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

# ENGINEERING TEST REPORT

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HIGH READ-RATE
METER TRANSMITTING UNIT

Model 2009-010C
FCC ID: LLB09010C

December 2, 2009

Report Prepared by

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Agency Certification Control Technician

# TEST REPORT

## INTRODUCTION

The Hexagram Model 2009-010C 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 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. The receiver 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 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 2009-010C 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 30 seconds at a 25% 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 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 properly 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.

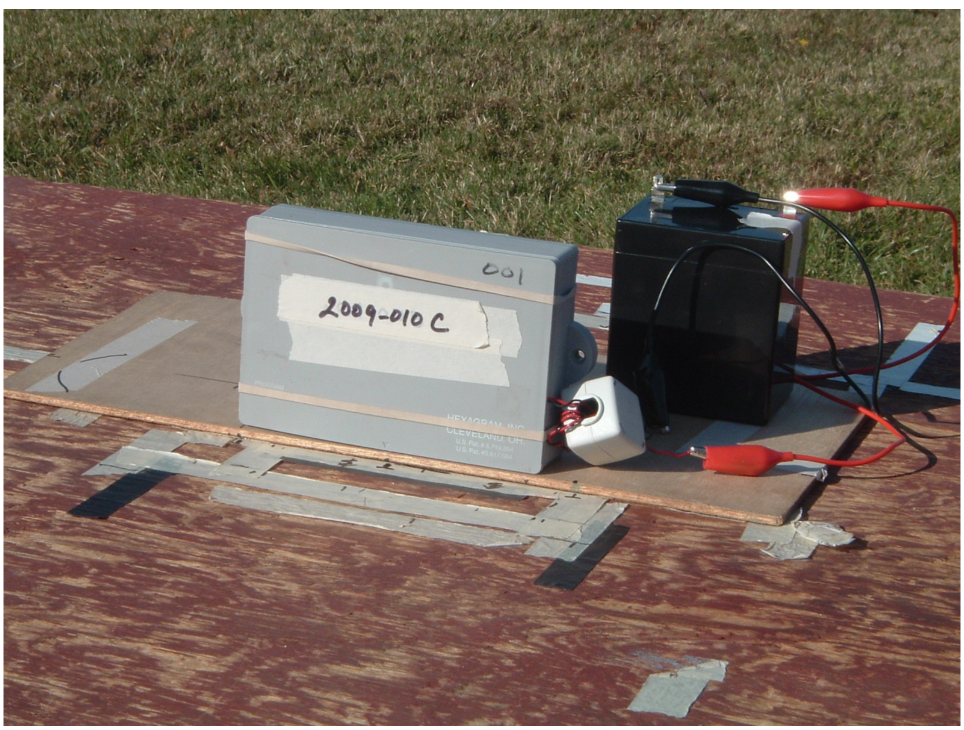
In order to convert the signal generator output value to equivalent radiated power from a dipole, the following equation is used:

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

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 2009-010C MTU
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

**TABLE 1a**
**HEXAGRAM MODEL 2009-010C 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 | 26.6 | 2.0 | -0.4 | 24.2 | |
| 900 | -40.0 | 2.9 | -0.7 | -43.6 | -67.8 |

**Output = 24.2 dBm**
**= 0.263 W**
**Req. Att.= 44.2 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) |
|---|---|---|---|---|---|
| 1350 | -51.2 | 0.8 | 5.5 | -46.5 | -70.7 |
| 1800 | -48.5 | 1.0 | 5.9 | -43.6 | -67.8 |
| 2250 | -53.0 | 1.2 | 6.8 | -47.4 | -71.6 |
| 2700 | -50.7 | 1.3 | 7.7 | -44.3 | -68.5 |
| 3150 | -47.6 | 1.4 | 7.8 | -41.2 | -65.4 |
| 3600 | -51.8 | 1.6 | 7.8 | -45.6 | -69.8 |
| 4050 | -50.5 | 1.7 | 7.7 | -44.5 | -68.7 |
| 4500 | -56.4 | 1.8 | 8.3 | --49.9 | --74.1 |

**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 | 34.0 | 2.0 | -0.4 | 31.6 | |
| 900 | -36.4 | 2.9 | -0.7 | -40.0 | -71.6 |

**Output = 31.6 dBm**
**= 1.445 W**
**Req. Att.= 51.6 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 | --54.8 | 0.8 | 5.5 | -50.1 | -81.7 |
| 1800 | -46.9 | 1.0 | 5.9 | --42.0 | --73.6 |
| 2250 | -54.2 | 1.2 | 6.8 | -48.6 | -80.2 |
| 2700 | -57.4 | 1.3 | 7.7 | -51.0 | -82.6 |
| 3150 | -52.9 | 1.4 | 7.8 | -46.5 | -78.1 |
| 3600 | -52.0 | 1.6 | 7.8 | -45.8 | -77.4 |
| 4050 | -55.3 | 1.7 | 7.7 | -49.3 | -80.9 |
| 4500 | -62.1 | 1.8 | 8.3 | -55.6 | -87.2 |

**TABLE 1b**
**HEXAGRAM MODEL 2009-010C 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 | 23.6 | 2.1 | -0.4 | 21.1 | |
| 920 | -40.7 | 3.0 | -0.6 | -44.3 | -65.4 |

**Output = 21.1 dBm**
**= 0.129 W**
**Req. Att.= 41.1 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 | -44.0 | 0.9 | 5.6 | -39.3 | -60.4 |
| 1840 | -51.1 | 1.0 | 5.9 | -46.2 | -67.3 |
| 2300 | -57.4 | 1.2 | 7.0 | -51.6 | -72.7 |
| 2760 | -61.0 | 1.3 | 7.7 | -54.6 | -75.7 |
| 3220 | -58.8 | 1.4 | 7.8 | -52.4 | -73.5 |
| 3680 | -52.7 | 1.6 | 7.7 | -46.6 | -67.7 |
| 4140 | -54.2 | 1.7 | 7.8 | -48.1 | -69.2 |
| 4600 | -61.6 | 1.8 | 8.4 | -55.0 | -76.1 |

**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) |
|---|---|---|---|---|---|
| 460 | 33.1 | 2.1 | -0.4 | 30.6 | |
| 920 | -41.0 | 3.0 | -0.6 | -44.6 | -75.2 |

**Output = 30.6 dBm**
**= 1.148 W**
**Req. Att.= 50.6 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 | -52.1 | 0.9 | 5.6 | -47.4 | -78.0 |
| 1840 | -50.3 | 1.0 | 5.9 | -45.4 | -76.0 |
| 2300 | -57.2 | 1.2 | 7.0 | -51.4 | -82.0 |
| 2760 | -61.4 | 1.3 | 7.7 | -55.0 | -85.6 |
| 3220 | -59.7 | 1.4 | 7.8 | -53.3 | -83.9 |
| 3680 | -58.2 | 1.6 | 7.7 | -52.1 | -82.7 |
| 4140 | -54.0 | 1.7 | 7.8 | -47.9 | -78.5 |
| 4600 | -64.2 | 1.8 | 8.4 | -57.6 | -88.2 |

**TABLE 1c**
**HEXAGRAM MODEL 2009-010C 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 | 19.5 | 2.1 | -0.4 | 17.0 | |
| 940 | -40.0 | 3.0 | -0.6 | -43.6 | -60.6 |

**Output = 17.0 dBm**
**= 0.050 W**
**Req. Att.= 37.0 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) |
|---|---|---|---|---|---|
| 1410 | -45.6 | 0.9 | 5.7 | -40.8 | -57.8 |
| 1880 | -57.7 | 1.0 | 5.9 | -52.8 | -69.8 |
| 2350 | -61.4 | 1.2 | 7.2 | --55.4 | --72.4 |
| 2820 | -62.4 | 1.3 | 7.7 | -56.0 | -73.0 |
| 3290 | -60.2 | 1.5 | 7.8 | -53.9 | -70.9 |
| 3760 | -57.0 | 1.6 | 7.7 | --50.9 | --67.9 |
| 4230 | -49.6 | 1.7 | 7.9 | -43.4 | -60.4 |
| 4700 | -59.6 | 1.8 | 8.4 | -53.0 | -70.0 |

**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 | 28.7 | 2.1 | -0.4 | 26.2 | |
| 940 | -44.0 | 3.0 | -0.6 | -47.6 | -73.8 |

**Output = 26.2 dBm**
**= 0.417W**
**Req. Att.= 46.2 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) |
|---|---|---|---|---|---|
| 1410 | -54.5 | 0.9 | 5.7 | -49.7 | -75.9 |
| 1880 | -58.0 | 1.0 | 5.9 | -53.1 | -79.3 |
| 2350 | -60.7 | 1.2 | 7.2 | -54.7 | -80.9 |
| 2820 | -67.0 | 1.3 | 7.7 | --60.6 | --86.8 |
| 3290 | -65.0 | 1.5 | 7.8 | -58.7 | -84.9 |
| 3760 | -62.6 | 1.6 | 7.7 | -56.5 | -82.7 |
| 4230 | -53.7 | 1.7 | 7.9 | -47.5 | -73.7 |
| 4700 | -62.9 | 1.8 | 8.4 | -56.3 | -82.5 |

**TEST EQUIPMENT USED**

| | |
|---|---|
| **Spectrum Analyzer** | Hewlett-Packard Model 8593EM Spectrum Analyzer<br>SN: 3536A00147 Cal Due: 8/2010 |
| **Antennas** | (2x) ETS-Lindgren Model DB-4 Tuned Dipole<br>Frequency Range 400 – 1000 MHz |
| | (2x) ETS-Lindgren Model 3115 Double Ridged Guide Horn<br>Frequency Range 0.75 – 18 GHz |
| **Signal Generator** | Hewlett-Packard Model 8340B,<br>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** | November 6-10, 2009 |

Unit Tested: 2009-010C Rev A SN—3012

## 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 2009-010C 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 1.445 W, 50 + 10 log(1.445) equals 51.6 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.

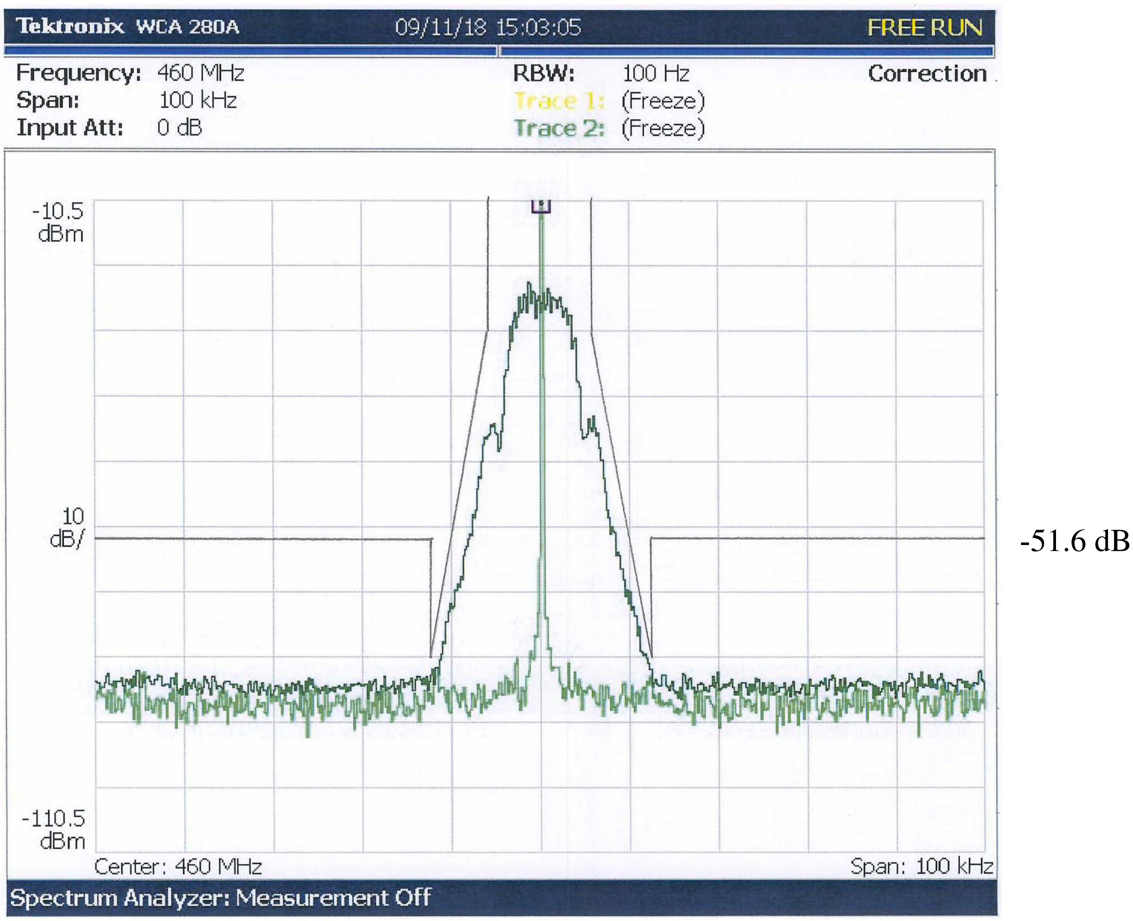



Fig. 1
Hexagram Model 2009-010C
Emissions Mask

**TEST EQUIPMENT USED**

| | |
|---|---|
| **<u>Spectrum Analyzer</u>** | Tektronix Model WCA 280A<br>SN: J300168 Cal Due: 7/2010 |
| **<u>Antenna</u>** | Maxrad MUF4505 whip antenna |
| **<u>Test Performed</u>** | November 18, 2009 |

Unit Tested: 2009-010C Rev A SN—3012

**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 25° 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 25° C. stabilized and then decreased to 20° 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 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 |
|---|---|---|---|
| +25 | 460.000146 | 146 | +0.32 |
| +30 | 460.000117 | 117 | +0.25 |
| +40 | 460.000098 | 98 | +0.21 |
| +50 | 460.000137 | 137 | +0.30 |
| +60 | 460.000254 | 254 | +0.55 |
| +70 | 460.000391 | 391 | +0.85 |
| +80 | 460.000400 | 400 | +0.87 |
| +85 | 460.000322 | 322 | +0.70 |
| +25 | 460.000225 | 225 | +0.49 |
| +20 | 460.000244 | 244 | +0.53 |
| +10 | 460.000273 | 273 | +0.59 |
| 0 | 460.000352 | 352 | +0.77 |
| -10 | 460.000342 | 342 | +0.74 |
| -20 | 460.000215 | 215 | +0.47 |
| -30 | 460.000186 | 186 | +0.40 |
| +25 | 460.000196 | 196 | +0.43 |

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 | 460.000195 | +195 | +0.42 |
| 7.2 VDC | 460.000195 | +195 | +0.42 |
| 7.0 VDC | 460.000166 | +166 | +0.36 |
| 6.5 VDC | 460.000195 | +195 | +0.42 |
| 6.0 VDC | 460.000186 | +186 | +0.40 |
| 5.5VDC | 460.000186 | +186 | +0.40 |
| 5.0 VDC | 460.000195 | +195 | +0.42 |
| 4.5 VDC | 460.000186 | +186 | +0.40 |
| 4.0 VDC | 460.000176 | +176 | +0.38 |

Reference frequency = 460.000000 MHz

**TEST EQUIPMENT USED**

| | |
|---|---|
| **Spectrum Analyzer** | Tektronix Model WCA 280<br>SN:  J300168   Cal Due:  7/2010 |
| **Antenna** | Maxrad MUF4505 whip antenna |
| **DC Power Supply** | Agilent Model E3534A<br>SN:  MY40010335 |
| **Digital Multi-Meter** | Fluke Model 179<br>SN:  94490545<br>Cal. Due:  7/1/3/10 |
| **Temperature Chamber** | Test Equity Model 1007H<br>Cal. due:  2/12/2010 |
| **Tests Performed** | Temperature    Nov. 17-18, 2009<br>Voltage    Nov. 19, 2009 |

Temperature

Unit Tested:  2009-010C Rev A   SN—3012

Voltage

Unit Tested:  2009-010C Rev A   SN—3012

**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 2009-010C 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 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 2009-010C.

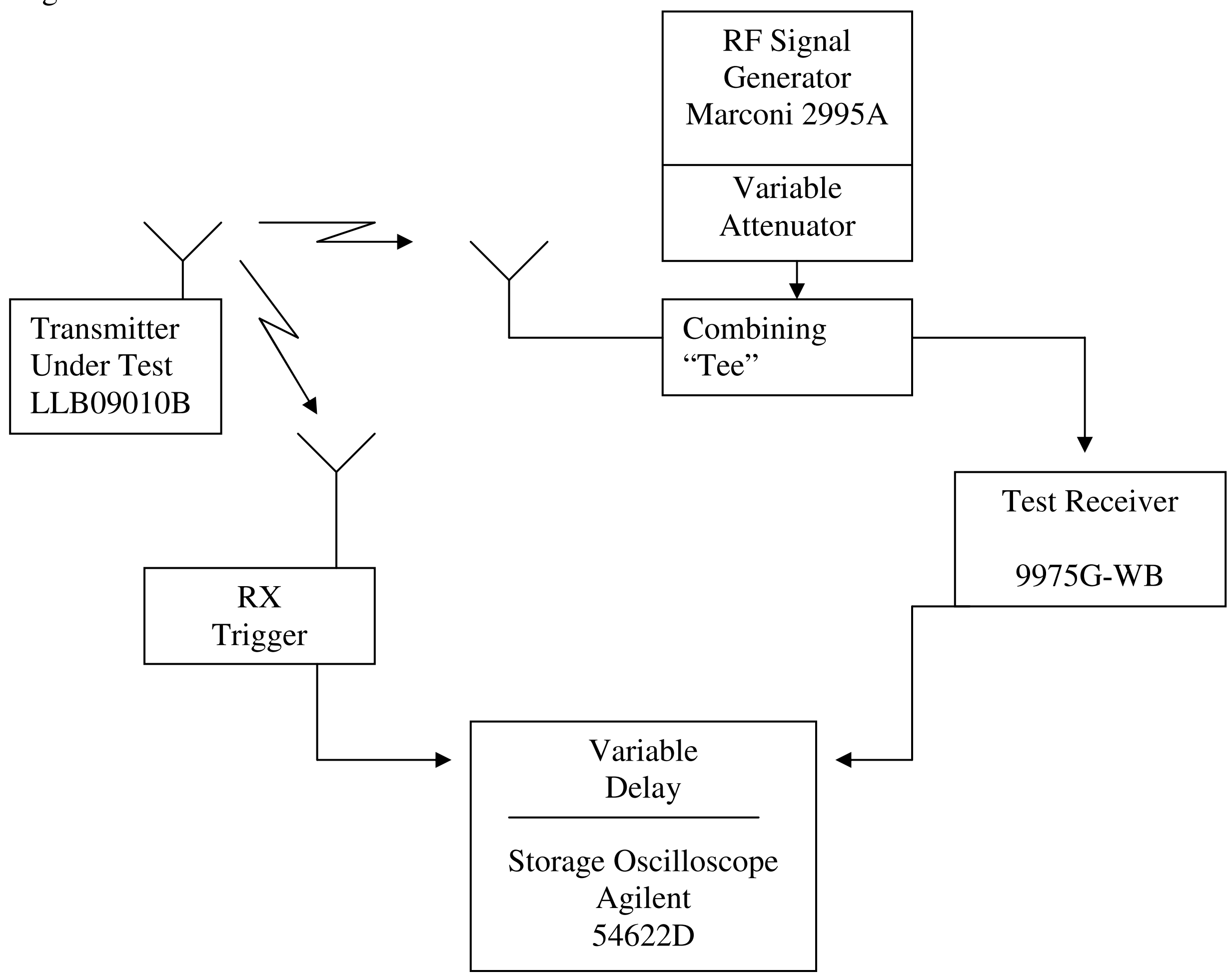



Fig. 2
Transient Frequency Behavior
Test Setup

**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 2009-010C's transient frequency characteristics. The limit masks are indicated on each of the figures.

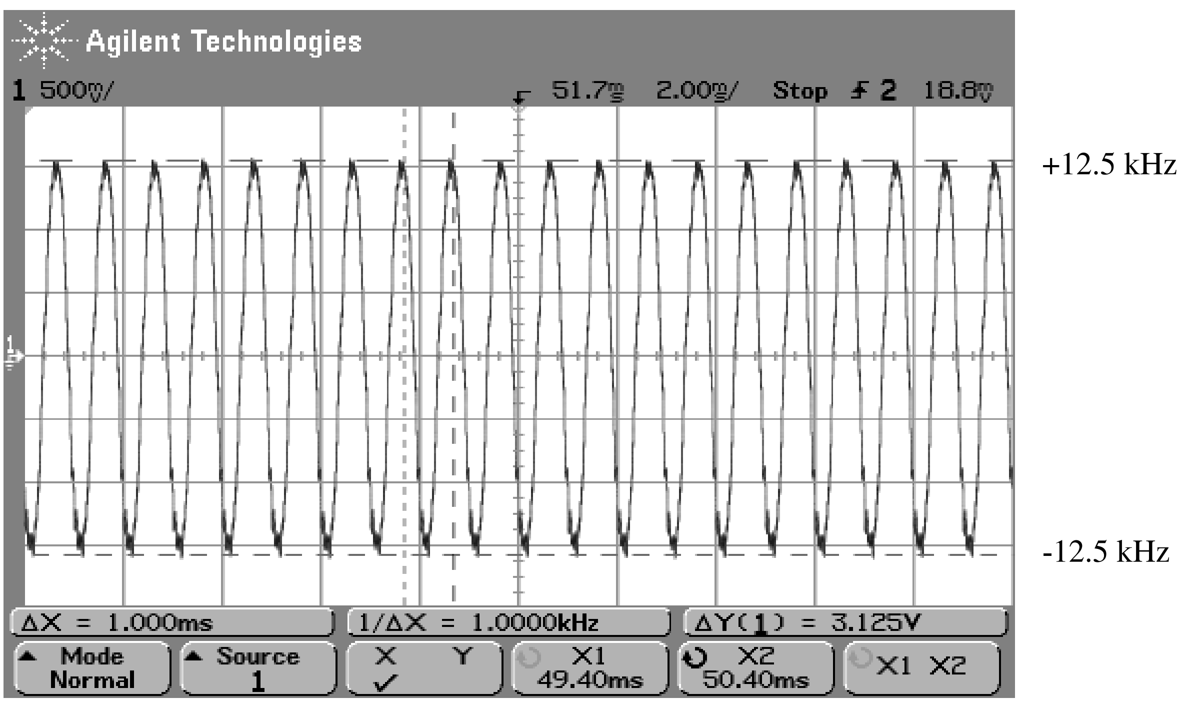



**Fig. 3 ±12.5 kHz modulated test signal .**

**±12.5 kHz = 3.125 V**
**±6.25 kHz = 1.563 V**
**±1.15 kHz = 288 mV**

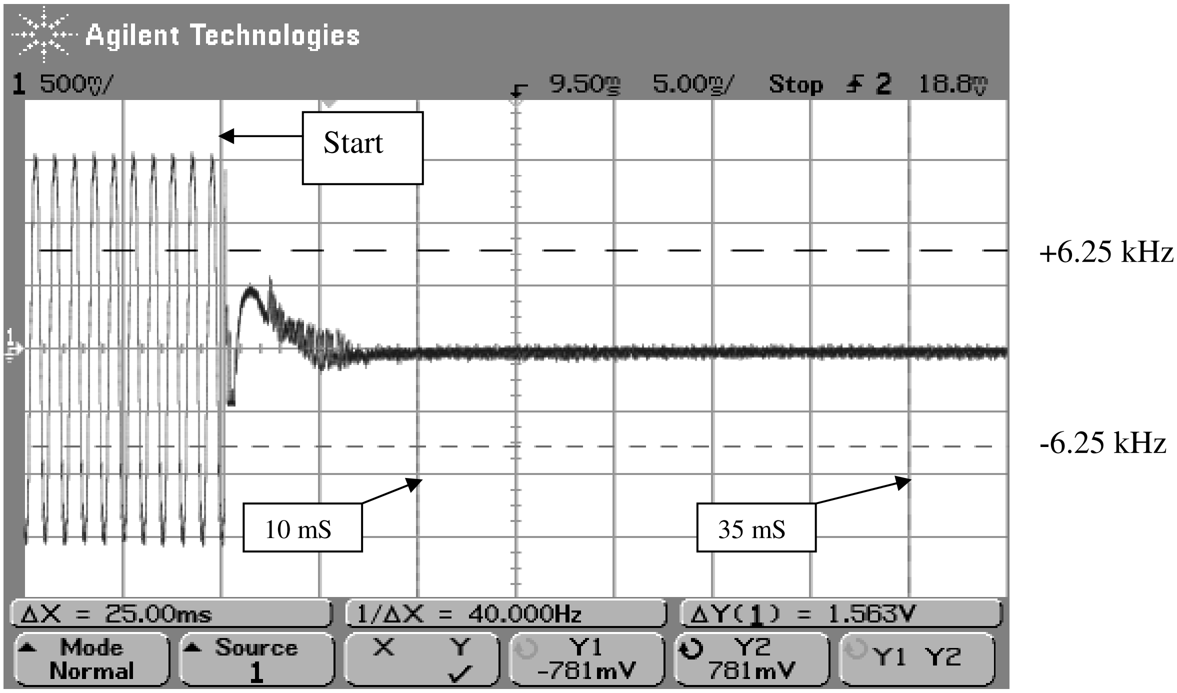
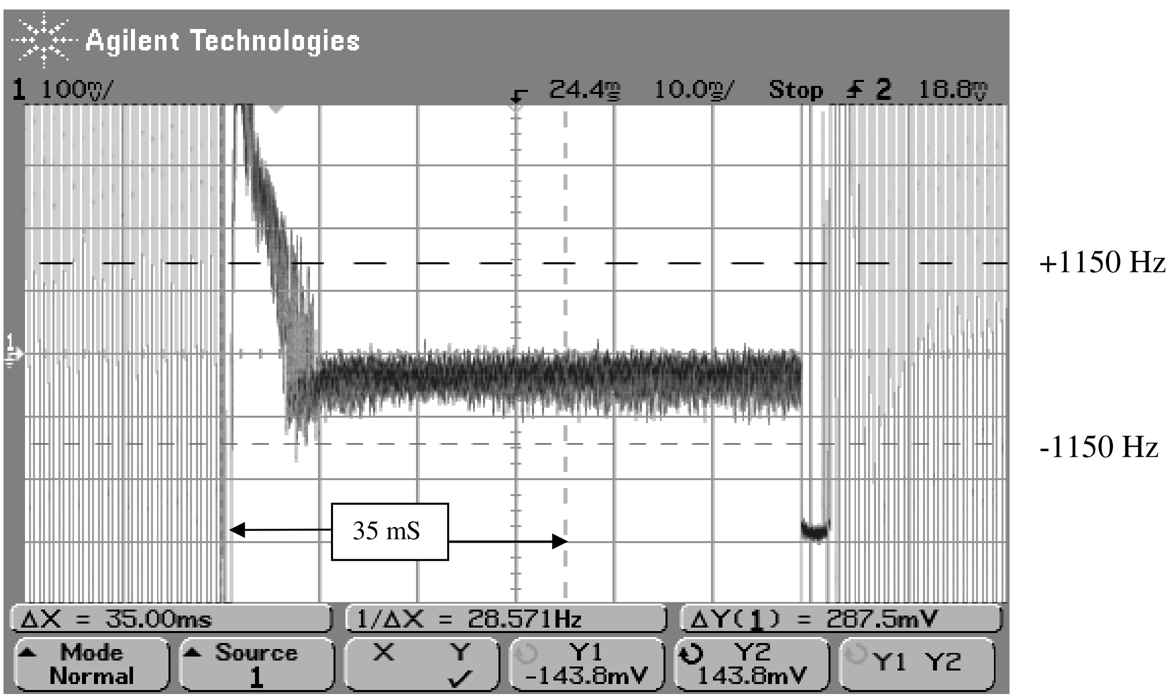



**Fig. 4   Start of Transmission**




+12.5 kHz

**Fig. 5   Full Transmission**

-12.5 kHz

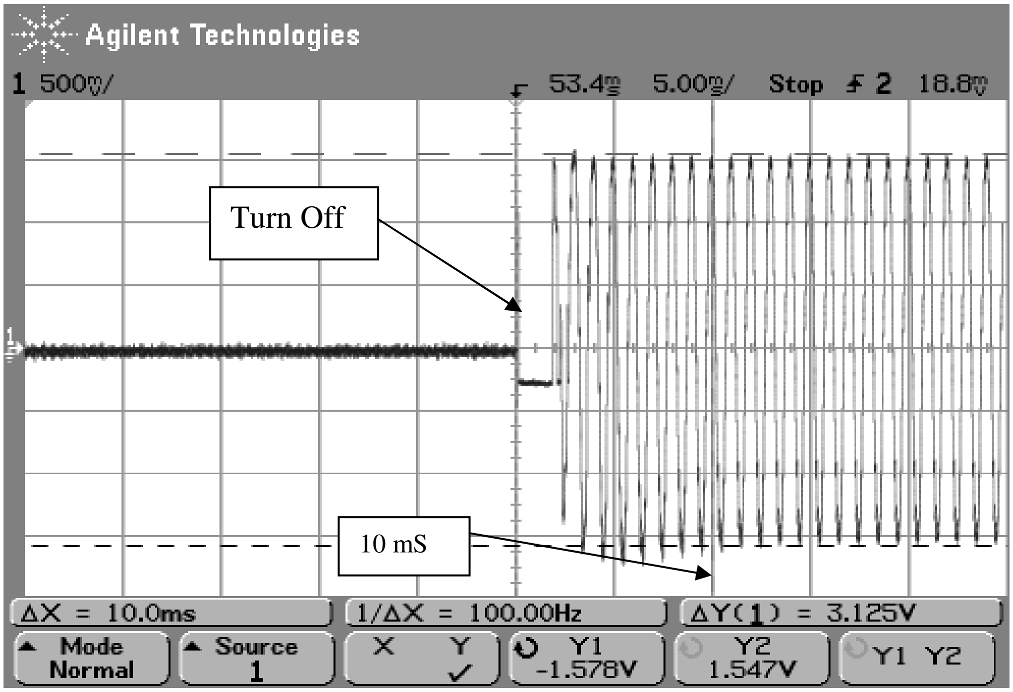



**Fig. 6 Turn Off Transient**

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<br>Cal. Due: 12/2009 |
| **Test Receiver** | Hexagram Broadband Receiver<br>Model 9975G-WB |
| **Oscilloscope** | Agilent Model 54622D<br>SN: MY40003551 Cal Due: 11/2010 |
| **RF Trigger** | Hexagram Detector Circuit |
| **Test Performed** | November 19, 2009 |

Unit Tested: 2009-010C Rev A SN—3012

## TEST INFORMATION

## SUMMARY

The Hexagram Model 2009-010C 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 2009-010C |
| **MANUFACTURER** | Hexagram, Inc.<br>30400 Solon Rd.<br>Solon, OH 44139 |
| **TEST DATES** | November 6 - 19, 2009 |
| **OPEN AREA TEST SITE** | Smith Electronics, Inc.<br>8200 Snowville Road<br>Cleveland, OH 44141<br>(330) 289-9306<br><br>FCC (Reg. #90938)<br>Industry Canada (File #4541A-1). |