SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

HIGH READ-RATE WATER METER
TRANSMITTING UNIT

Model 2009-003
FCC ID: LLB09003

May 5, 2009

Prepared by: James R. Pollock

Prepared for: Hexagram, Inc.
23905 Mercantile Road
Cleveland, OH 44122

Smith Electronics, Inc.
2730 Old Mill Rd.
Brecksville, OH 44141
Phone: (330) 289-9306

TEST REPORT

INTRODUCTION

The Hexagram Model 2009-003 transceiver is a “Meter Transmitting Unit” (MTU) designed to provide remote meter reading capability for utility meters that provide a pulsed output. The transceiver is self-powered and connects to a meter pulse output with an electrical cable. An on-board battery provides power. 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 for upgrading firmware, requests for meter reads or other options available in the system. Due to software considerations two different units were used for testing. The revision and serial number of each unit tested is shown in the appropriate section. There are no differences in the RF section of the units tested. 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 of the Model 2009-003 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.

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 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.

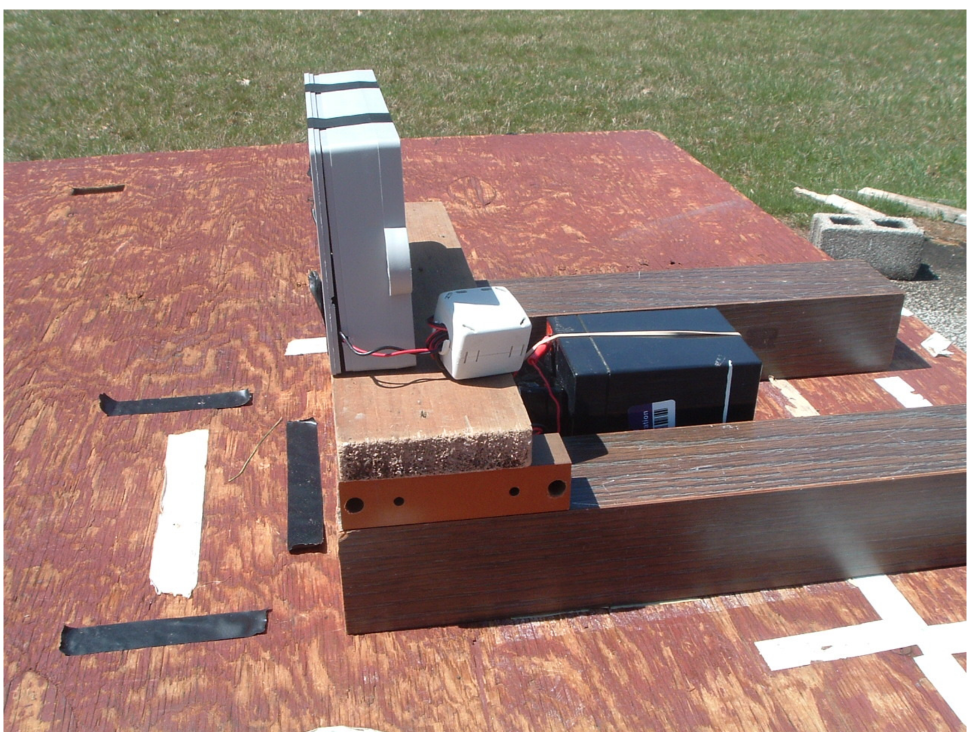
In order to convert the signal generator output value to equivalent radiated power from a dipole, the following equation is used:

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

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 2009-003 MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 1a
HEXAGRAM MODEL 2009-003 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	25.7	2.0	-0.4	23.3	
900	-20.4	2.9	-0.7	-24.0	-47.3

Output = 23.3 dBm
= 0.214 W
Req. Att.= 43.3 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)
1350	-28.4	0.9	5.5	-23.8	-47.1
1800	-42.2	1.0	5.9	-37.3	-60.6
2250	-37.3	1.2	6.8	-31.7	-55.0
2700	-31.7	1.3	7.7	-25.3	-48.6
3150	-36.3	1.5	7.8	-30.0	-53.3
3600	-33.0	1.6	7.8	-26.8	-50.1
4050	-31.5	1.7	7.7	-25.5	-48.8
4500	-49.3	1.8	8.3	-42.8	-66.1

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	25.8	2.0	-0.4	23.4	
900	-22.3	2.9	-0.7	-25.9	-49.3

Output = 23.4 dBm
= 0.219 W
Req. Att.= 43.4 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	-33.7	0.9	5.5	-29.1	-52.5
1800	-43.8	1.0	5.9	-38.9	-62.3
2250	-34.5	1.2	6.8	-28.9	-52.3
2700	-27.6	1.3	7.7	-21.2	-44.6
3150	-42.1	1.5	7.8	-35.8	-59.2
3600	-37.3	1.6	7.8	-31.1	-54.5
4050	-30.9	1.7	7.7	-24.9	-48.3
4500	-55.6	1.8	8.3	-49.1	-72.5

TABLE 1b
HEXAGRAM MODEL 2009-003 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	24.6	2.1	-0.4	22.1	
920	-26.1	3.0	-0.6	-29.7	-51.8

Output = 22.1 dBm
= 0.162 W
Req. Att.= 42.1 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	-31.5	0.9	5.6	-26.8	-48.9
1840	-44.7	1.0	5.9	-39.8	-61.9
2300	-39.1	1.2	7.0	-33.3	-55.4
2760	-31.8	1.3	7.7	-25.4	-47.5
3220	-34.4	1.5	7.8	-28.1	-50.2
3680	-28.7	1.6	7.7	-22.6	-44.7
4140	-34.3	1.7	7.8	-28.2	-50.3
4600	-39.0	1.9	8.4	-32.5	-54.6

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	23.9	2.1	-0.4	21.4	
920	-32.0	3.0	-0.6	-35.6	-57.0

Output = 21.4 dBm
= 0.138 W
Req. Att.= 41.4 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	-34.5	0.9	5.6	-29.8	-51.2
1840	-44.5	1.0	5.9	-39.6	-61.0
2300	-36.1	1.2	7.0	-30.3	-51.7
2760	-29.2	1.3	7.7	-22.8	44.2
3220	-42.8	1.5	7.8	-36.5	-57.9
3680	-33.5	1.6	7.7	-27.4	-48.8
4140	-30.7	1.7	7.8	-24.6	-46.0
4600	-43.9	1.9	8.4	-37.4	-58.8

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	23.4	2.1	-0.4	20.9	
940	-30.1	3.0	-0.6	-33.7	-54.6

Output = 20.9 dBm
= 0.123 W
Req. Att.= 40.9 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	-39.4	0.9	5.7	-34.6	-55.5
1880	-53.9	1.1	5.9	-49.1	-70.0
23.50	-51.5	1.2	7.2	-45.5	-66.4
2820	-55.3	1.4	7.7	-49.0	-69.9
3290	-52.8	1.5	7.8	-46.5	-67.4
3760	-43.8	1.6	7.7	-37.7	-58.6
4230	-49.0	1.8	7.9	-42.9	-63.8
4700	-45.7	1.9	8.4	-39.2	-60.1

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	25.3	2.1	-0.4	22.8	
940	-30.0	3.0	-0.6	-33.6	-56.4

Output = 22.8 dBm
= 0.191 W
Req. Att.= 42.8 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)
1410	-36.9	0.9	4.4	-33.4	-56.2
1880	-54.5	1.1	4.7	-50.9	-73.7
2350	-47.1	1.2	6.7	-41.6	-64.4
2820	-57.2	1.4	7.9	-50.7	-73.5
3290	-57.8	1.5	8.1	-51.2	-74.0
3760	-44.5	1.6	7.9	-38.2	-61.0
4230	-51.6	1.8	8.5	-44.9	-67.7
4700	-55.2	1.9	9.6	-47.5	-70.3

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Model 8563A Spectrum Analyzer SN: 3020AO0522 Cal Due: 9/09
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: 5/09
Miscellaneous	12.2 m RG-213/U coaxial cable
	22.5 m LMR-400 coaxial cable
	3.0 m RG-213/U coaxial cable
	1.8 m RG-214/U coaxial cable
Tests Performed	April 23-24, 2009

Unit Tested: 001-2009-003 Rev A SN—0002

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 2009-003 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 0.219 W, 50 + 10 log(0.219) equals 43.4 dB (44 dB 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.

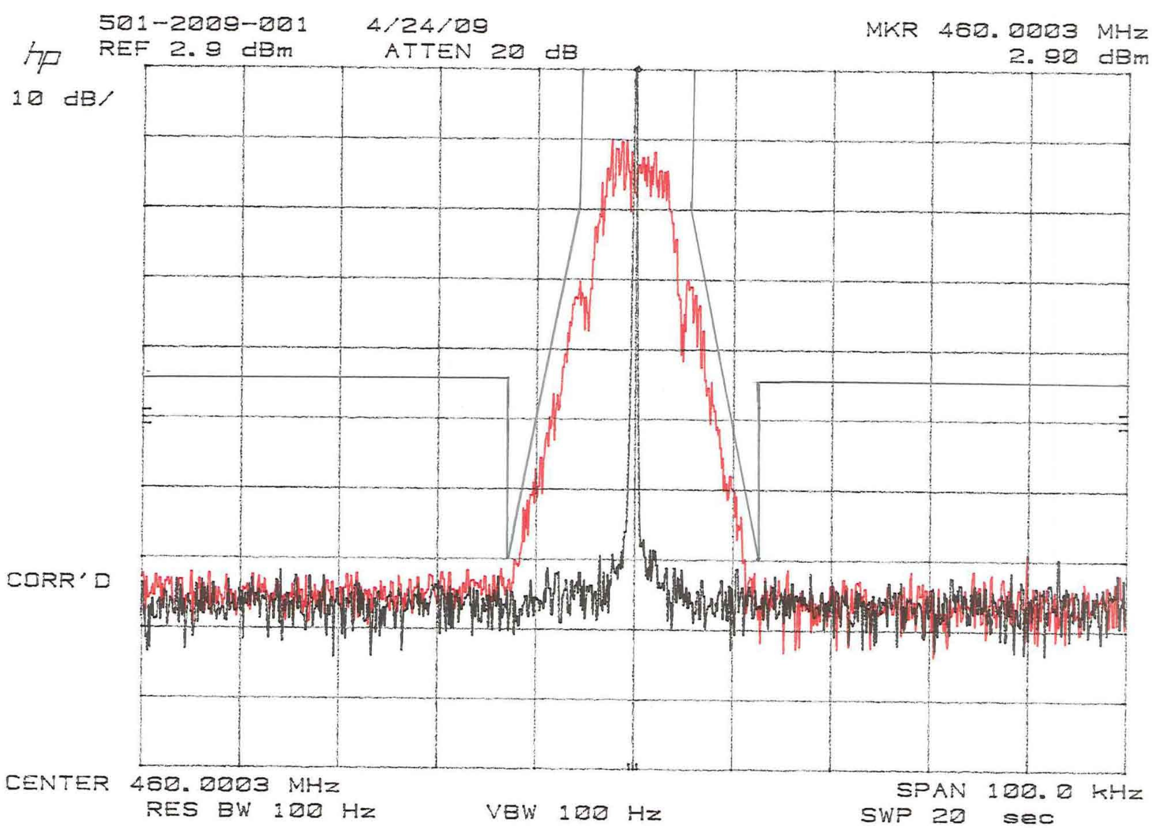


Fig. 1
Hexagram Model 2009-003
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard 8568B with 85680A RF Section S/N: 2216A02120 85662A Display Section SN: 2152A03683 Calibration due: 11/09
Antenna	EMCO Model 3146 Log Periodic Frequency Range 200 MHz – 1000 MHz
Test Performed	April 24, 2009

Unit Tested: 001-2009-003 Rev A   SN—0002

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 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 -40° 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	460.000234	234	+0.51
+30	460.000234	234	+0.51
+40	460.000234	234	+0.51
+50	460.000391	391	+0.85
+60	460.000391	391	+0.85
+70	460.000391	469	+1.02
+80	460.000547	547	+1.19
+85	460.000547	547	+1.19
+20	460.000313	313	+0.68
+10	460.000313	313	+0.68
0	460.000469	469	+1.02
-10	460.000469	469	+1.02
-20	460.000234	234	+0.51
-30	460.000391	391	+0.85
-40	460.000391	391	+0.85
+20	460.000313	313	+0.68

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 both the TIA default standard of 7.50 V of the Lithium Ion battery, the nominal 7.2 V and at the 85% level of both or 6.37 and 6.12 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
7.50 VDC	460.000313	313	+0.68
7.20 VDC	460.000313	313	+0.68
6.38 VDC	460.000313	313	+0.68
6.12 VDC	460.000313	313	+0.68

Reference frequency = 460.000000 MHz

TEST EQUIPMENT USED

Spectrum Analyzer	Tektronix Model WCA 280 S/N J300168 Cal Due: 7/09
Antenna	Whip antenna
DC Power Supply	Agilent E3645A S/N MY40003562 Cal. Due: 3/10
Digital Multi-Meter	Fluke Model 179 Cal. Due: 5/1/2010
Temperature Chamber	Test Equity Model 1007H Cal. due: 2/12/2010
Tests Performed	Temperature May 4, 2009 Voltage May 5, 2009

Temperature & Voltage

Unit Tested: 001-2009-003 Rev A SN—0007

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 2009-003 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 2009-003.

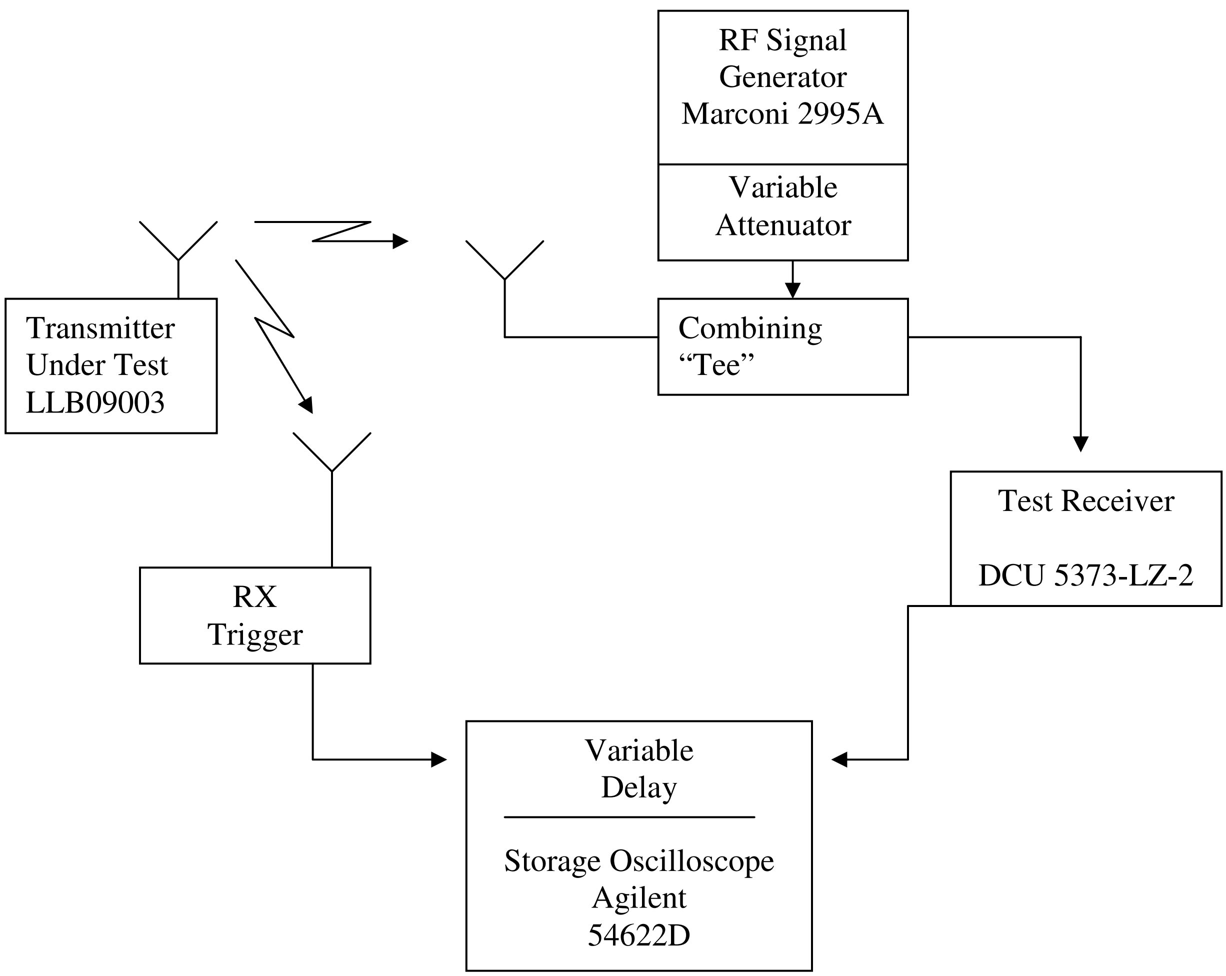


Fig. 2
Transient Frequency Behavior
Test Setup

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.

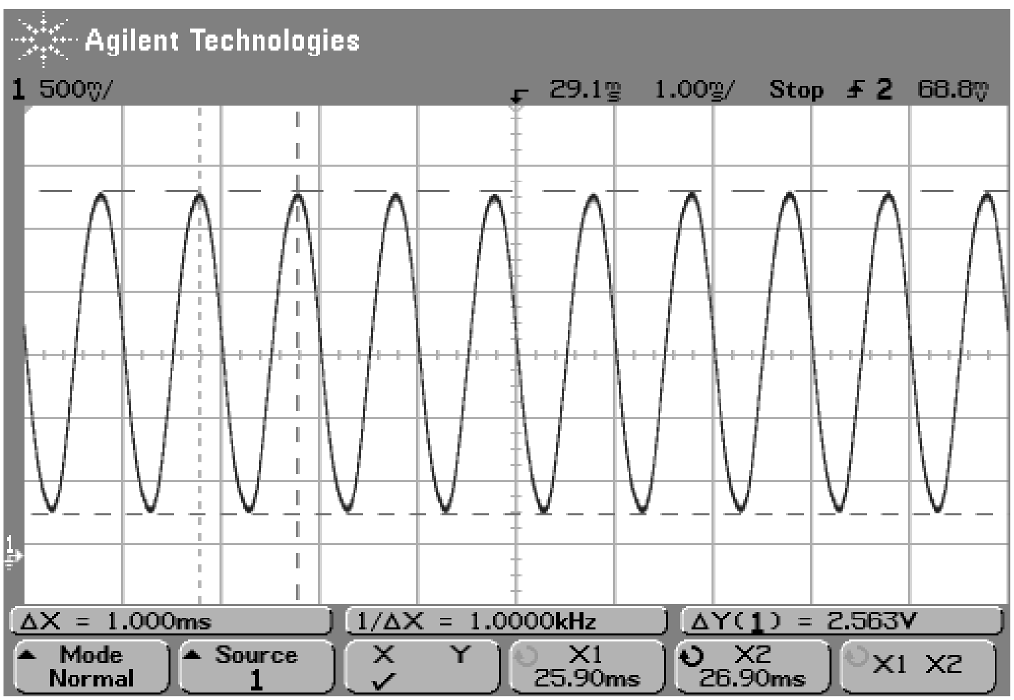
2. Frequency deviation during t_2 (25 ms duration after t_1) must be less than ±6.25 kHz.

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 2009-003's 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 = 2.563 V
±6.25 kHz = 1.282 V
±1.15 kHz = 236 mV

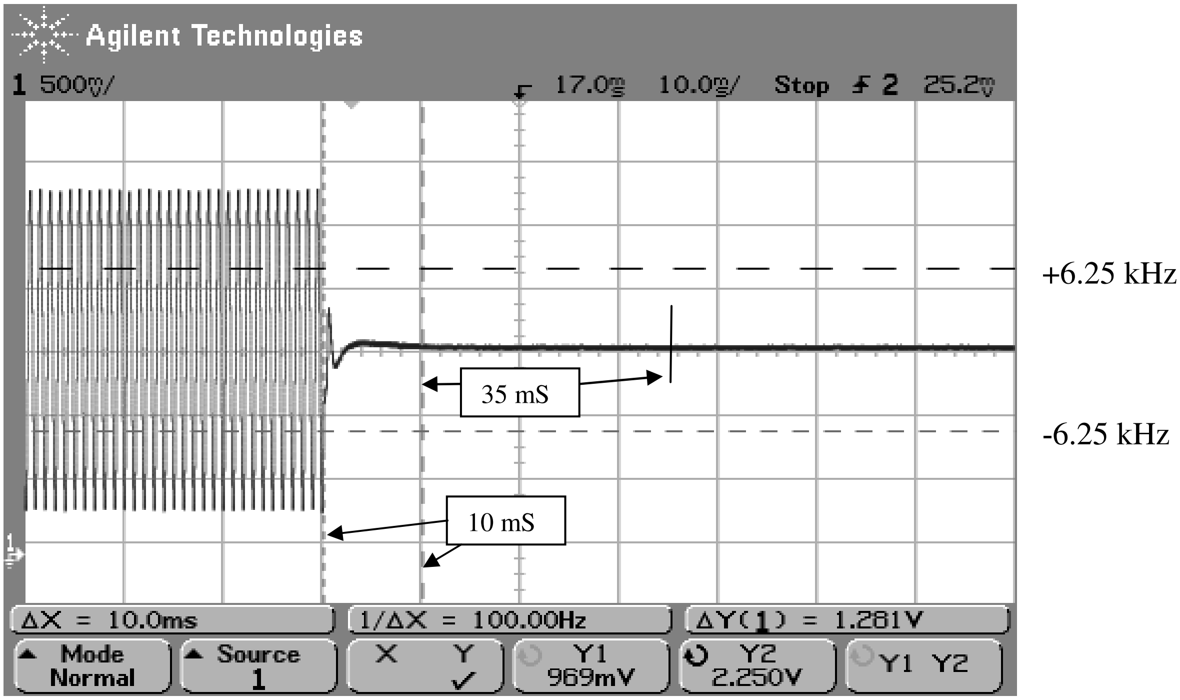


Fig. 4 Start of Transmission

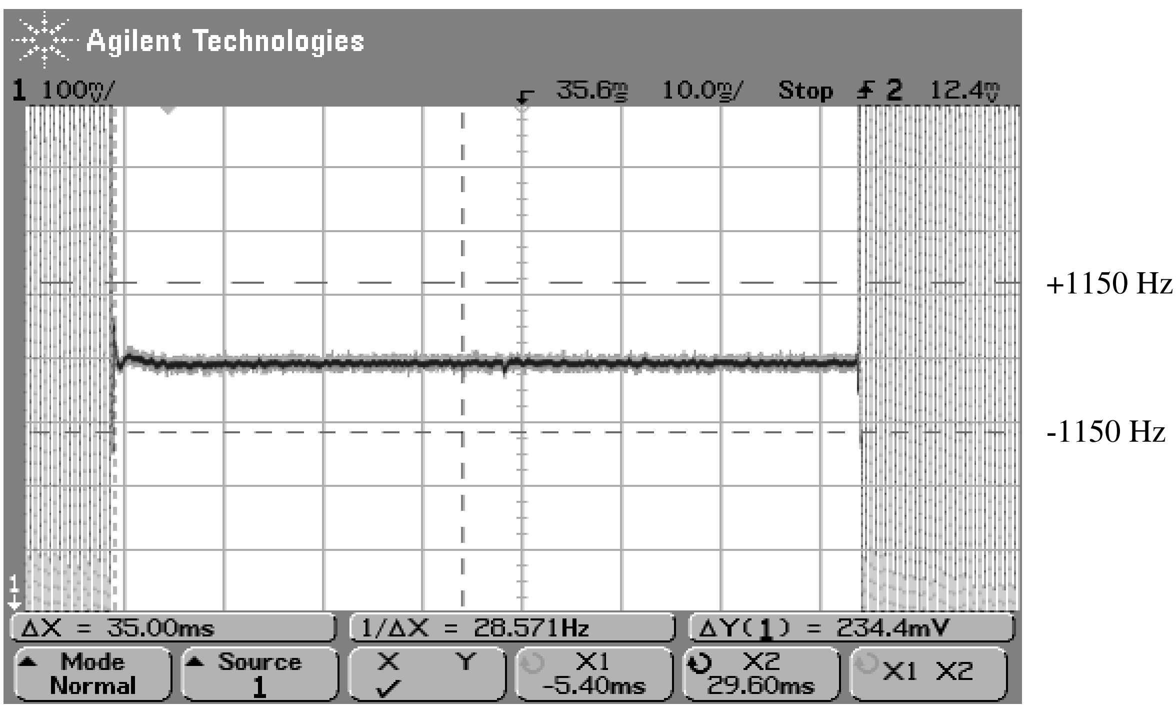


Fig. 5 Full Transmission

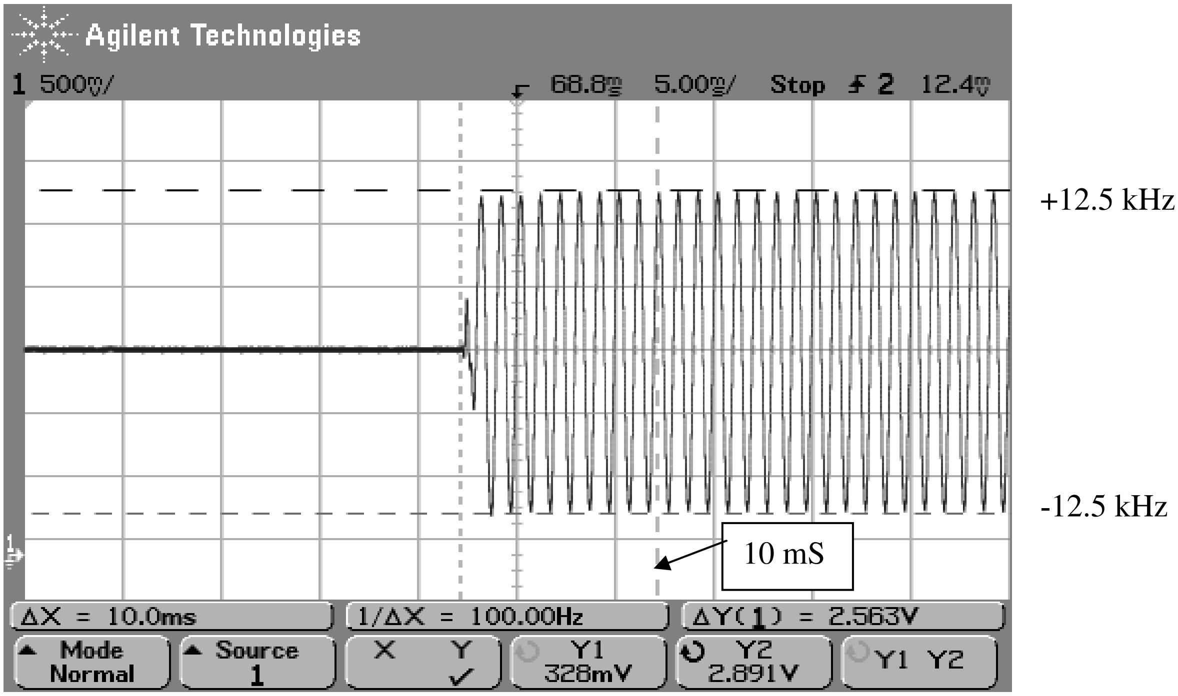


Fig. 6 Turn Off Transient

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: 132004/153 Cal. Due: 11/09
Test Receiver	Hexagram Broadband Receiver
Oscilloscope	Agilent Model 54622D SN: MY40003551 Cal:Due: 11/09
RF Trigger	Hexagram Detector Circuit
Test Performed	April 30, 2009

Unit Tested: : 001-2009-003 Rev A SN—0007

TEST INFORMATION

SUMMARY

The Hexagram Model 09001 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 2009-003
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Cleveland, OH 44122
TEST DATES	April 23 – May 5, 2009
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (330) 289-9306 Mail: 2730 Old Mill Rd. Hudson, OH 44236