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RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

UTILITY METER TRANSMITTING UNIT

Model 2009-014
FCC ID: LLB09014

December 22, 2009

Report Prepared by

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Agency Certification Control Technician

TEST REPORT

INTRODUCTION

The Hexagram Model 2009-014 transmitter is a "Meter Transmitting Unit" (MTU) designed to provide remote meter reading capability for utility meters. The transmitter is self-powered and connects to a meter with mechanical connection. On board batteries provide power. The transmitter provides a very short, intermittent radio frequency transmission to send 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. Two prototype units were used as test subjects for this report. This report presents the data obtained in support of an application for certification.

MEASUREMENTS PERFORMED

The microprocessor 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.

UNITS TESTED

SN – A00030	Tested for temperature and voltage frequency stability
SN – A00033	Tested for power output & harmonics, occupied bandwidth and transient stability.

POWER OUTPUT AND SPURIOUS EMISSIONS

Within the tuning range of 450 – 470 MHz, the transmitter portion of the Model 2009-014 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 very short transmissions of the normally operating transmitter a larger, external battery pack was connected directly to the transmitter and the transmitter was forced to transmit for 20 seconds at a 50% duty cycle to obtain 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 a vertically polarized 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 vertically oriented 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:

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

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 2009-014 MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 1a
HEXAGRAM MODEL 2009-014 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	28.9	2.0	-0.4	26.5	
900	-31.9	2.9	-0.7	-35.5	-62.0

Output = 26.5 dBm
= 0.447 W
Req. Att.= 46.5 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	-49.3	0.8	5.5	-44.6	-71.1
1800	-52.7	1.0	5.9	-47.8	-74.3
2250	-53.4	1.2	6.8	-47.8	-74.3
2700	-64.0	1.3	7.7	-57.6	-84.1
3150	-54.9	1.4	7.8	-48.5	-75.0
3600	-57.2	1.6	7.8	-51.0	-77.5
4050	-36.9	1.7	7.7	-30.9	-57.4
4500	-35.8	1.8	8.3	-29.3	-55.8

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)
450	33.6	2.0	-0.4	31.2	
900	-26.4	2.9	-0.7	-30.0	-61.2

Output = 31.2 dBm
= 1.318 W
Req. Att.= 51.2 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	-46.1	0.8	5.5	-41.4	-72.6
1800	-43.3	1.0	5.9	-38.4	-69.6
2250	-47.2	1.2	6.8	-41.6	-72.8
2700	-57.1	1.3	7.7	-50.7	-81.9
3150	-51.2	1.4	7.8	-44.8	-76.0
3600	-53.8	1.6	7.8	-47.6	-78.8
4050	-37.1	1.7	7.7	-31.1	-62.3
4500	-37.9	1.8	8.3	-31.4	-62.6

TABLE 1b
HEXAGRAM MODEL 2009-014 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	30.5	2.1	-0.4	28.0	
920	-20.5	3.0	-0.6	-24.1	-52.1

Output = 28.0 dBm
= 0.631 W
Req. Att.= 48.0 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	-45.9	0.9	5.6	-41.2	-69.2
1840	-49.2	1.0	5.9	-44.3	-72.3
2300	-50.0	1.2	7.0	-44.2	-72.2
2760	-65.5	1.3	7.7	-59.1	-87.1
3220	-55.5	1.4	7.8	-49.1	-77.1
3680	-49.5	1.6	7.7	-43.4	-71.4
4140	-34.9	1.7	7.8	-28.8	-56.8
4600	-41.3	1.8	8.4	-34.7	-62.7

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	34.8	2.1	-0.4	32.3	
920	-24.5	3.0	-0.6	-28.1	-60.4

Output = 32.3 dBm
= 1.698 W
Req. Att.= 52.3 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)
1380	-43.4	0.9	5.6	-38.7	-71.0
1840	-42.2	1.0	5.9	-37.3	-69.6
2300	-47.4	1.2	7.0	-41.6	-73.9
2760	-58.4	1.3	7.7	-52.0	-84.3
3220	-51.7	1.4	7.8	-45.3	-77.6
3680	-51.0	1.6	7.7	-44.9	-77.2
4140	-32.7	1.7	7.8	-26.6	-58.9
4600	-42.3	1.8	8.4	-35.7	-68.0

TABLE 1c
HEXAGRAM MODEL 2009-014 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	29.0	2.1	-0.4	26.5	
940	-25.1	3.0	-0.6	-28.7	-55.2

Output = 26.5 dBm
= 0.447 W
Req. Att.= 46.5 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	-43.7	0.9	5.7	-38.9	-65.4
1880	-48.5	1.0	5.9	-43.6	-70.1
2350	-51.8	1.2	7.2	-45.8	-72.3
2820	-58.5	1.3	7.7	-52.1	-78.6
3290	-56.2	1.5	7.8	-49.9	-76.4
3760	-47.0	1.6	7.7	-40.9	-67.4
4230	-39.9	1.7	7.9	-33.7	-60.2
4700	-40.3	1.8	8.4	-33.7	-60.2

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	33.2	2.1	-0.4	30.7	
940	-25.0	3.0	-0.6	-28.6	-59.3

Output = 30.7 dBm
= 1.175W
Req. Att.= 50.7 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	-37.2	0.9	5.7	-32.4	-63.1
1880	-43.1	1.0	5.9	-38.2	-68.9
2350	-46.1	1.2	7.2	-40.1	-70.8
2820	-57.8	1.3	7.7	-51.4	-82.18
3290	-57.0	1.5	7.8	-50.7	-81.4
3760	-46.0	1.6	-39.9	-70.6	-82.7
4230	-37.4	1.7	7.9	-31.2	-61.9
4700	-37.0	1.8	8.4	-30.4	-61.1

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Model 8593EM Spectrum Analyzer SN: 3536A00147 Cal Due: 8/26/2010
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: 6/04/2010
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	December 10 – 14, 2009

Unit Tested: 2009-014 Rev A SN—A00033

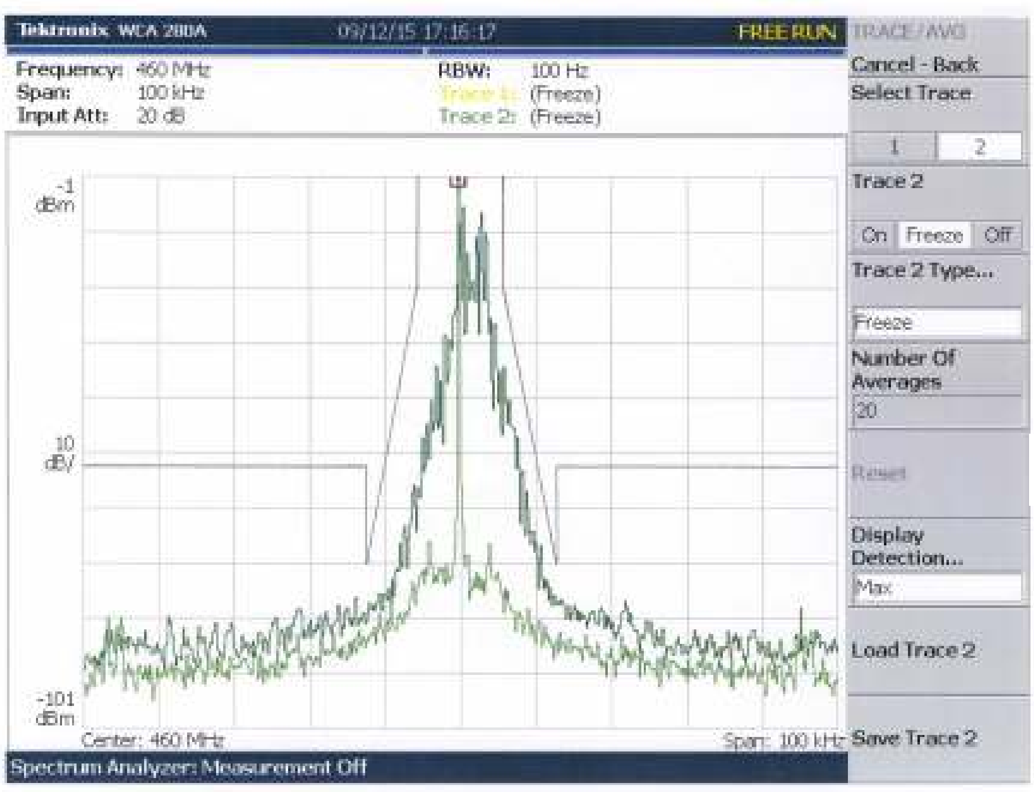
OCCUPIED BANDWIDTH

The emissions close to the center of the specified channel are limited by the emissions masks described in Part 90.210. For the frequency range of the 2009-014 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 1.698 W, 50 + 10 log(1.698) equals 52.3 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 test 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.



-52.3 dB

Fig. 1
Hexagram Model 2009-014
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Tektronix Model WCA 280A SN: J300168 Cal Due: 7/23/2010
Antenna	Maxrad MUF4505 whip antenna
Test Performed	December 15, 2009

Unit Tested: 2009-014 Rev A SN—A00033

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 then decreased to 10° and then 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 transmission frequency of the initial 20° measurement 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	460.002109	0	0.000
+30	460.002012	-29	-0.63
+40	460.001758	-351	-0.763
+50	460.001934	-175	-0.380
+60	460.002100	-9	-0.020
+70	460.001973	-136	-0.296
+20	460.002246	+137	+0.298
+10	460.002402	+293	+0.637
0	460.002344	+235	+0.511
-10	460.002324	+215	+0.467
-20	460.002344	+235	+0.511
-27	460.002109	0	0.000
-30	No Transmission	--	--
+20	460.002188	+79	+0.172

Reference frequency = 460.002109 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 3.75 V of the Lithium Ion batteries, and at, or below, the 85% level of the nominal 3.6 V or 3.06 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 value obtained at the nominal battery voltage of 3.6 VDC. The data for these measurements are found in Table 3. 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
3.75 VDC	460.02022	-58	-0.126
3.6 VDC	460.002080	0	-0.000
3.5 VDC	460.002041	-39	-0.085
3.4 VDC	460.002031	-49	-0.107
3.3 VDC	460.002012	-68	-0.148
3.2 VDC	460.001992	-88	-0.191
3.1 VDC	460.002002	-78	-0.170
3.0 VDC	460.002012	-68	-0.148
2.9 VDC	460.002197	117	+0.254

Reference frequency = 460.002080 MHz

TEST EQUIPMENT USED

Spectrum Analyzer	Tektronix Model WCA 280 SN: J300168 Cal Due: 7/23/2010
Antenna	Maxrad MUF4505 whip antenna
DC Power Supply	Agilent Model E3534A SN: MY40010335
Digital Multi-Meter	Fluke Model 179 SN: 96480042 Cal. Due: 7/14/10
Temperature Chamber	Test Equity Model 1007H Cal. due: 2/12/2010
Tests Performed	Temperature Dec. 17-21, 2009 Voltage Dec. 16, 2009

Unit Tested: 2009-014 Rev A   SN—A00030

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 2009-014 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 modified DCU wideband receiver 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 modulated test signal at 460 MHz was provided by the 8920D test set. 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 2009-014.

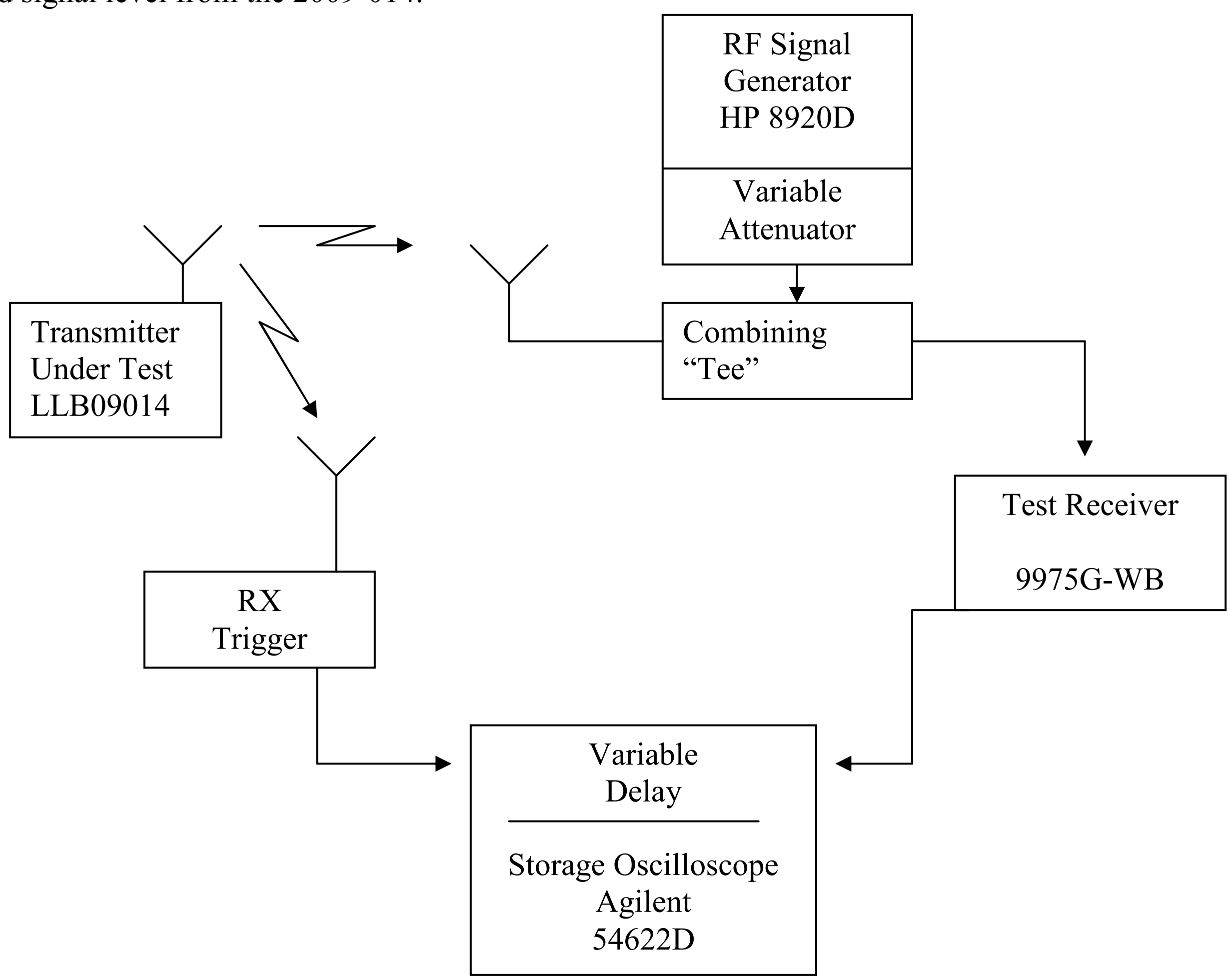


Fig. 2
Transient Frequency Behavior
Test Setup

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.

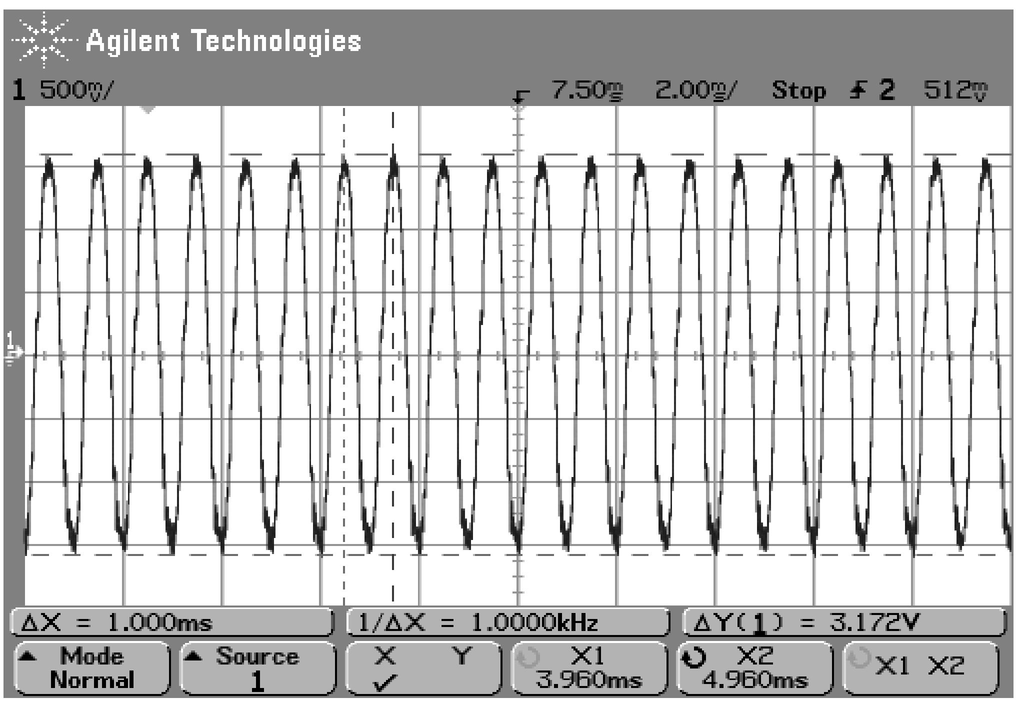
2. Frequency deviation during t_2 (25 ms duration after t_1) must be less than ±6.25 kHz.

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 2009-014'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 = 3.172 V
±6.25 kHz = 1.586 V
±1.15 kHz = 292 mV

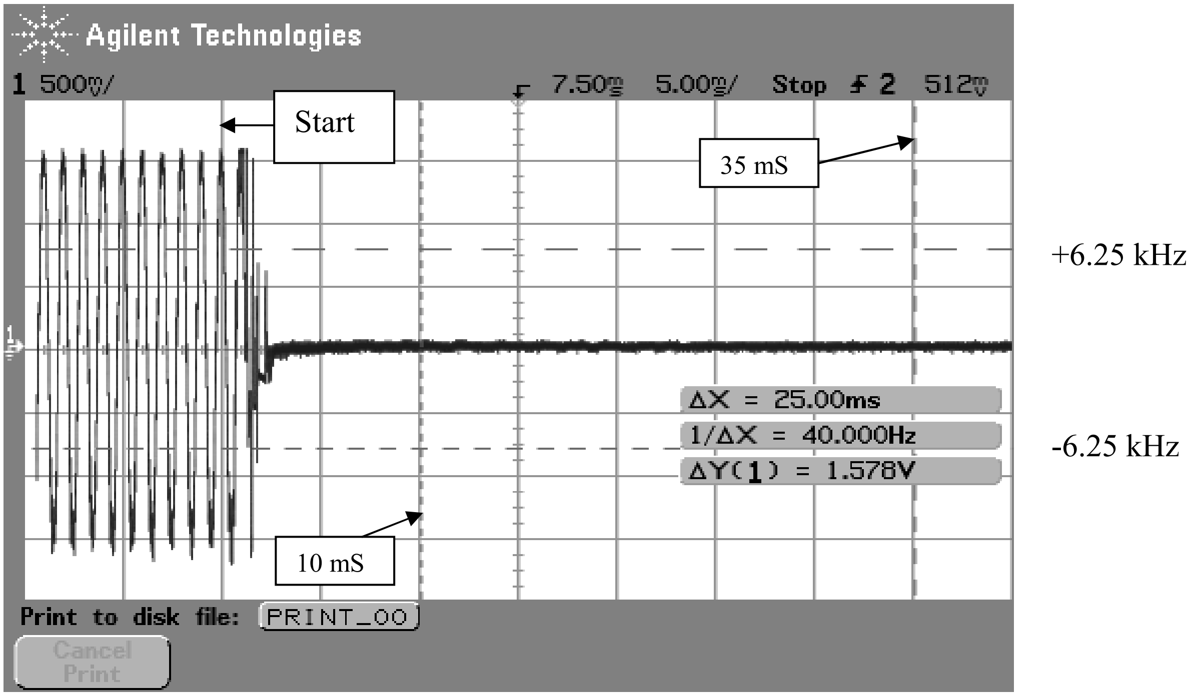


Fig. 4   Start of Transmission

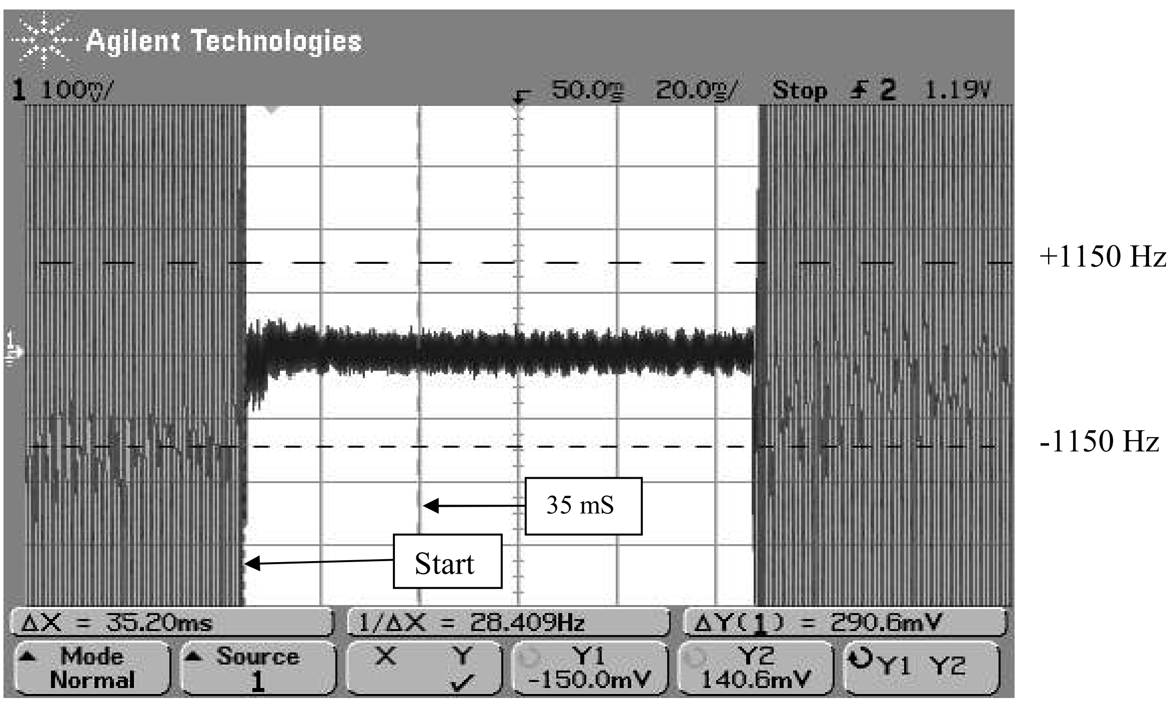


Fig. 5   Full Transmission

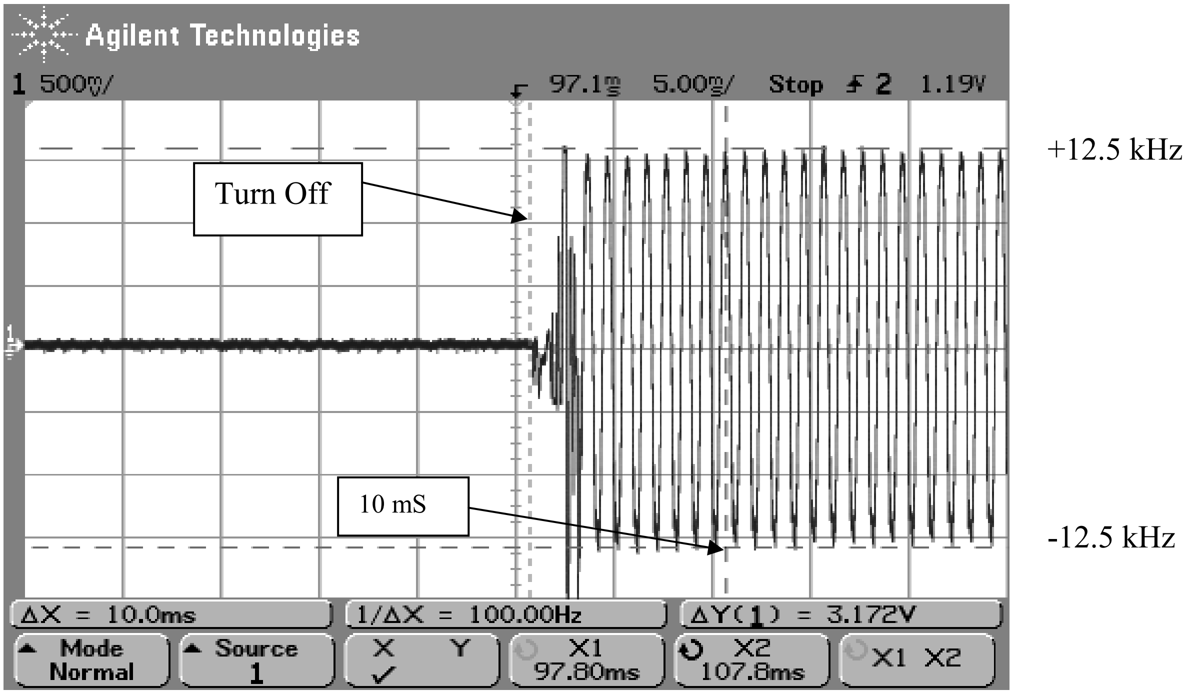


Fig. 6   Turn Off Transient

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	Hewlett-Packard Model 8920D RF Communications Test Set SN: US37253192 Cal Due: 7/21/10
Test Receiver	Hexagram Broadband Receiver Model 9975G-WB
Oscilloscope	Agilent Model 54622D SN: MY40003551 Cal Due: 11/2010
RF Trigger	Hexagram Detector Circuit
Test Performed	December 16, 2009

Unit Tested: 2009-014 Rev A   SN—A00033

TEST INFORMATION

SUMMARY

The Hexagram Model 2009-014 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 2009-014
MANUFACTURER	Hexagram, Inc. 30400 Solon Rd. Solon, OH 44139
TEST DATES	December 9 - 21, 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).