-002G
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer

Tektronix Model WCA 280A
SN: J300168 Cal Due: 4/2012

Antenna

None: Direct Measurement made.

Test Performed

June 9, 2011

Unit Tested: 2009-002G Rev G MTU ID: 312

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 30 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	460.000176	176	+0.38
+30	460.000171	171	+0.37
+40	460.000142	142	+0.31
+50	460.000151	151	+0.33
+60	460.000186	186	+0.40
+70	460.000200	200	+0.44
+80	460.000229	229	+0.50
+85	460.000264	264	+0.57
+20	460.000210	210	+0.46
+10	460.000205	205	+0.45
0	460.000156	249	+0.54
-10	460.000313	313	+0.68
-20	460.000215	215	+0.47
-30	460.000249	249	+0.54
+20	460.00186	186	+0.40

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 power batteries. 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	460.000215	215	+0.47
7.2 VDC	460.000200	200	+0.44
6.9 VDC	460.000205	205	+0.45
6.6 VDC	460.000205	205	+0.45
6.3 VDC	460.000205	205	+0.45
6.0 VDC	460.000215	215	+0.47
5.7 VDC	460.000210	210	+0.46
5.4 VDC	460.000220	220	+0.48
5.1 VDC	460.000220	220	+0.48
4.8 VDC	460.000190	198	+0.43
4.5 VDC	460.000185	185	+0.40
4.2 VDC	460.000186	186	+0.40

Reference frequency = 460.000000 MHz

TEST EQUIPMENT USED

Spectrum Analyzer

Tektronix Model WCA 280
S/N J300168 Cal Due: 4/2012

Antenna

Antenna Specialists Model AV-15 whip
450 – 470 MHz

DC Power Supply

MPJA Regulated Power Supply
SN: 001606

Digital Multi-Meter

Fluke Model 87III
Cal. Due: 4/2012

Thermometer

Cooper Model SRH77A
SN: 460525 Cal Due: 6/2010

Temperature Chamber

Test Equity Model 1007H
Cal. due: 2/2012

Tests Performed

Temperature June 10-11, 2011
Voltage June 9, 2011

Unit Tested: 2009-002G MTU ID: 312

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

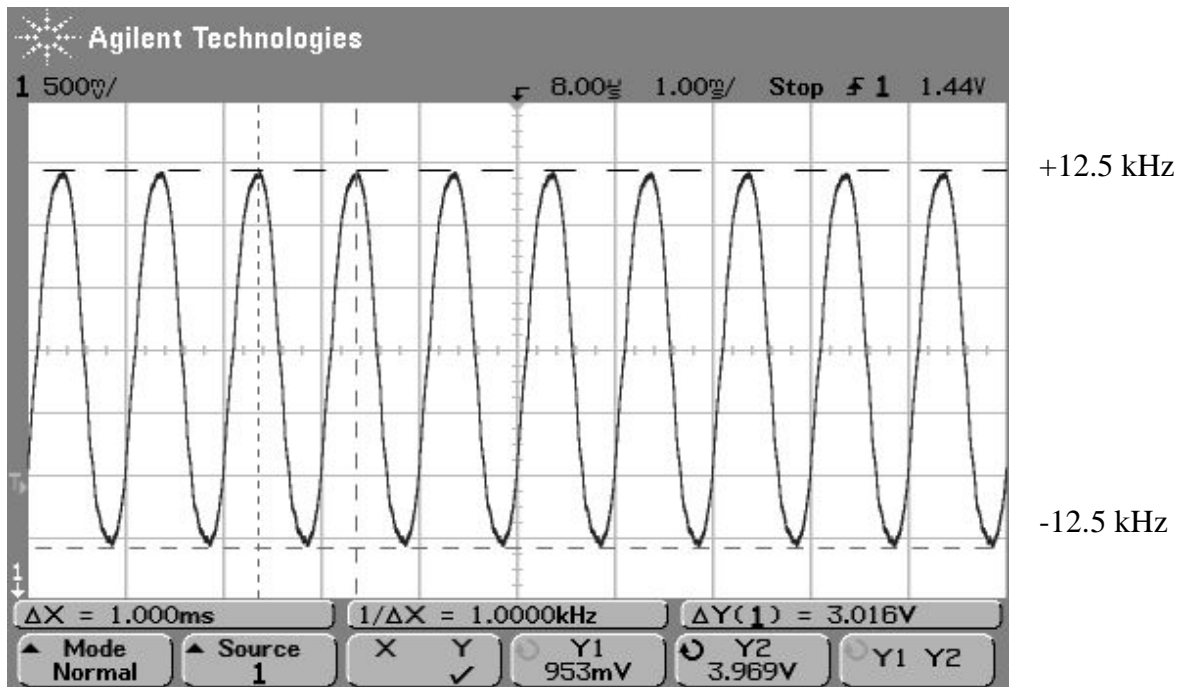


Fig. 3 ±12.5 kHz modulated test signal .

- ± 12.5 kHz = 3.016 V**
- ± 6.25 kHz = 1.508 V**
- ± 1.15 kHz = 277 mV**

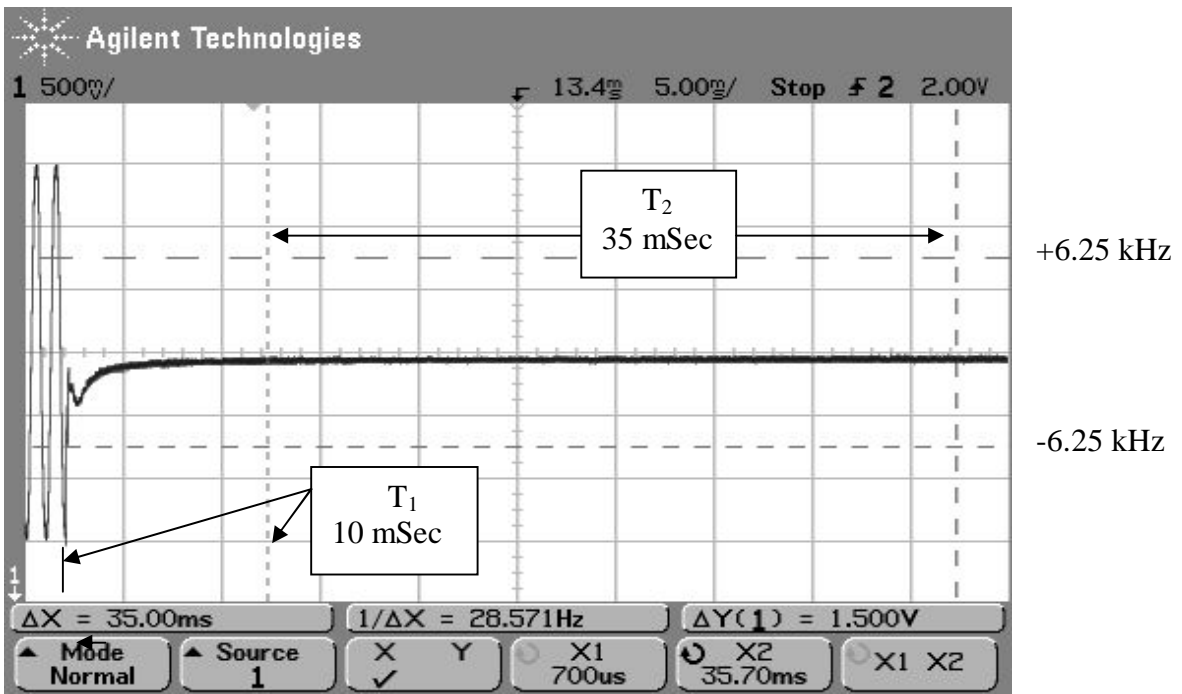


Fig. 4 Start of Transmission

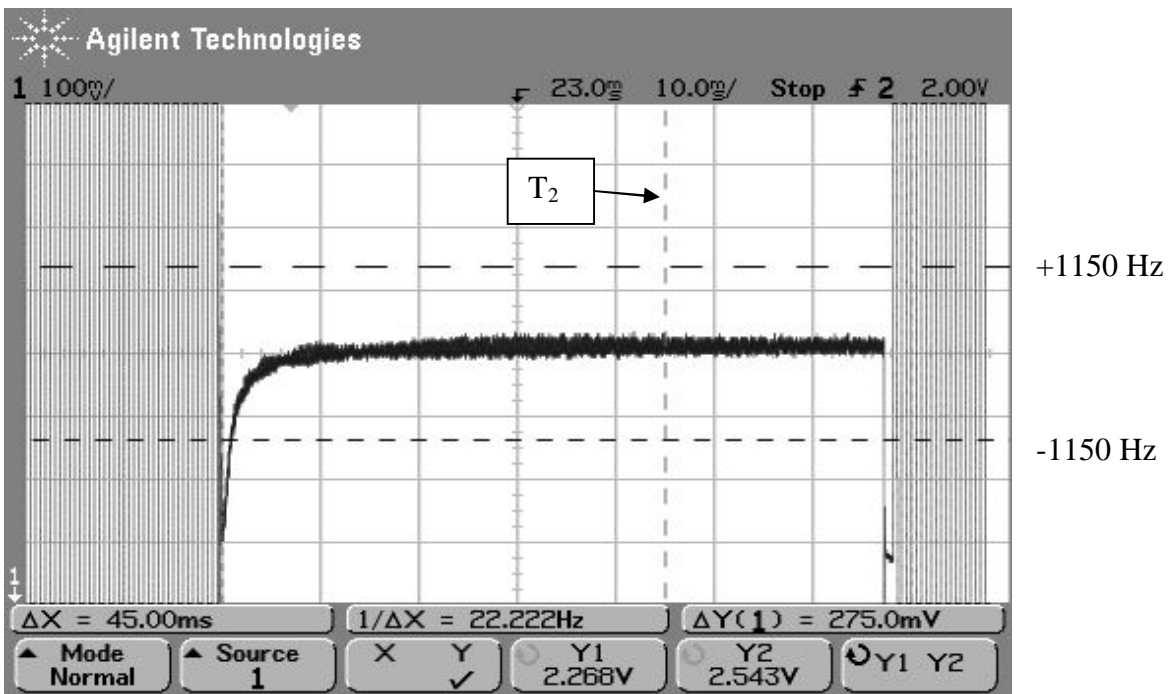


Fig. 5 Full Transmission

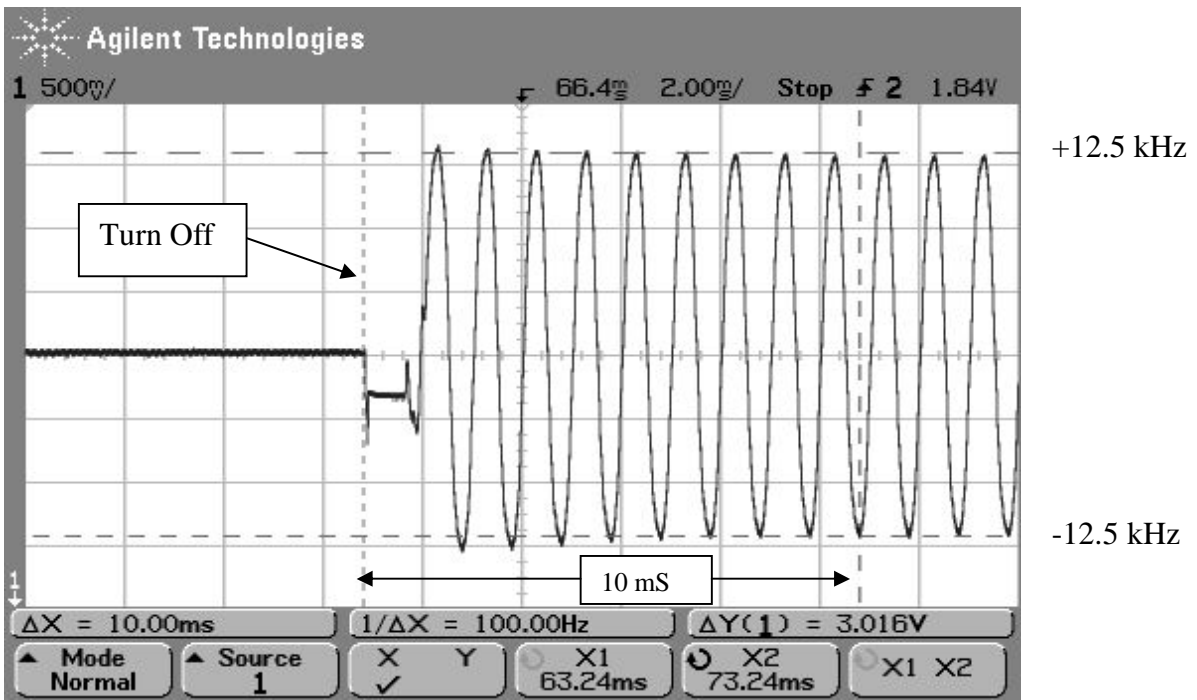


Fig. 6 Turn Off Transient

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: 2/2012

Test Receiver

Hexagram Broadband Receiver w/RSSI
trigger output

Oscilloscope

Agilent Model 54622D
SN: MY40003551 Cal Due: 2/20012

Test Performed

June 10, 2011

Unit Tested: 2009-002G MTU ID: 303

TEST INFORMATION

SUMMARY

The Hexagram Model 2009-002G 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 2009-002G

MANUFACTURER

Hexagram, Inc.
30400 Solon Rd.
Solon, OH 44139

TEST DATES

June 4 – 11, 2011

OPEN AREA TEST SITE

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FCC (Reg. #90938)