SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

DCU II
(TRANSMITTER)

Model 9975
FCC ID: LLB9975

September 13, 2006

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TEST REPORT

INTRODUCTION

The Hexagram DCU II is a data collection unit and communication point between a utility control center and individual Meter Transmitting Units (MTUs) connected to individual meters. The transmitter is part of a transceiver module (DataRadio/3473-2W) that can contact MTUs individually for purposes of time synchronization and rate change information. This report contains the results of tests performed to meet the requirements for certification of the transmitter portion under FCC Parts 2 and 90. The DCU II also contains digital circuitry and a second transceiver which is only used as a receiver. The test data for certification and verification requirements for these parts is covered in other reports.

The transmitter contained in the DCU is a battery-powered transmitter housed in a coated copper enclosure. This enclosure and the other electronics are placed within a plastic housing and the entire system is within a weather-proof stainless-steel enclosure. The transmitter is connected to an external antenna. When requested, the transmitter provides a very short, intermittent radio frequency transmission to communicate with a particular meter. A microprocessor provides timing, control and data processing functions. The external antenna supplied with the transmitter will be determined by the transmission requirements, but will not exceed the ERP limits of 90.267(d)(2). AC power is provided to maintain battery voltage. One transmitter was tested and this report presents the worst case data obtained in support of an application for certification.

MEASUREMENTS PERFORMED

The microprocessor portion of the transmitter was also examined for radiated emissions per Part 15, and has been verified to comply with the appropriate sections of that part. The data used for verification of the microprocessor portion is presented in a separate report.

POWER OUTPUT AND SPURIOUS EMISSIONS

Measurements of the RF power output and spurious emissions were made at the antenna terminal per 2.1046 and 2.1051.

The output of the transmitter was connected to the spectrum analyzer through a 30 dB attenuator and 3 ft. of RG-214U coaxial cable. The transmitter was activated using a computer controller. The fundamental and harmonic emissions were observed and the signal strengths recorded for three frequencies covering the tuning range of the transmitter. No spurious signals other than harmonics were noted.

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 signal level of all harmonics greater than the third were more than 20 dB below the required suppression level and are not tabulated

The determined power outputs, the required harmonic attenuation as well as the attenuation for each harmonic are found in Table 1.

TABLE 1
HEXAGRAM MODEL DCU II TRANSMITTER OUTPUT POWER AND SPURIOUS DIRECT MEASUREMENT

Frequency (MHz)	Measured Signal (dBm)	Coax Loss (dB)	Attenuation (dB)	Output. Power (dBm)	Difference (dB)
450	3.9	0.2	30.0	34.1	**-54.1 Req**.
900	-65.1	0.3	30.0	-34.8	-68.9
1350	-71.0	0.3	30.0	-40.7	-91.5
460	4.3	0.2	30.0	34.5	**-54.5 Req**.
920	-65.9	0.3	30.0	-35.6	-70.1
1380	-74.6	0.3	30.0	-44.3	-78.8
470	4.2	0.2	30.0	34.4	**-54.4 Req.**
940	-66.9	0.3	30.0	-36.6	-71.0
1410	-75.6	0.3	30.0	-45.3	-79.7

All other harmonics to the tenth were at least 85 dB below the fundamental. These are not required to be reported as they are more than 20 dB below the required values.

34.1 dBm = 2.57 W
Required attenuation for harmonics is 50 + log (2.57) = 54.1dB

34.5 dBm = 2.82 W
Required attenuation for harmonics is 50 + log (2.82) = 54.5dB

34.4 dBm = 2.75 W
Required attenuation for harmonics is 50 + log (2.75) = 54.4dB

Field Strength of Spurious Emissions

Using the power measurements of the fundamental described in the previous section as the reference, measurement of the harmonic emissions was made using the substitution method of TIA/EIA 603. These measurements were made with a 50 Ohm dummy load connected to the transmitter output.

All measurements below 1 GHz were made 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 and Industry Canada. The harmonic measurements above 1 GHz were made above a ground plane at a distance of 1 meter.

Measurements below 1000 MHz were made at a three-meter test distance with frequencies above 1000 MHz being measured at one meter. A tuned dipole was used for receiving 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 and very short transmission times of the normally operating transmitter, the transmitter was forced to transmit continually for the measurements.

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 signal recorded.

Peak detection with some video filtering was used for all measurements of this test. The video filtering reduces the effect of noise and permits more accurate measurement of the CW signal.

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 and the receive antenna positioned for maximum reception. The signal generator output was then adjusted until the received signal from the antenna 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 2a – 2c.

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, P_g is the generator output into the substitution antenna and “antenna gain” is the gain of the substitution antenna with respect to a 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 2a – 2c.

PICTORIAL 1
HEXAGRAM MODEL DCU II
FIELD STRENGTH OF SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 2a
HEXAGRAM MODEL DCU II TRANSMITTER
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
450				34.1*	**-54.1 dB Req.**
900	-62.0	1.7	0	-63.7	-97.8

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1350	-73.5	0.7	3.1	-71.1	-105.2
1800	-70.0	0.8	4.9	-65.9	-100.0
2250	-70.0	0.9	5.6	-65.4	-99.5
2700	-67.5	1.1	6.2	-62.4	-96.5
3150	-65.1	1.2	6.7	-59.6	-93.7
3600	-61.0	1.3	6.6	-55.7	-89.8
4050	-61.0	1.4	6.5	-55.9	-90.0
4500	-64.0	1.5	7.2	-58.3	-92.4

* Direct measurement from antenna terminal. See Table 1.

34.1 dBm = 2.56 W
Required attenuation for harmonics is 50 + log (2.56) = 54.1 dB

TABLE 2b
HEXAGRAM MODEL DCU II TRANSMITTER
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
460				34.5*	**-54.5 dB Req.**
920	-58.0	1.7	0	-59.7	-94.2

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1380	-73.0	0.7	3.1	-70.6	-105.1
1840	-70.8	0.8	4.9	-66.8	-101.3
2300	-69.5	0.9	5.6	-64.9	-99.4
2760	-68.0	1.1	6.2	-62.9	-97.4
3220	-63.2	1.2	6.7	-57.7	-92.2
3680	-60.0	1.3	6.6	-54.7	-89.2
4140	-63.0	1.4	6.5	-57.9	-92.4
4600	-62.5	1.5	7.2	-56.8	-91.3

* Direct measurement from antenna terminal. See Table 1.

34.5 dBm = 2.82 W
Required attenuation for harmonics is 50 + log (2.82) = 54.5 dB

TABLE 2c
HEXAGRAM MODEL DCU II TRANSMITTER
SUBSTITUTION METHOD

3 meter measurement using tuned dipole antenna

Frequency (MHz)	Gen. Output (dB)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm)	Difference (dB)
469				34.4*	**-54.4 dB Req.**
938	-50.4	1.7	0	-52.1	-86.5

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1407	-72.8	0.7	3.1	-40.4	-104.8
1876	-69.8	0.8	4.9	-65.8	-100.2
2345	-69.0	0.9	5.6	-64.4	-98.8
2814	-69.0	1.1	6.2	-63.9	-98.3
3283	-62.3	1.2	6.7	-56.8	-91.2
3752	-61.1	1.3	6.6	-55.8	-90.2
4221	-65.0	1.4	6.5	-59.9	-94.3
4690	-64.0	1.5	7.2	-58.3	-92.7

* Direct measurement from antenna terminal. See Table 1.

34.4 dBm = 2.75 W
Required attenuation for harmonics is 50 + log (2.75) = 54.4 dB

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Spectrum Analyzer Model 8593EM S/N 3536A00147 Calibrated 7/06
Antennas	(2x) Stoddart 91598-2 Tuned Dipole Frequency Range 400 – 1000 MHz
	EMCO 3115 Double Ridged Guide Horn Frequency Range 1 – 18 GHz (Rcv)
	Eaton Model 96001 Double Ridged Guide Horn Frequency Range 1 – 18 GHz (Xmt)
Signal Generator	Hewlett-Packard Model 8340B, S/N 3010A01889 Calibrated 12/05
Miscellaneous	12.2 m RG-214/U coaxial cable
	6.1 m RG-214/U coaxial cable
	1.8 m RG-214/U coaxial cable
	0.9 m RG-214/U coaxial cable

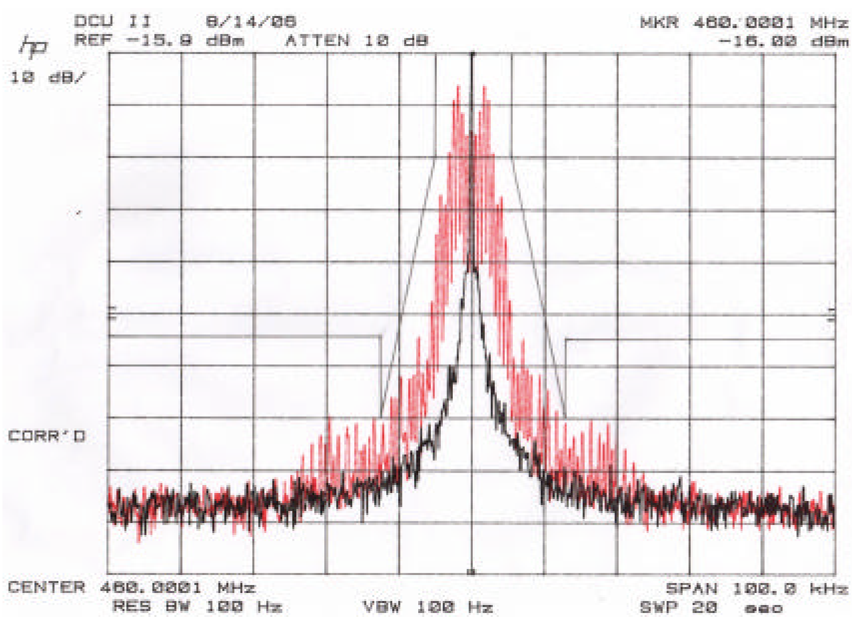
OCCUPIED BANDWIDTH

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 DCU II 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 2.82 W, 50 + 10 log(2.82) equals 54.5 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 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.



-54.5 dB

Fig. 1
Hexagram Model 9975 DCU II
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard 8568B with 85680A RF Section S/N: 2216A02120 85662A Display Section SN: 2152A03683 Calibration 11/05

FREQUENCY STABILITY VS. TEMPERATURE

The temperature stability of the frequency generating components of the transmitter was observed and compared to the tuned frequency of 460 MHz.. The DCU was placed in a temperature chamber with an external antenna connected by coaxial cable. The battery-powered transmitter was set to transmit when instructed by a control computer. 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 for about 10 minutes or more. The transmitted signal was captured by the spectrum analyzer and the frequency determined. The temperature in the chamber was then increased to 60° C. At each new temperature, time was allowed for stabilization of the transmitter, a transmission was made and the frequency determined. The temperature was then decreased to -30° C, again stabilizing before a reading was made. The temperature was then increased in 10°C increments back up to 60°C, checking the frequency at each 10° point. The frequency at each temperature was recorded, compared to the tuned frequency, and is recorded in Table 3. It can be seen from the table that all readings are within the deviation limit of ±2.5 ppm. If the temperature is outside the calibrated range, no transmission occurs.

TABLE 3
FREQUENCY STABILITY VS. TEMPERATURE

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	460.00010*	+100	+0.217
+60	No Transmission	-	-
-30	460.00030	+300	+0.652
-20	460.00025	+250	+0.543
-10	460.00015	+150	+0.326
0	460.00025	+250	+0.543
+10	460.00020	+200	+0.435
+20	460.00020	+200	+0.435
+30	460.00020	+200	+0.435
+40	460.00015	+150	+0.326
+50	459.99995	-50	-0.109
+57	459.99965	-350	-0.761
+60	No Transmission	-	-

The transmitter tested meets the requirements of 2.1055 (a)(1).

FREQUENCY STABILITY VS. SUPPLY VOLTAGE

The frequency stability was also determined as a function of the AC & DC voltage. A variable DC power supply was used to set the DC voltage between about 85% of the nominal 12 VDC input and the maximum level obtainable of 13.8 DCV. The AC input voltage was also varied between 85% and 115% of the nominal voltage of 120 VAC. Measurements were made at the voltages shown in Table 4. With the voltage set to a measurement point, the transmitted signal was captured by the spectrum analyzer and the frequency determined. The frequencies are compared to the tuned frequency of 460 MHz.. All data for these measurements are found in Table 4. It can be seen that all values obtained are within the deviation limit of ±2.5 ppm.

TABLE 4
FREQUENCY STABILITY
VS. SUPPLY VOLTAGE

Input Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
10.2 VDC	460.00015	+150	+0.326
12.0 VDC	460.00015	+150	+0.326
12.4 VDC	460.00015	+150	+0.326
13.8 VDC	460.00015	+150	+0.326
102 VAC	460.00015	+150	+0.326
120 VAC	460.00015	+150	+0.326
138 VAC	460.00015	+150	+0.326

When changing AC voltage levels, the battery was connected and providing its nominal voltage to the transmitter.

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard 8568B with 85680A RF Section S/N: 2216A02120 85662A Display Section SN: 2152A03683 Calibration 11/05
Antennas	Whip XMT Log-Periodic RCV
DC Power Supply	Harrison Laboratories, Inc. Model 8028 Twin Low Voltage Power Supply
Thermometer	Cooper Instrument Corp. Model SRH 77A,
Digital Volt Meter	Fluke Model 23
Temperature Chamber	Standard Environmental Systems, Inc. Model TK/5

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 DCU II 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 DCU II.

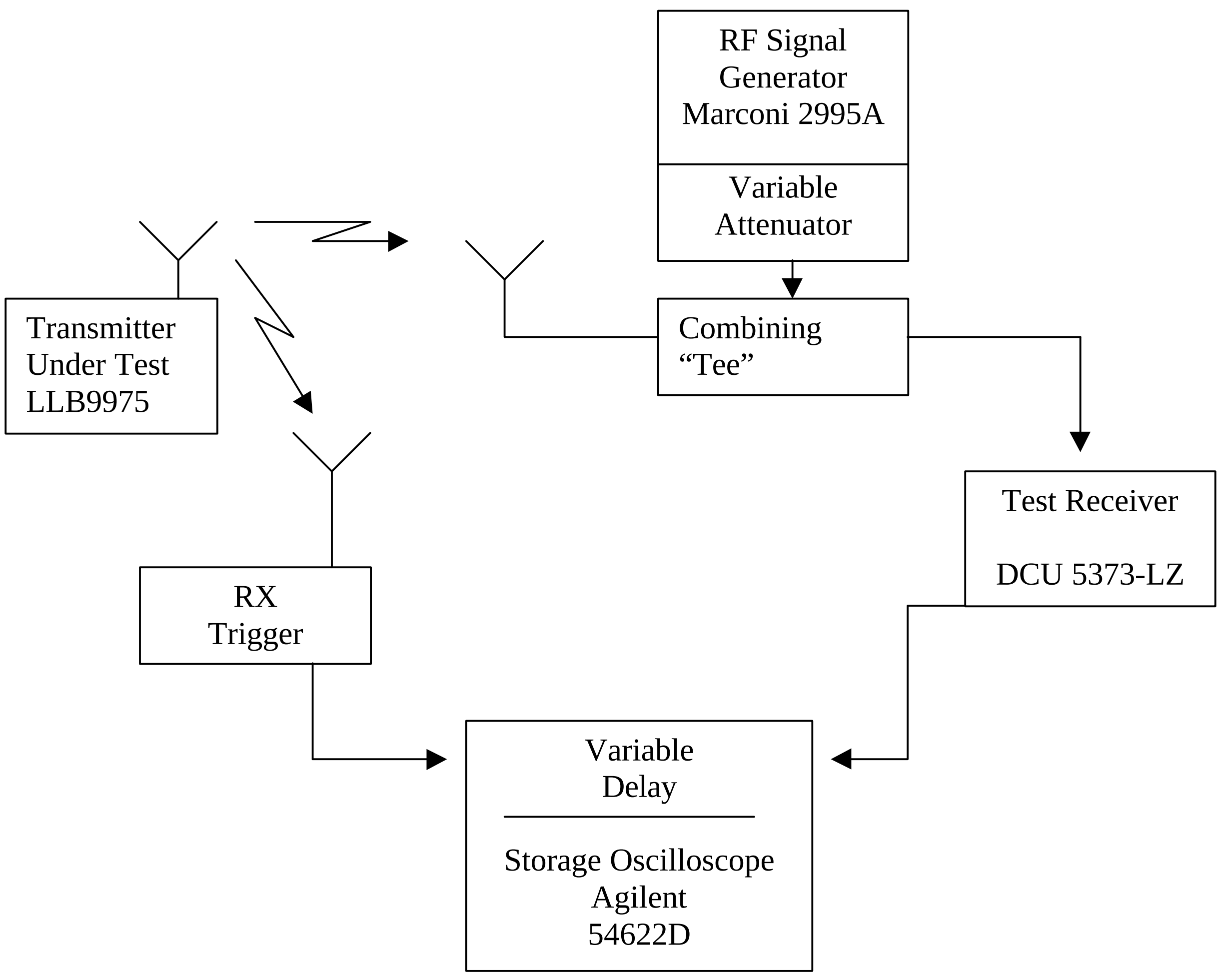


Fig. 2
Transient Frequency Behavior
Test Setup

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.

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 9975's transient frequency characteristics. The limit masks are indicated on each of the figures.

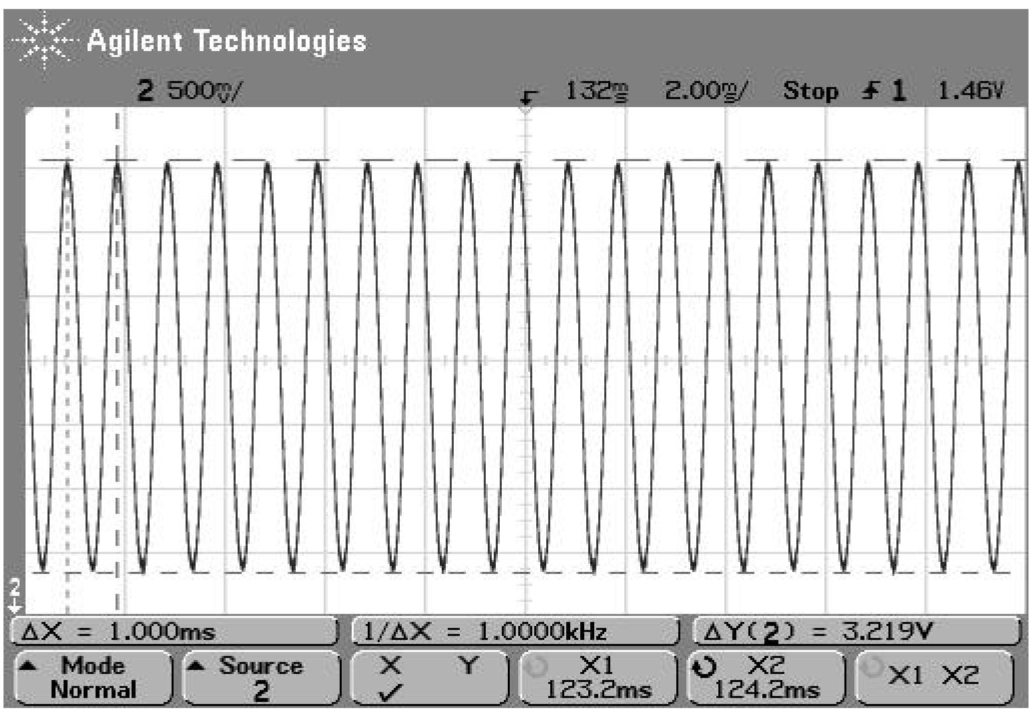


Fig. 3 ±12.5 kHz modulated injected signal 25 kHz = 3.219 V.

±6.25 kHz = 1.609 V
±1.15 kHz = 296 mV

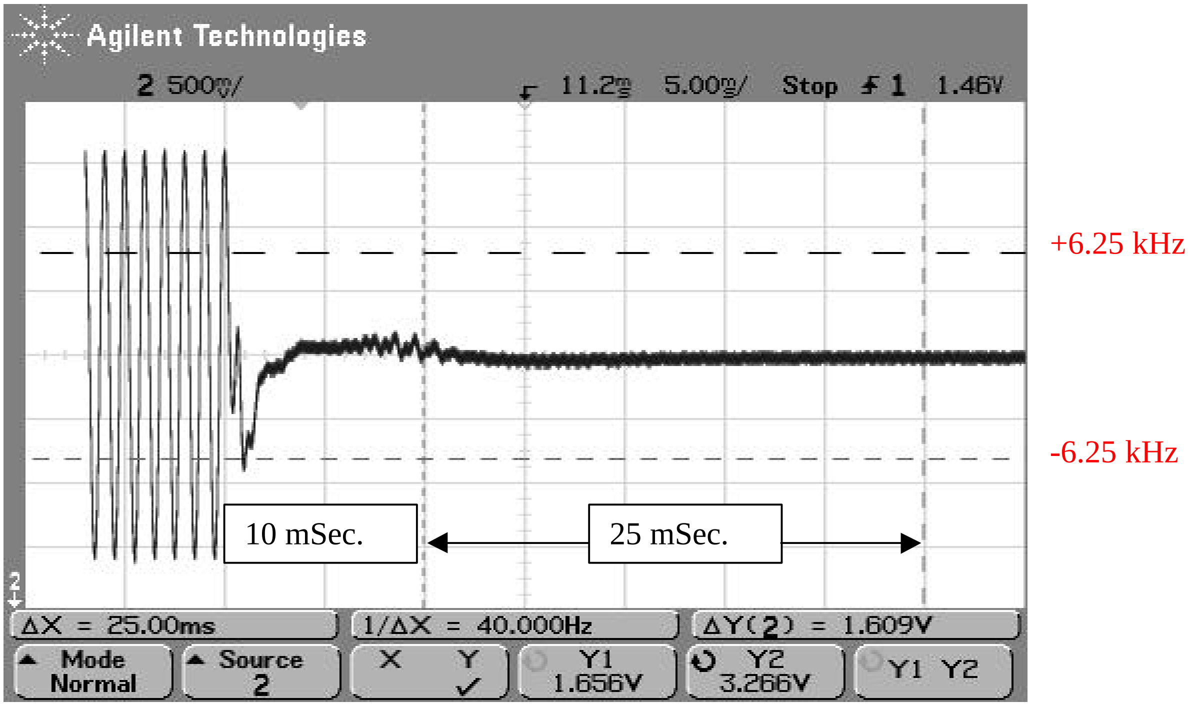


Fig. 4 Start of Transmission

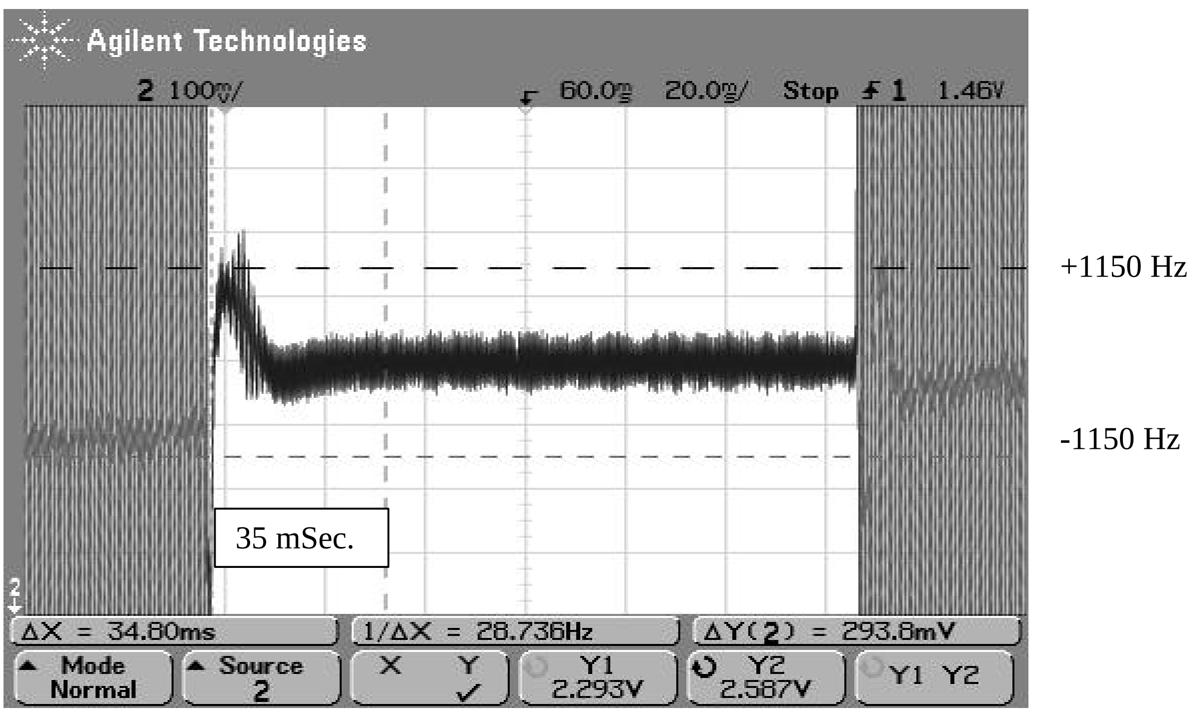


Fig. 5 Full Transmission

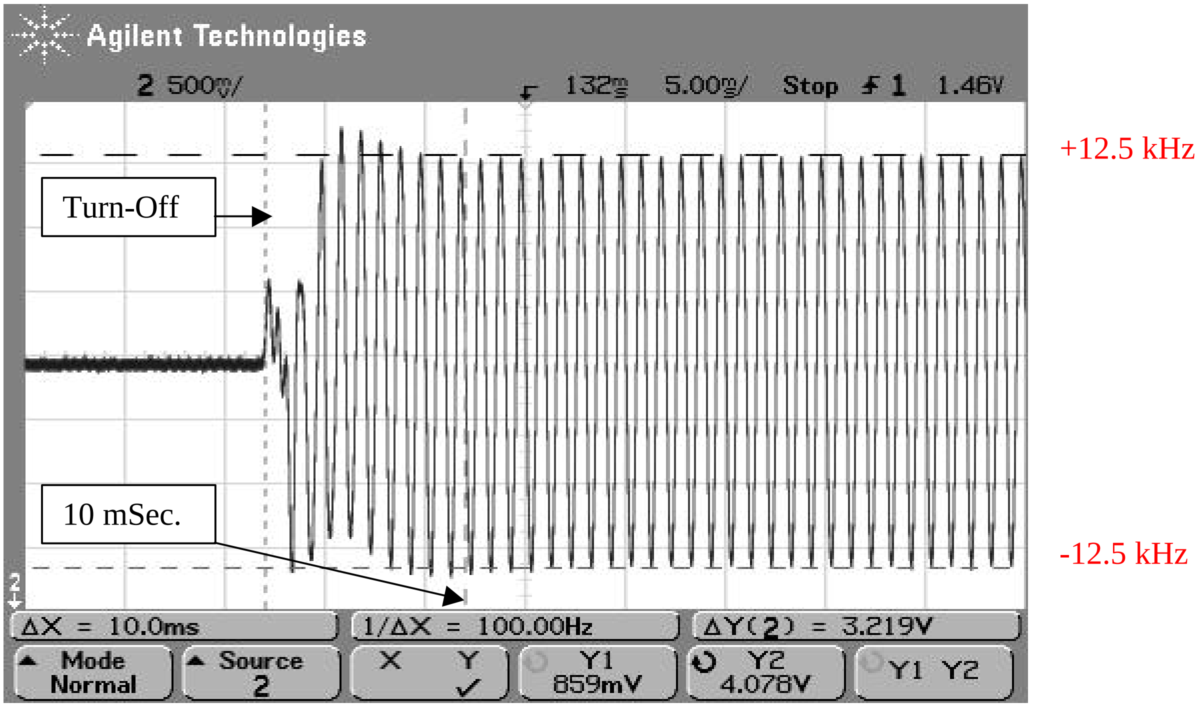


Fig. 6 Turn Off Transient

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 Calibration 12/05
Test Receiver	Hexagram DCU-1 (Modified)
Oscilloscope	Agilent Model 54622D S/N MY40006228 Calibration 1/06
RF Trigger	Hexagram Detector Circuit

TEST INFORMATION

SUMMARY

The transmitter portion of the Hexagram Data Collection Unit, Model 9975 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	DCU II (Transmitter), Model 9975
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Cleveland, OH 44122
TEST DATES	July 26 – August 14, 2006
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (440)526-4386