HEXAGRAM INC.

An ESCO Technologies Company

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ENGINEERING TEST REPORT

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HIGH READ-RATE
GAS METER TRANSMITTING UNIT

Model 2011-001, Rev. D
FCC ID: LLB11001

September 14, 2011

Report Prepared by

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Agency Certification Control Technician

TEST REPORT

INTRODUCTION

The Hexagram Model 2011-001 transceiver is a "Meter Transmitting Unit" (MTU) designed to provide remote meter reading capability for a gas meter. The transceiver is self-powered and connects by a cable to a passive pulser unit which mounts on the gas meter. On board batteries provide power. The transmitter provides a very short, intermittent radio frequency transmission to send a remote reading of the meter to a data collector unit. A microprocessor provides timing, control and data processing functions. The internal antenna is inaccessible to the user and no external antenna is provided. A prototype unit was used as a test subject for this report. This report presents the data obtained in support of an application for Certification under Part 90 of the FCC rules.

MEASUREMENTS PERFORMED

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POWER OUTPUT AND SPURIOUS EMISSIONS

Within the tuning range of 450 – 470 MHz, the transmitter portion of the Model 2011-001 (EUT) 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, the transmitter was forced to transmit continuously for about 30 seconds at a 50% duty cycle for these measurements. Power to the meter necessary to sustain the transmission was provided by an external 6 V battery.

With the transmitter powered and 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 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.

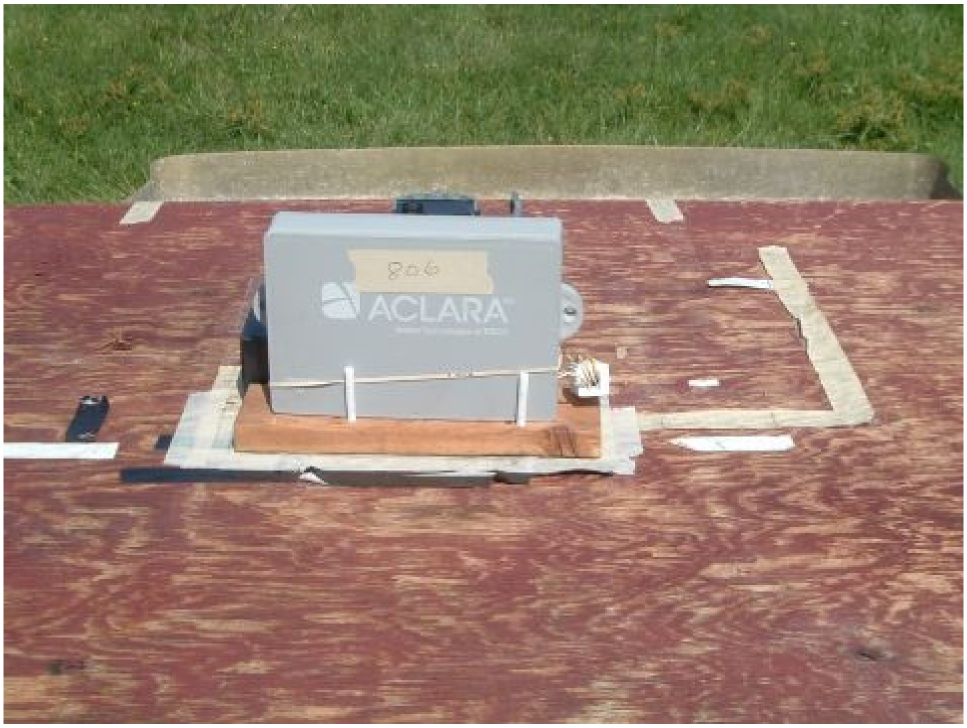
In order to convert the signal generator output value to equivalent radiated power from a dipole, the following equation is used:

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

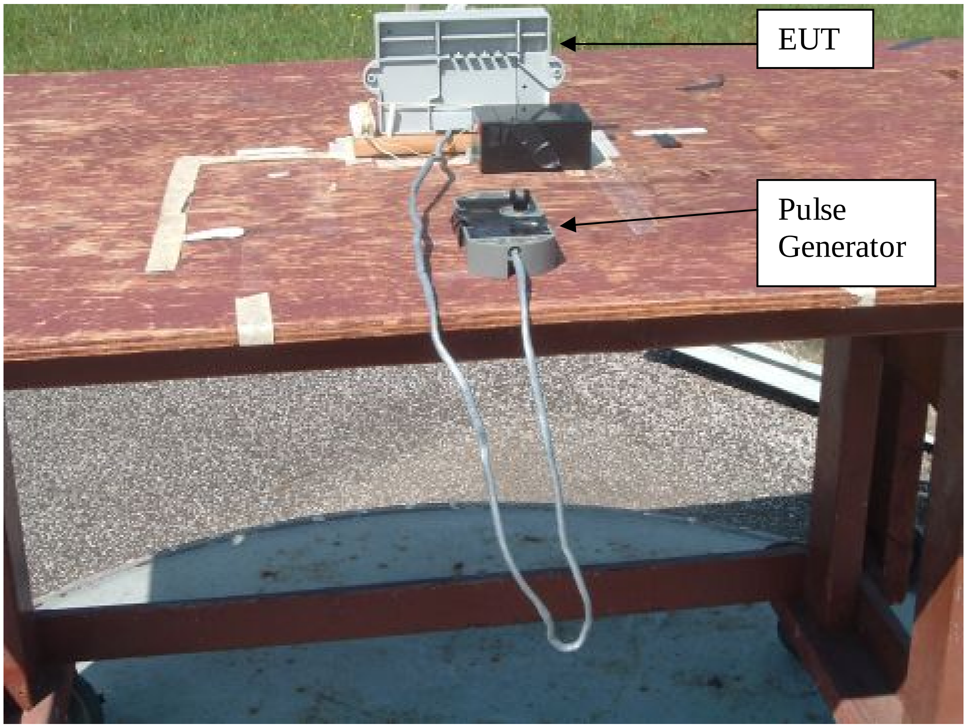
where:

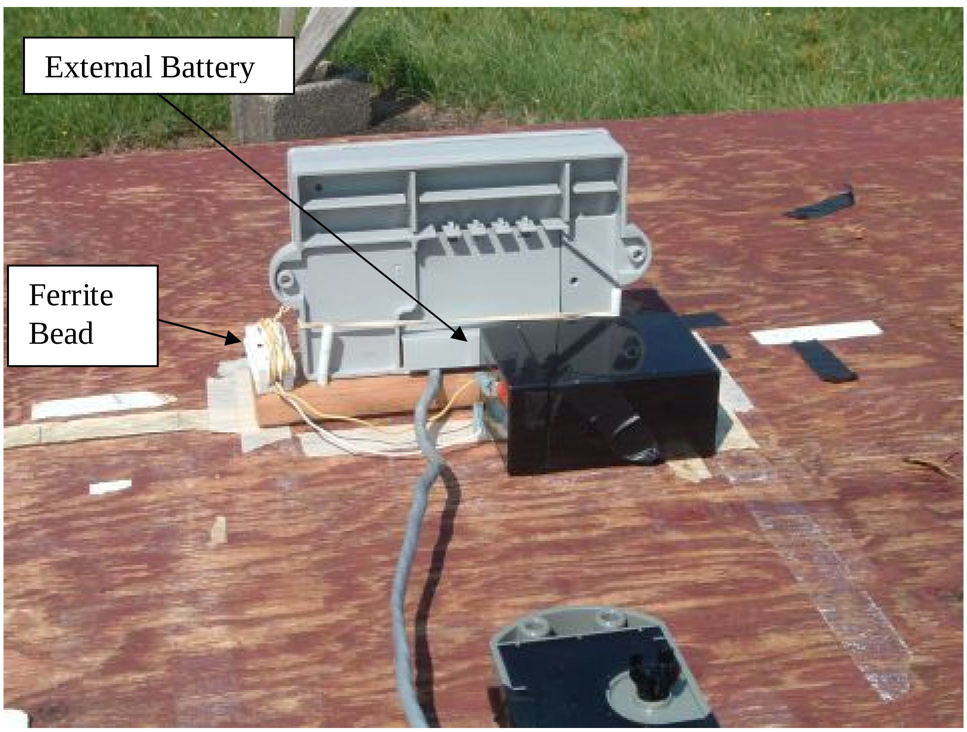
P_d is the dipole equivalent power in dBm, P_g is the generator output into the substitution antenna, also in dBm, and “antenna gain” is the dB gain of the substitution antenna with respect to a theoretical dipole.

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 2011-001 MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP





PICTORIAL 2
HEXAGRAM MODEL 2011-001 MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 1a
HEXAGRAM MODEL 2011-001 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	26.9	2.1	-1.0	23.8	
900	-31.3	3.2	-0.7	-35.2	-59.0

Output = 23.8dBm
= 0.240 W
Req. Att.= 43.8 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	-45.1	0.8	6.5	-39.4	-63.2
1800	-56.7	1.0	7.4	-50.3	-74.1
2250	-61.0	1.2	6.2	-56.0	-79.8
2700	-50.0	1.3	6.4	-44.9	-68.7
3150	-51.0	1.4	7.2	-45.2	-69.0
3600	-42.9	1.6	8.3	-36.2	-60.0
4050	-50.1	1.7	8.0	-43.8	-67.6
4500	-39.5	1.8	8.6	-32.7	-56.5

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	31.5	2.1	-1.0	28.4	
900	-26.7	3.2	-0.7	-30.6	-59.0

Output = 28.4 dBm
= 0.692 W
Req. Att.= 48.4 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	-46.8	0.8	6.5	-41.1	-69.5
1800	-49.1	1.0	7.4	-42.7	-71.1
2250	-54.0	1.2	6.2	-49.0	-77.4
2700	-51.7	1.3	6.4	-46.6	-75.0
3150	-45.0	1.4	7.2	-39.2	-67.6
3600	-40.6	1.6	8.3	-33.9	-62.3
4050	-53.1	1.7	8.0	-46.8	-75.2
4500	-42.9	1.8	8.6	-36.1	-64.5

TABLE 1b
HEXAGRAM MODEL 2011-001 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	27.4	2.2	-1.1	24.1	
920	-26.6	3.3	-1.1	-31.0	-55.1

Output = 24.1 dBm
= 0.257 W
Req. Att.= 44.1 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	-44.6	0.9	6.8	-38.7	-62.8
1840	-57.9	1.0	7.2	-51.7	-75.8
2300	-61.7	1.2	6.2	-56.7	-80.8
2760	-54.7	1.3	6.5	-49.5	-73.6
3220	-52.3	1.4	7.5	-46.2	-70.3
3680	-40.9	1.6	8.3	-34.2	-58.3
4140	-51.2	1.7	8.1	-44.8	-68.9
4600	-41.1	1.8	8.4	-34.5	-58.6

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	32.5	2.2	-1.1	29.2	
920	-26.1	3.3	-1.1	-30.5	-59.7

Output = 29.2 dBm
= 0.832 W
Req. Att.= 49.2 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)
1380	-43.8	0.9	6.8	-37.9	-67.1
1840	-54.6	1.0	7.2	-48.4	-77.6
2300	-55.7	1.2	6.2	-50.7	-79.9
2760	-52.4	1.3	6.5	-47.2	-76.4
3220	-46.5	1.4	7.5	-40.4	-69.6
3680	-41.3	1.6	8.3	-34.6	-63.8
4140	-51.9	1.7	8.1	-45.5	-74.7
4600	-48.6	1.8	8.4	-42	-71.2

TABLE 1c
HEXAGRAM MODEL 2011-001 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	26.6	2.2	-1.2	23.2	
940	-30.8	3.3	-1.1	-35.2	-58.4

Output = 23.2 dBm
= 0.209W
Req. Att.= 43.2 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	-42.1	0.9	7.0	-36.0	-59.2
1880	-63.8	1.0	7.0	-57.8	-81.0
2350	-55.5	1.2	6.3	-50.4	-73.6
2820	-61.2	1.3	6.5	-56.0	-79.2
3290	-49.2	1.5	7.8	-42.9	-66.1
3760	-38.1	1.6	8.2	-31.5	-54.7
4230	-52.3	1.7	8.2	-45.8	-69.0
4700	-39.6	1.8	8.2	-33.2	-56.4

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)
470	31.7	2.2	-1.2	28.3	
940	-23.3	3.3	-1.1	-27.7	-56.0

Output = 28.3 dBm
= 0.676 W
Req. Att.= 48.3 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	*-46.3*	0.9	7.0	-40.2	-68.5
1880	-56.1	1.0	7.0	-50.1	-78.4
2350	-52.4	1.2	6.3	-47.3	-75.6
2820	-53.5	1.3	6.5	-48.3	-76.6
3290	-44.6	1.5	7.8	-38.3	-66.6
3760	-39.9	1.6	8.2	-33.3	-61.6
4230	-51.3	1.7	8.2	-44.8	-73.1
4700	-46.7	1.8	8.2	-40.3	-68.6

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Model 8593EM Spectrum Analyzer SN: 3536A00147 Cal Due: 8/24/2012
Antennas	ETS-Lindgren Model DB-4 Tuned Dipole SN: 69064 Receive Only Frequency Range 400 – 1000 MHz Cal N/A
	A.H. Systems Model FCC-4 Tuned Dipole SN: 592A Transmit Only Frequency Range 375 – 1000 MHz Cal Date: 8/19/2011 Cal Due: 8/19/2012
	ETS-Lindgren Model 3115 Double Ridged Guide Horn SN: 69713 Receive Only Frequency Range 0.75 – 18 GHz Cal N/A
	A.H. Systems Model SAS-571 Double Ridged Guide Horn SN: 1488 Transmit Only Frequency Range 0.7 – 18 GHz Cal Date: 8/19/2011 Cal Due: 8/19/2012
Signal Generator	Hewlett-Packard Model 8340B, S/N 3010A01889 Cal Due: 6/10/2012
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	August 22 – September 12, 2011

Unit Tested: 2011-001 Rev. D SN: 80000806

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 2011-001 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. The maximum dipole equivalent power was determined to be 29.2 dBm or 0.832 W and 50 + 10 log(0..832) equals 49.2 dB. The mask measurement was a radiated measurement, and as seen in Fig. 1, the received output power was about 11 dBm so the maximum allowed is shown on the plot as 49.2 dB below the measured level.

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.

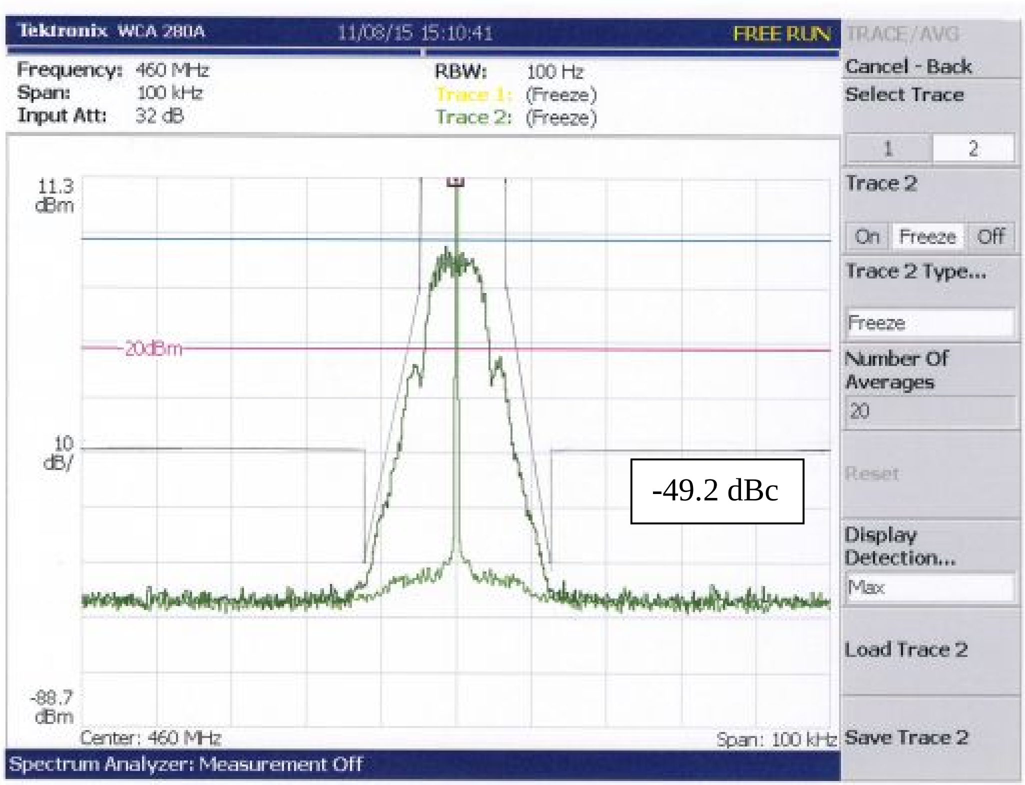


Fig. 1
Hexagram Model 2011-001
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Tektronix Model WCA 280A SN: J300168 Cal Due: 4/26/2012
Antenna	Antenna Specialists Model AV-15 450-470 MHz
Test Performed	August 15, 2011

Unit Tested: 2011-001 Rev. D SN: 80000806

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 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 temperature 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 70° 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 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 1150 Hz at 460 MHz.

TABLE 2
FREQUENCY STABILITY VS. TEMPERATURE
460 MHz

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	459.999992	-8	-0.017
+30	459.999925	-75	-0.163
+40	459.999925	-75	-0.163
+50	459.999933	-67	-0.146
+60	459.999950	-50	-0.109
+70	460.000058	+58	+0.126
+20	459.999942	-58	-0.126
+10	460.000058	+58	+0.126
0	460.000058	+58	+0.126
-10	459.999875	-125	-0.272
-20	459.999667	-333	-0.724
-30	459.999708	-292	-0.635
-40	460.000158	+158	+0.343
+20	459.999983	-17	-0.037

Reference Frequency= 460.000000 MHz

FREQUENCY STABILITY VS. SUPPLY VOLTAGE

To vary the DC test voltage, a variable DC power supply was inserted in place of one of the series lithium cells. The frequency was measured at the TIA-603-C default standard test voltage of lithium ion cells. Measurements were also made at voltages down to and below the 85% level of 6.375 Volts.

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 reference frequency.

TABLE 3
FREQUENCY STABILITY VS. SUPPLY VOLTAGE

460 MHz

INPUT Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
7.5 VDC	459.999970	-30	-0.065
7.2 VDC	459.999960	-40	-0.087
7.0 VDC	459.999970	-30	-0.065
6.5 VDC	459.999951	-49	-0.107
6.0 VDC	459.999951	-49	-0.107
5.5 VDC	459.999970	-30	0.065

Reference frequency = 460 MHz

TEST EQUIPMENT USED

<u>Spectrum Analyzer</u>	Tektronix Model WCA 280 (Voltage) S/N J300168 Cal Due: 4/26/2012
	Hewlett-Packard 8563A (Frequency) S/N 3020AO0246 Cal Due: 8/8/2012
<u>Antenna</u>	Antenna Specialists AV-15 (450-470 MHz)
<u>DC Power Supply</u>	Mastech Model HY1503D SN: 0036790
<u>Digital Multi-Meter</u>	Fluke Model 179 SN: 96440070 Cal. Due: 2/25/2012
<u>Temperature Chamber</u>	Test Equity Model 115 Cal. due: 2/17/2012
<u>Tests Performed</u>	Temperature August 25-26, 2011 Voltage August 16, 2011

Temperature & Voltage

Unit Tested: 2011-001 Rev. D SN: 80000806

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 2011-001 transmitter was tested for transient frequency behavior using the test method of TIA/EIA-603-C. A block diagram of the test setup is seen in Fig. 2. A Hexagram model 9975G-WB receiver was used. The storage oscilloscope was triggered by the output of the RSSI output of the receiver. 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 2011-001.

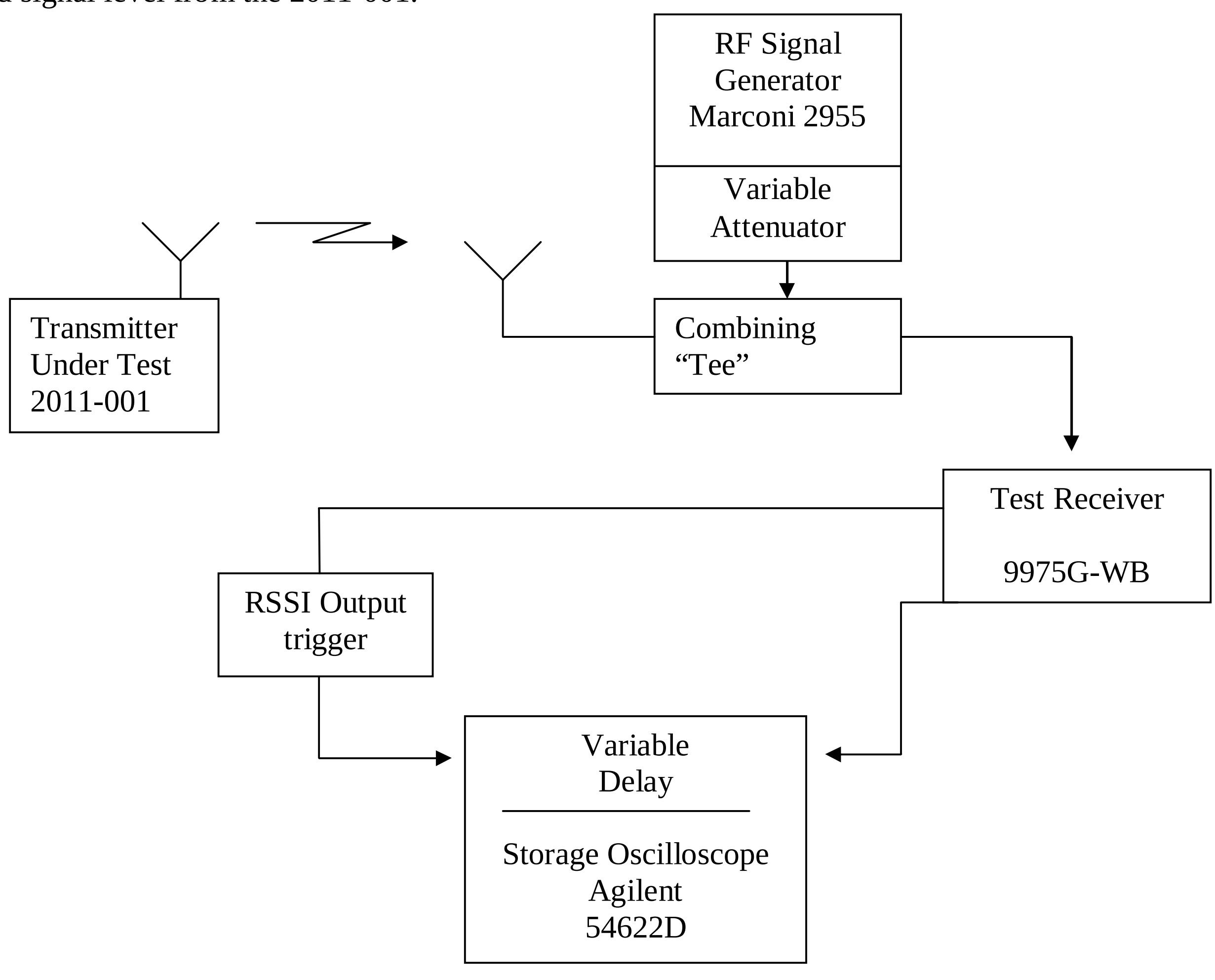


Fig. 2
Transient Frequency Behavior
Test Setup

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.

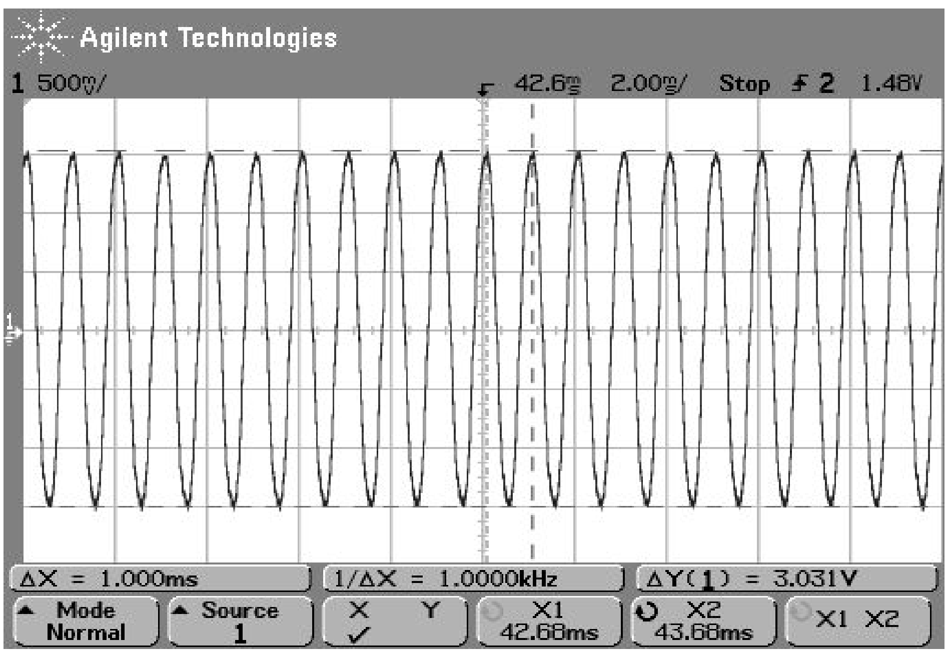
2. Frequency deviation during t_2 (25 ms duration after t_1) must be less than ±6.25 kHz.

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 2011-001 transient frequency characteristics. The limit masks are indicated on each of the figures.



+12.5 kHz

-12.5 kHz

Fig. 3 ±12.5 kHz modulated test signal .

±12.5 kHz = 3.03 V
±6.25 kHz = 1.52 V
±1.15 kHz = 278 mV

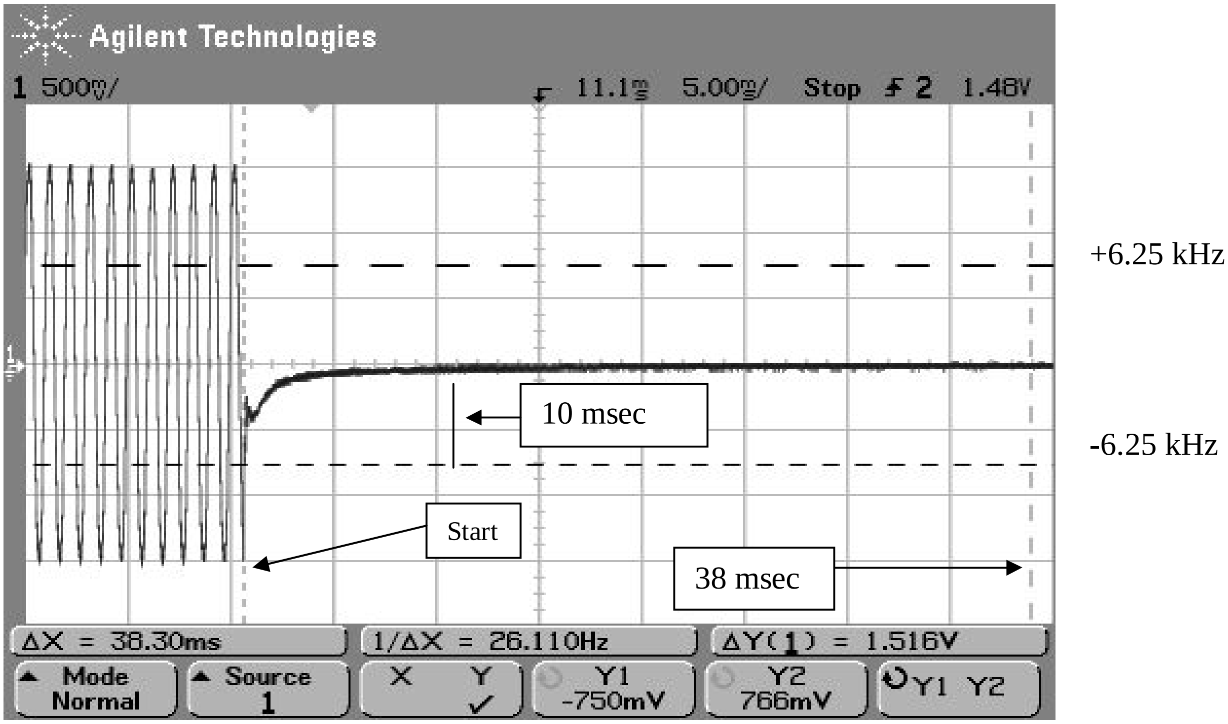


Fig. 4 Start of Transmission

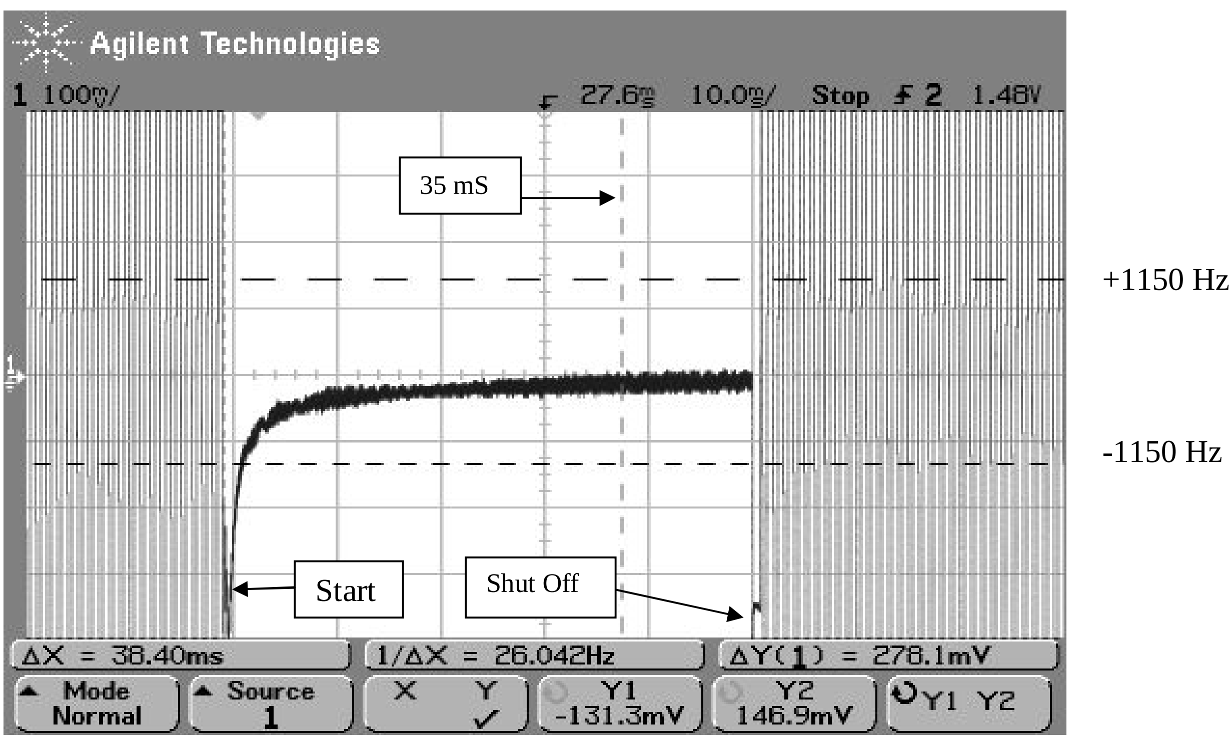


Fig. 5 Full Transmission

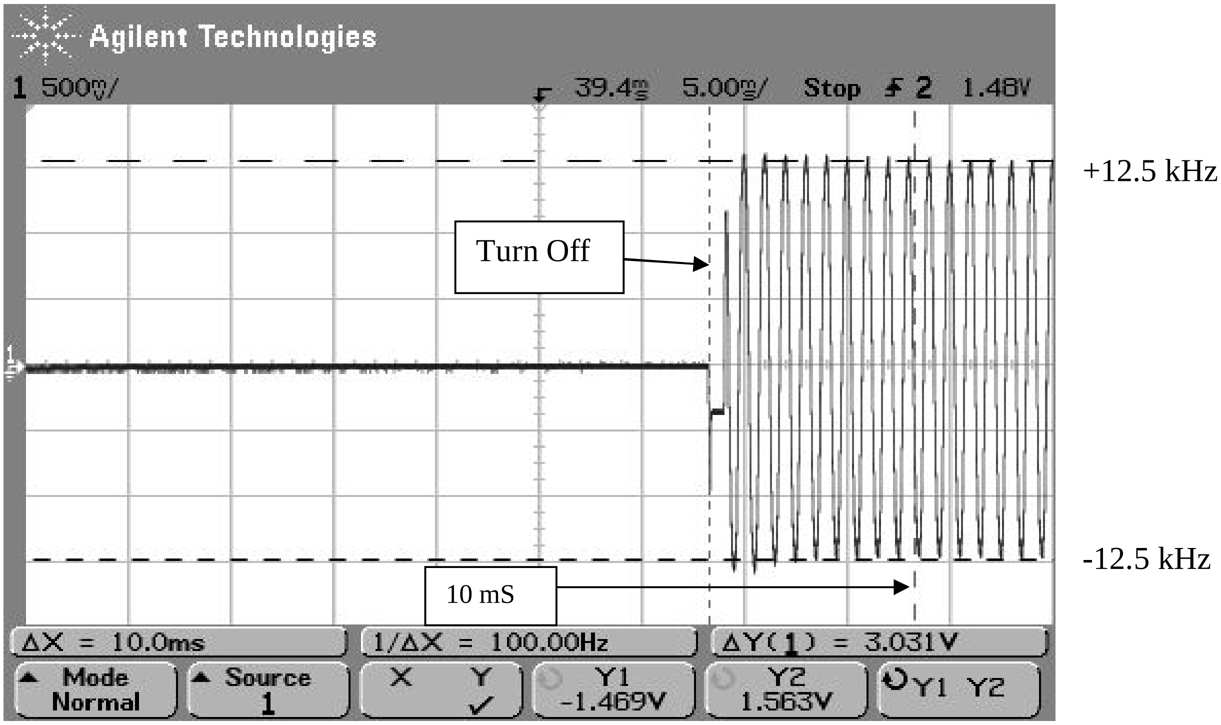


Fig. 6 Turn Off Transient

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 2955 RF Test Set S/N 132061 Cal Due: 2/25/2012
Test Receiver	Hexagram 9975G-WB w/ RSSI trigger output
Oscilloscope	Agilent Model 54622D SN: MY40003551 Cal Due: 2/28/12
Test Performed	August 16, 2011

Unit Tested: 2011-001 Rev. D SN: 80000806

TEST INFORMATION

SUMMARY

The Hexagram Model 2011-001 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 2011-001 Rev. D
MANUFACTURER	Hexagram, Inc. 30400 Solon Rd. Solon, OH 44139
TEST DATES	August 15 – September 9, 2011
OPEN AREA TEST SITE	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (330) 289-9306 FCC (Reg. #90938)