SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

UTILITY METER TRANSMITTING UNIT (MTU)
WITH EXTERNAL WIRES

Model 6327PWM
FCC ID: LLB6327PWM

January 28, 2004

Prepared by: James R. Pollock

James R. Pollock

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

Smith Electronics, Inc.
8200 Snowville Road
Brecksville, OH 44141
Phone: (440) 526-4386
Fax: (440) 526-9205

TEST REPORT

INTRODUCTION

The Hexagram Model 6327PWM transmitter is a battery-powered transmitter designed to be connected to a typical utility meter. The transmitter is available in two configurations. One is designed to be mounted directly to a meter and has no external cables. The second is for connecting electrically to a meter and is provided with a cable about 3.6 m in length. 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. One transmitter of each configuration was tested (with one cable and with no cables) and this report presents the worst case data obtained in support of an application for certification.

MEASUREMENTS PERFORMED

POWER OUTPUT AND SPURIOUS EMISSIONS

A sample of each configuration was examined at three fundamental frequencies and their harmonics. All measurements below 1 MHz 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. Due to inclement weather, the harmonic measurements above 1 MHz of these units were made in an unobstructed area of a garage. The measurements were made using the substitution method described in TIA/EIA-603-A.

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 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 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 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. The receive 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. The worse case data from the units is shown in this report.

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, 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 + 10log(P). The determined power outputs, the required harmonic attenuation as well as the attenuation for each harmonic are found in Tables 1a – 1c.

No wire 6327PWM

1-wire 6327PWM

PICTORIAL 1
HEXAGRAM METER TRANSMITTING UNIT
MODEL 6327PWM
OUTPUT POWER AND SPURIOUS EMISSIONS
TYPICAL TEST SETUP

TABLE 1a
HEXAGRAM MODEL 6327PWM TRANSMITTER
WITH NO EXTERNAL WIRES
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	20.4	1.1	0	19.3	
900	-22.1	1.7	0	-23.8	-43.1

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1350	-65.1	0.3	3.1	-62.3	-81.6
1800	-48.1	0.4	4.9	-43.6	-62.9
2250	-49.7	0.5	5.6	-44.6	-63.9
2700	-39.8	0.5	6.2	-34.1	-53.4
3150	-38.6	0.6	6.7	-32.5	-51.8
3600	-37.2	0.6	6.6	-31.2	-50.5
4050	-45.4	0.7	6.5	-39.6	-58.9
4500	-51.5	0.7	7.2	-45.0	-64.3

19.3 dBm = 85.1 mW or 0.0851 W
Required attenuation for harmonics is 50 + log (.0851) = 39.3dB

TABLE 1b
HEXAGRAM MODEL 6327PWM TRANSMITTER
WITH ONE EXTERNAL WIRE
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	22.3	1.1	0	21.2	-
920	-22.2	1.7	0	-23.9	-45.1

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1380	-67.6	0.3	3.1	-64.8	-86.0
1840	-52.7	0.4	4.9	-48.2	-69.4
2300	-46.1	0.5	5.6	-41.0	-62.2
2760	-37.7	0.5	6.2	-32.0	-53.2
3220	-38.4	0.6	6.7	-32.3	-53.5
3680	-36.1	0.6	6.6	-30.1	-51.3
4140	-48.0	0.7	6.5	-42.2	-63.4
4600	-47.0	0.7	7.2	-40.5	-61.7

21.2 dBm = 132 mW or 0.132 W
Required attenuation for harmonics is 50 + log (.132) = 41.2 dB

TABLE 1c
HEXAGRAM MODEL 6327PWM TRANSMITTER
WITH NO EXTERNAL WIRES
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)
470	20.4	1.1	0	19.3	-
940	-24.7	1.7	0	-26.4	-45.7

1 meter measurement using horn antenna

Frequency (MHz)	Gen. Output (dBm)	Coax Loss (Db)	Ant. Gain (dBd)	Dipole Eq. Power (Dbm)	Difference (dB)
1410	-47.1	0.3	3.1	-44.3	-63.6
1880	-43.9	0.4	4.9	-39.4	-58.7
2350	-33.5	0.5	5.6	-28.4	-47.7
2820	-30.2	0.5	6.2	-24.5	-43.8
3290	-27.5	0.6	6.7	-21.4	-40.7
3760	-30.5	0.6	6.6	-24.5	-43.8
4230	-40.3	0.7	6.5	-34.5	-53.8
4700	-40.8	0.7	7.2	-34.3	-53.6

19.3 dBm = 85.1 mW or 0.0851 W
Required attenuation for harmonics is 50 + log (.0851) = 39.3 dB

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard Spectrum Analyzer Model 8593EM S/N 3536A00147 Calibrated 6/00
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 1/04
Miscellaneous	12.2 m RG-214/U coaxial cable
	6.1 m RG-214/U coaxial cable
	1.0 m RG-214/U coaxial cable
	1.8 m RG-214/U coaxial cable

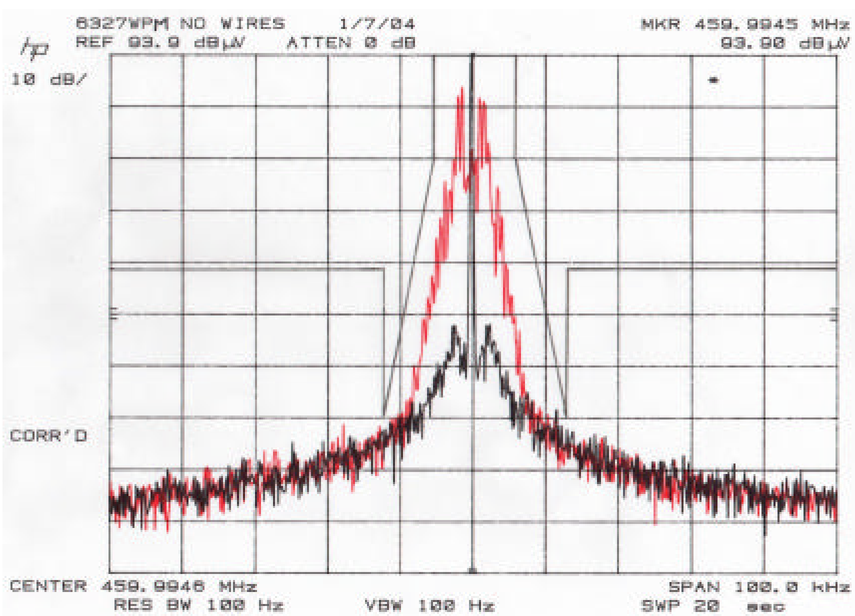
OCCUPIED BANDWIDTH

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 6327PWM 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 P of the two units was determined to be 0.132 W, so 50 + 10 log(0.132) equals 41.2 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.



-41.2 dB

Fig. 1
Hexagram Model 6327PWM MTU
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard 8568B with 85680A RF Section S/N: 2216A02120 85662A Display Section SN: 2152A03683 Calibration 6/03
Antenna	EMCO Model 3146 Log Periodic Frequency Range 200 MHz – 1000 MHz

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. The battery-powered meter was set to transmit at intervals of about 40 seconds. A receiving antenna outside the chamber picked up the transmitted signal, which was fed to the real-time spectrum analyzer.

With the transmitter programmed to transmit at 461 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 transmission signal was captured by the real-time spectrum analyzer and the frequency was determined and considered the “reference” frequency. The temperature in the chamber was then increased in 10° C increments up to 70° C. At each new temperature, time was allowed for stabilization of the transmitter, a transmission was made and the frequency determined. The temperature was decreased to 20° C again, stabilizing before a reading was made. The temperature was then decreased in 10°C increments down to -30°C, checking the frequency at each point. The frequency at each temperature was recorded, compared to the “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

TABLE 2
FREQUENCY STABILITY
VS. TEMPERATURE

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	461.000156*	0	0
+30	461.000312	+156	0.338
+40	461.000156	0	0
+50	461.000000	-156	0.338
+60	460.999844	-312	0.678
+70	460.999844	-312	0.678
+20	461.000312	+156	0.338
+10	461.000468	+312	0.678
0	461.000312	+156	0.338
-10	461.000000	-156	0.338
-20	460.999688	-468	1.015
-30	460.999688	-468	1.015

MTU 6327PWM * = “reference frequency”

FREQUENCY STABILITY VS. SUPPLY VOLTAGE

The frequency stability was also determined as a function of the DC battery voltage. A variable DC power supply was used to set the voltage between about 85% and 115% of the nominal 3.60 VDC input. Measurements were made at 3.60 V, 3.06 V and 4.14 V. With the voltage set to a measurement point, the transmitted signal was captured by the real-time spectrum analyzer and the frequency value determined. The frequencies are compared to the "reference" frequency obtained at the nominal operating voltage. All 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.

TABLE 3
FREQUENCY STABILITY
VS. SUPPLY VOLTAGE

INPUT DC Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
3.06	461.000312	+156	0.338
3.60	461.000156*	0	0
4.14	461.000312	+156	0.338

* = "reference frequency"

Note: Worst case transmitter tuned to 461 MHz.

TEST EQUIPMENT USED

Real-Time Spectrum Analyzer	Tektronix/Sony Model 3086 S/N J300195 Calibration 12/03
Antenna	SEI Loop Probe 2” diameter
DC Power Supply	Harrison Laboratories, Inc. Model 8028 Twin Low Voltage Power Supply
Thermometer	Cooper Instr. Co. Model SRH77A Thermometer Cal. 12/03
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 Model 6327PWM 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 6327PWM.

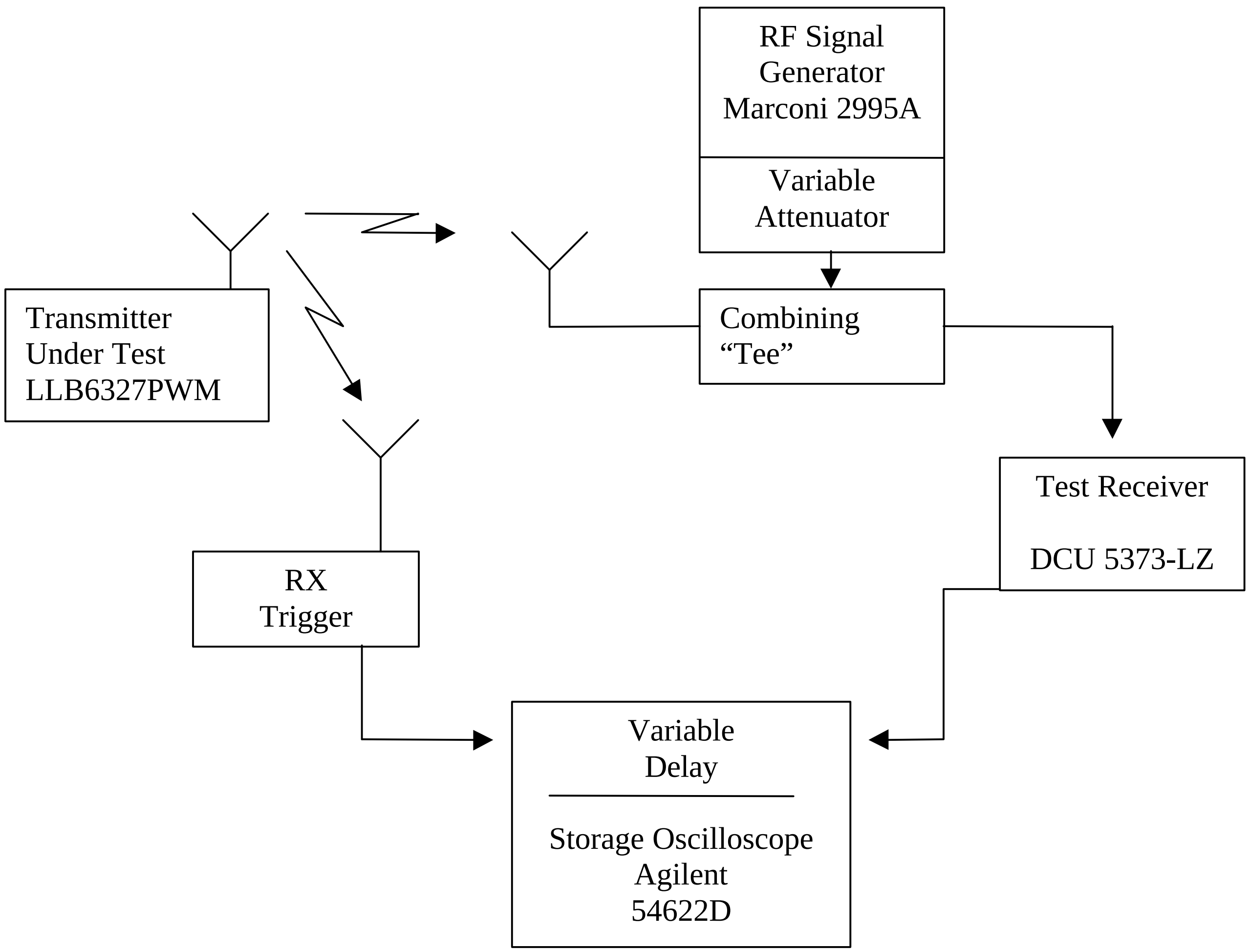


Fig. 2
Transient Frequency Behavior
Test Setup

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 the ±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 6327PWM's transient frequency characteristics. The limit masks are indicated on each of the figures.

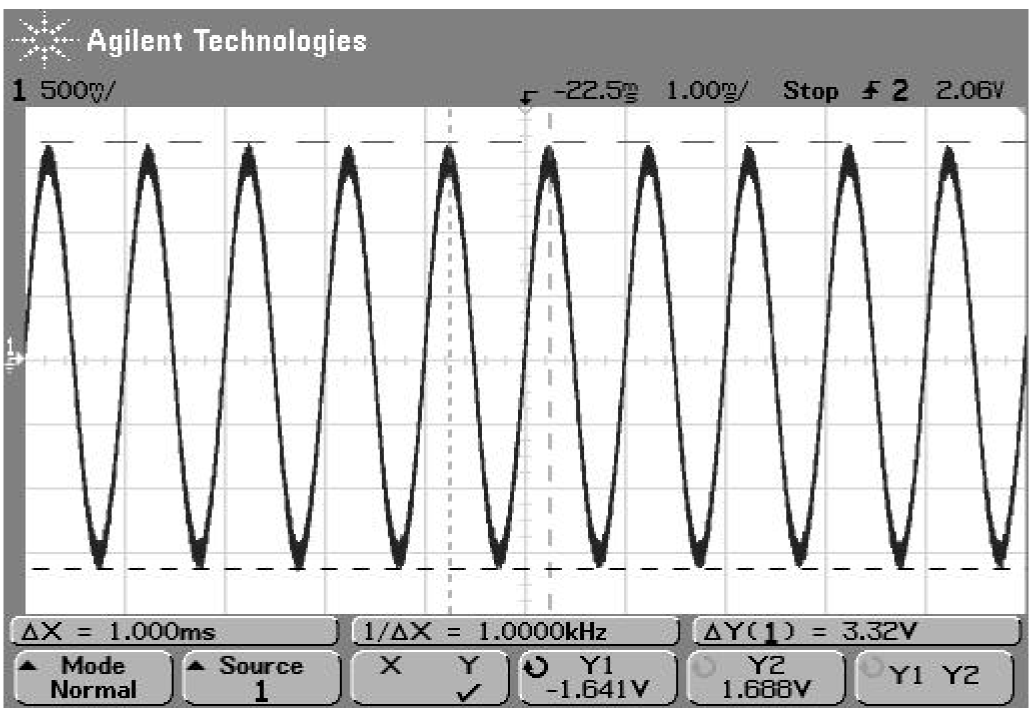


Fig. 3 ±12.5 kHz modulated test signal 25 kHz = 3.32 V.

6.25 kHz = 830 mV
1.15 kHz = 153 mV

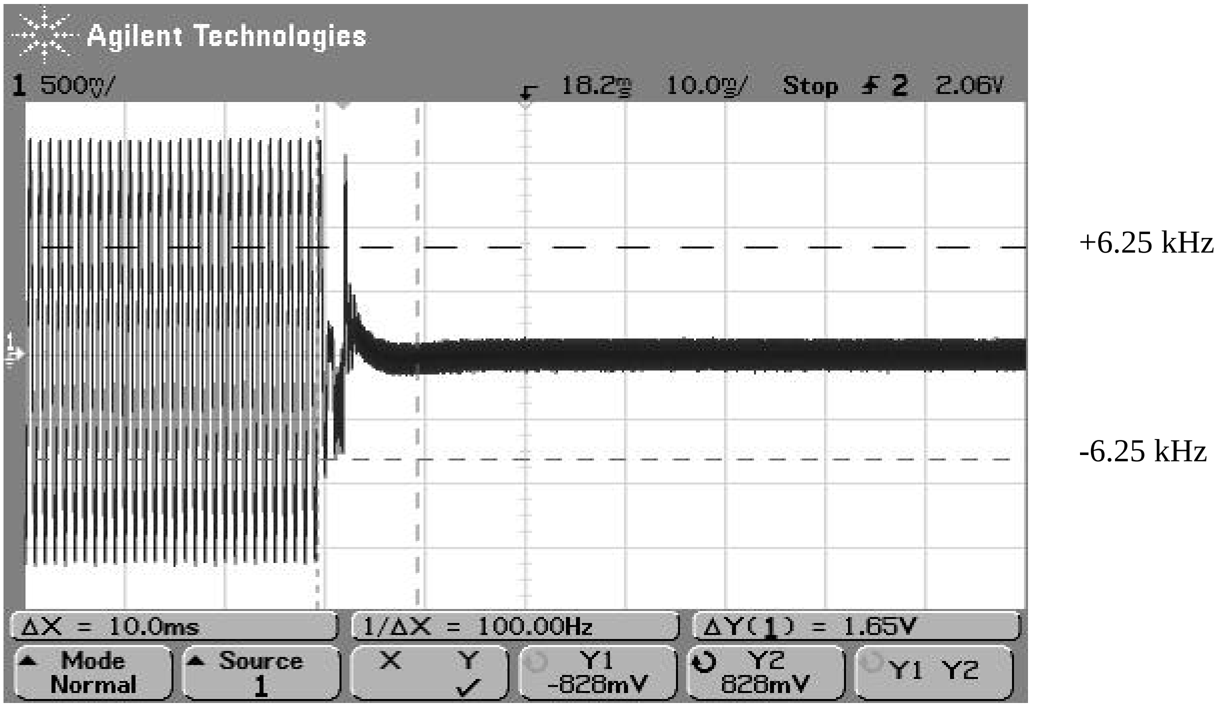


Fig. 4 Start of Transmission

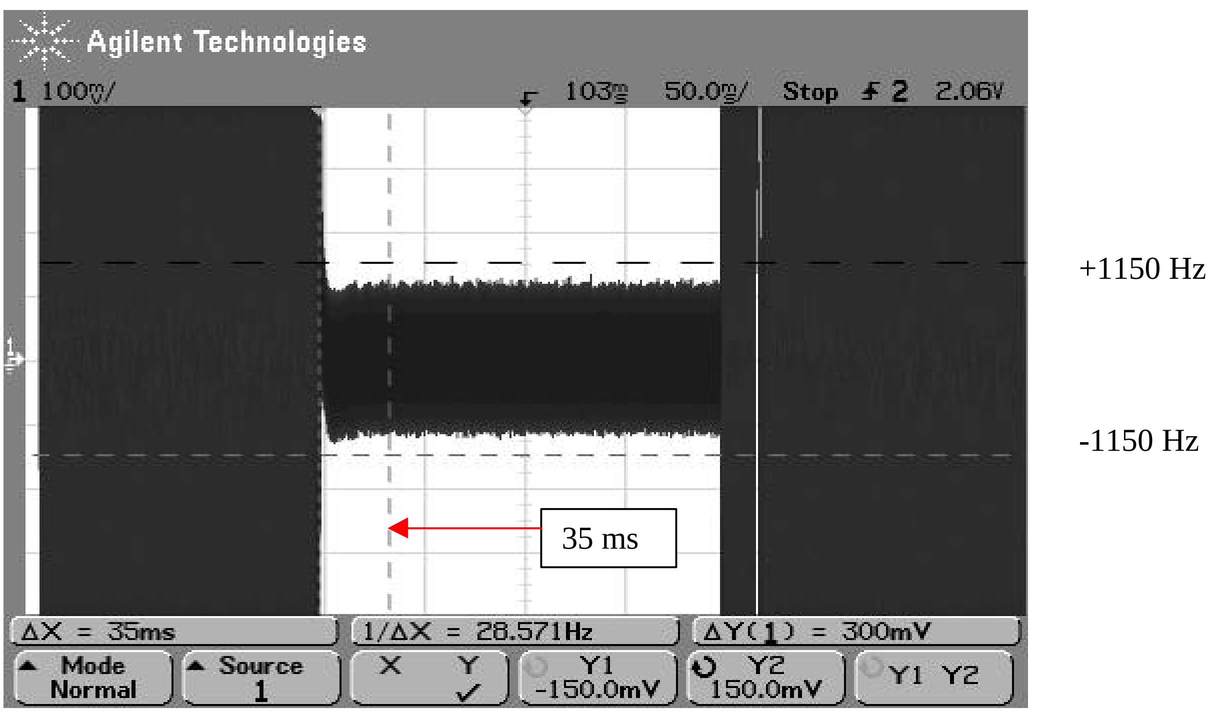


Fig. 5 Full Transmission

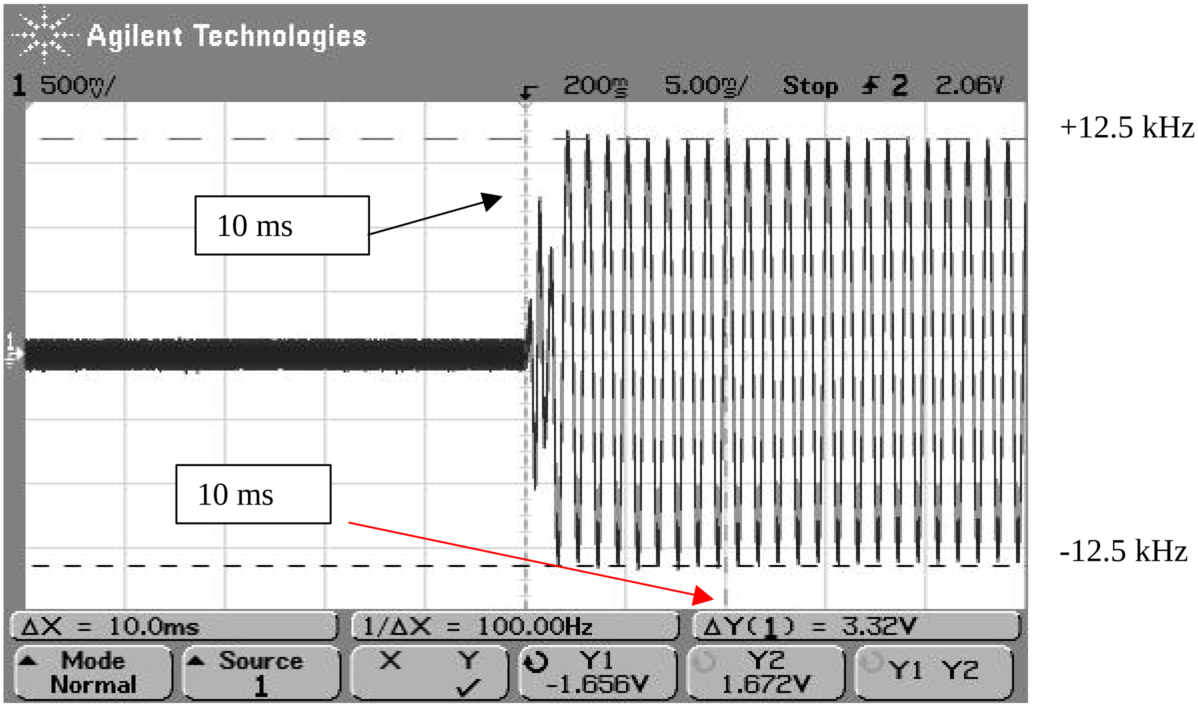


Fig. 6   Turn Off Transient

The modulated signal appears well within the allowed 10 ms and does not exceed ±12.5 kHz beyond 10 ms.

MTU 6327PWM

TEST EQUIPMENT USED

Signal Generator	Marconi Model 2955A Calibration 12-03
Test Receiver	Hexagram DCU-1 (Modified)
Oscilloscope	Agilent Model 54622D S/N MY40006228 Calibration 7/03
RF Trigger	Hexagram Detector Circuit

TEST INFORMATION

SUMMARY

The Hexagram Meter Transmitting Unit transmitter, Model 6327PWM 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 6327PWM
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Cleveland, OH 44122
TEST DATES	January 5 – 14, 2004
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (440)526-4386