SMITH ELECTRONICS, INC.
ELECTROMAGNETIC COMPATIBILITY LABORATORIES

RADIO-FREQUENCY EMISSIONS TEST REPORT

FOR

HEXAGRAM, INC.

ELECTRIC METER TRANSMITTING UNIT (MTU)
Class II Permissive Change

Model 6327P
FCC ID: LLB6327P

May 24, 2007

Prepared by:

Prepared for:

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TEST REPORT

INTRODUCTION

The Hexagram Model 6327P is a battery-powered transmitter designed to be connected to a typical utility meter. At programmed intervals 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 version tested has been changed in several ways. The circuit board has been modified to fit the changes. These include placing the two batteries on the same side of the board, a different RF power amplifier and discrete output filtering. This report describes the tests performed on the transmitter in support of an application for certification.

MEASUREMENTS PERFORMED

. The microprocessor portion of the transmitter has been 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

A series of measurements of the operating frequencies and any harmonic emissions was made. 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 over a ground plane at a distance of one-meter.. 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 the receiver for both distances.

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 and its mode of operation, an external battery pack was connected directly to the transmitter and 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.

No differences were observed with different signal detectors, so a peak detector was used for the signals below and above 1000 MHz. Measurements were made with the transmitter tuned to 450 MHz, 460 MHz and 469 MHz. This covers the ends and center of the range to which the transmitter will be tuned in practice.

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 transmitting antenna connected to a signal generator. 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 receive antenna was positioned vertically for maximum reception. The signal generator output was then adjusted until the received signal was equal to the 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. Transmitting antenna gain and coax loss figures are also included in the Tables.

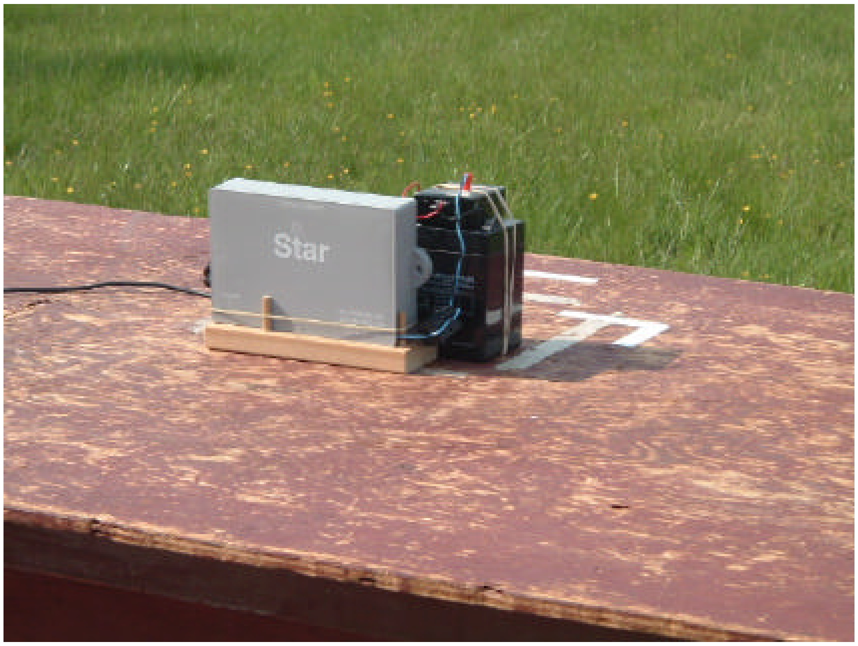
In order to convert the signal generator output value to equivalent radiated power from a dipole, the following equation is used:

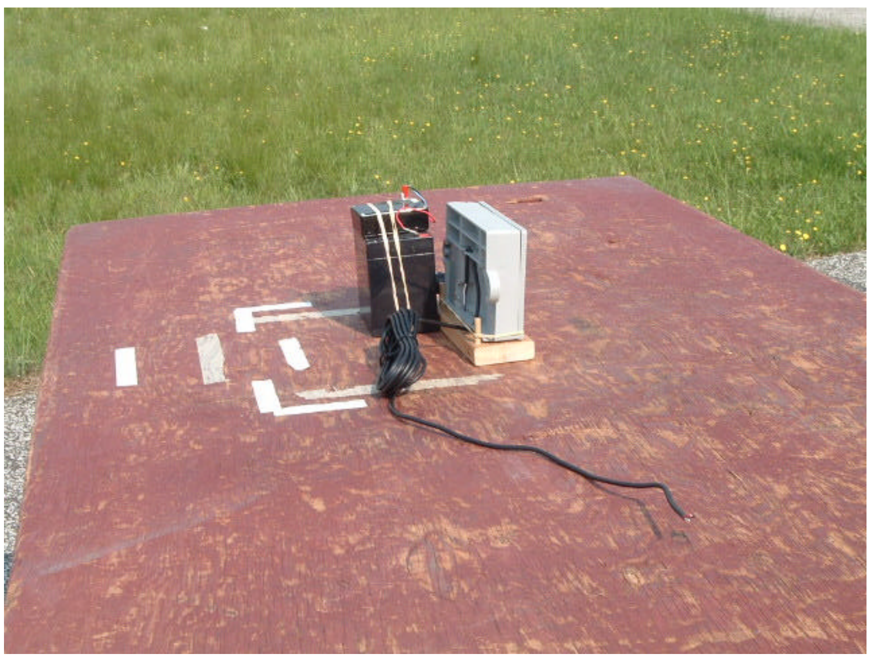
$$P_d = P_g - \text{cable loss(dB)} + \text{antenna gain}(dB_d)$$

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 tuned 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). Using P = 0.132 W, the required attenuation is 41.2 dB. An examination of Table 1 shows that all emissions are below the required level.





PICTORIAL 1
HEXAGRAM 6327P METER TRANSMITTING UNIT
OUTPUT POWER AND SPURIOUS EMISSIONS
TEST SETUP

TABLE 1a
HEXAGRAM 6327P TRANSMITTER
SUBSTITUTION METHOD
450 MHz

3 meter measurement using tuned dipole transmit antenna

Frequency (MHz)	Gen. Output (dB) V/H	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm) V/H	Difference (dB) V/H
450	22.2/20.5	1.1	0	21.1/19.4	**41.1/39.4 Required**
900	-23.9/-27.6	1.7	0	-25.6/-29.3	-46.7/-48.7

1 meter measurement using horn transmit antenna

Frequency (MHz)	Gen. Output (dBm) V/H	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm) V/H	Difference (dB) V/H
1350	-48.3/-57.8	0.7	3.1	-45.9/-55.4	-67.0/-74.8
1800	-39.6/-46.8	0.8	4.9	-35.5/-42.7	-56.6/-62.1
2250	-36.7/-42.8	1.0	5.6	-32.1/-38.2	-53.2/-57.6
2700	-43.2/-47.0	1.1	6.2	-38.1/-41.9	-59.2/-61.3
3150	-29.7/-36.5	1.2	6.7	-24.2/-31.0	-45.3/-50.4
3600	-47.8/-58.0	1.3	6.6	-42.5/-52.7	-63.6/-72.1
4050	-40.2/-39.9	1.4	6.5	-35.1/-34.8	-56.2/-54.2
4500	-31.8/-29.5	1.9	7.2	-26.1/-23.8	-47.2/-43.2

21.1 = 129 mW or 0.129 W
Required attenuation for harmonics is 50 + 10log (.129) = 41.1 dB

TABLE 1b
HEXAGRAM 6327P TRANSMITTER
SUBSTITUTION METHOD
460 MHz

3 meter measurement using tuned dipole transmit antenna

Frequency (MHz)	Gen. Output (dB) V/H	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm) V/H	Difference (dB) V/H
460	21.3/22.3	1.1	0	20.2/21.2	**40.2/41.2 Required**
920	-25.3/-28.1	1.7	0	-27.0/-29.8	-47.2/-51.0

1 meter measurement using horn transmit antenna

Frequency (MHz)	Gen. Output (dBm) V/H	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm) V/H	Difference (dB) V/H
1380	-45.4/-56.0	0.7	3.1	--43.0/-53.6	-63.2/-74.8
1840	-37.4/-45.9	0.9	4.9	-33.4/-41.9	-53.6/-63.1
2300	-36.1/-41.2	1.0	5.6	-31.5/-36.6	-51.7/-57.8
2760	-40.1/-43.8	1.1	6.2	-35.0/-38.7	-55.2/-59.9
3220	-31.0/-40.0	1.2	6.7	-25.5/-34.5	-45.7/-55.7
3680	-47.5/-50.0	1.3	6.6	-42.2/-44.7	-62.4/-65.9
4140	-38.0/-33.7	1.4	6.5	-32.9/-28.6	-53.1/-49.8
4600	-35.5/-32.7	1.5	7.2	-29.8/-27.0	-50.0/-48.2

21.2 dBm = 132 mW or 0.132 W
Required attenuation for harmonics is 50 + 10log (.132) = 41.2 dB

.

TABLE 1c
HEXAGRAM 6327P TRANSMITTER
SUBSTITUTION METHOD
469 MHz

3 meter measurement using tuned dipole transmit antenna

Frequency (MHz)	Gen. Output (dB) V/H	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm) V/H	Difference (dB) V/H
469	19.3/22.2	1.1	0	18.2/21.1	**38.2/41.1 Required**
938	-26.5/-26.6	1.7	0	-28.2/-28.3	-46.4/-49.4

1 meter measurement using horn transmit antenna

Frequency (MHz)	Gen. Output (dBm) V/H	Coax Loss (dB)	Ant. Gain (dBd)	Dipole Eq. Power (dBm) V/H	Difference (dB) V/H
1407	-42.3/-52.8	0.7	3.1	-39.9/-50.4	-58.1/-71.5
1876	-36.3/-43.9	0.9	4.9	-32.3/-39.9	-50.5/-61.0
2345	-36.3/-41.9	1.0	5.6	-31.7/-37.3	-49.9/-58.4
2814	-35.8/-40.0	1.1	6.2	-30.7/-34.9	-48.9/-56.0
3283	-32.6/-40.2	1.2	6.7	-27.1/-34.7	-45.3/-55.8
3752	-48.4/-51.0	1.3	6.6	-43.1/-45.7	-61.3/-66.8
4221	-35.6/-30.0	1.4	6.5	-30.5/-24.9	-48.7/-46.0
4690	-41.6/-34.0	1.5	7.2	-35.9/-28.3	-54.1/-49.4

22.2 dBm = 129 mW or 0.129 W
Required attenuation for harmonics is 50 + 10log (.129) = 41.1 dB

.

TEST EQUIPMENT USED

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 11/06
Miscellaneous	12.2 m RG-214/U coaxial cable
	6.1 m RG-214/U coaxial cable
	3.0 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 MTU 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 P was determined to be 0.132 W, 50 + 10 log(0.132) equals 41.2 dB.

The plot of Fig. 1 shows the unmodulated carrier (in black), the modulated signal and the emissions mask. The plot indicates that the modulated emission does comply with the requirement for occupied bandwidth as found in 90.210. The unmodulated signal is shifted either high or low by the circuitry. An unmodulated signal is not a normal operating condition.

For purposes of this test, the transmitter 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.

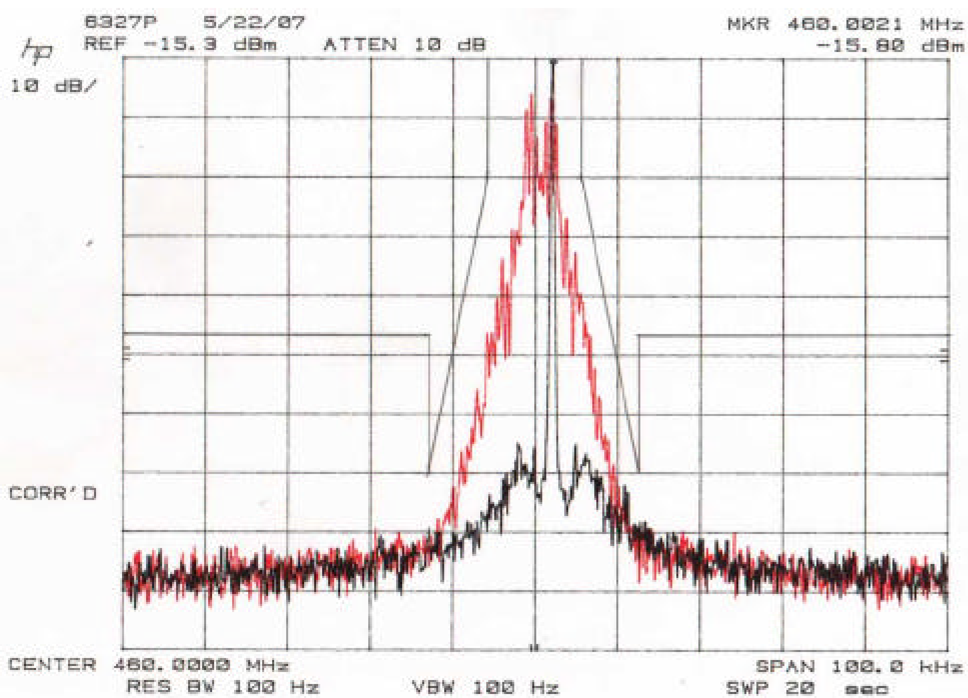


Fig. 1
Hexagram Model 6327P Meter Unit
Emissions Mask

TEST EQUIPMENT USED

Spectrum Analyzer	Hewlett-Packard 8568B with 85680A RF Section S/N: 2216A02120 85662A Display Section SN: 2152A03683 Calibration 11/06
Antenna	EMCO Model 3146 Log Periodic Frequency Range 200 MHz – 1000 MHz

FREQUENCY STABILITY (Temperature)

With the transmitter circuit board placed in a non-conducting rack, the temperature stability of the frequency generating components was observed. The transmitter was placed in a temperature chamber, with the battery-powered transmitter 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 analyzer.

With the transmitter programmed to transmit at 460.000000 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 analyzer and the frequency was determined. As the unmodulated signal is offset from the tuned frequency, the 20° frequency is considered the "standard", and any variation is determined from that frequency. The temperature in the chamber was then changed. At each new temperature, time was allowed for stabilization of the transmitter, a transmission was made and the frequency determined. From 20° C, the temperature was increased to 70° C, and then lowered to -30° C to cover the required end-points. From -30° C, the temperature was increased by 10° C increments to 80° C. The frequency at each temperature was recorded and is found in Table 2. It can be seen from the table that all readings are within the ±2.5 ppm allowance.

TABLE 2
FREQUENCY STABILITY
(TEMPERATURE)

Temperature ° C	Measured Frequency MHz	Dev. Hz	Dev. ppm
+20	459.998906*	0	0
+70	No Transmission**	NA	NA
+69	459.998906	0	0
-30	459.999375	+469	1.020
-20	459.999063	+157	0.341
-10	459.998750	-156	0.339
0	459.998750	-156	0.339
+10	459.998750	-156	0.339
+20	459.998906	0	0
+30	459.998906	0	0
+40	459.999063	+157	0.341
+50	459.999063	+157	0.341
+60	459.999063	+157	0.341

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* Reference frequency
** If the temperature falls outside the calibrated values, no transmission occurs

FREQUENCY STABILITY (Voltage)

The frequency stability was also determined as a function of the battery input voltage. With the transmitter set to 460 MHz, a variable transformer was used to set the voltage between about 100% and 85% of the nominal 3.6 VDC input. When the voltage was set to a measurement point, a transmission was captured by the real-time analyzer and the frequency value determined. The data for these measurements are found in Table 3. Again, it can be seen that all values obtained are within the allowed amount of 2.5 ppm.

TABLE 3
FREQUENCY STABILITY
(VOLTAGE)

INPUT DC Volts	Measured Frequency MHz	Dev. Hz	Dev. ppm
	459.999219*		
3.6	459.999219	0	0
3.06	459.998594	-312	0.678

* Reference Value: Determined by initial measured value at 3.6 Volts. Temperature of measurements about 24° C

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TEST EQUIPMENT USED

Real-Time Spectrum Analyzer — Tektronix/Sony Model 3086
S/N J300247 Calibration 10/06

Antenna — EMCO Model 3146 Log Periodic
Frequency Range 200 MHz – 1000 MHz

AC Power Supply — Superior Electric Co. Type 1226 Powerstat
Variable Transformer

Thermometer — Cooper Instrument Co. Model SRH77A
Thermometers   Calibration 1/07

Digital Volt Meter — Fluke Model 23   Calibration 1/04

Temperature Chamber — Standard Environmental Systems, Inc.
Model TK/5

TRANSIENT STABILITY

The transient stability measurements indicate the variation in tuned frequency in the brief interval of time during the start of the transmission and the end of the transmission.

The Model 6327P transmitter was tested for transient frequency behavior using the test method TIA/EIA-603. A block diagram of the test setup is seen in Fig. 2. A Hexagram 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 signal was at least 50 dB below the received signal level from the 6327P.

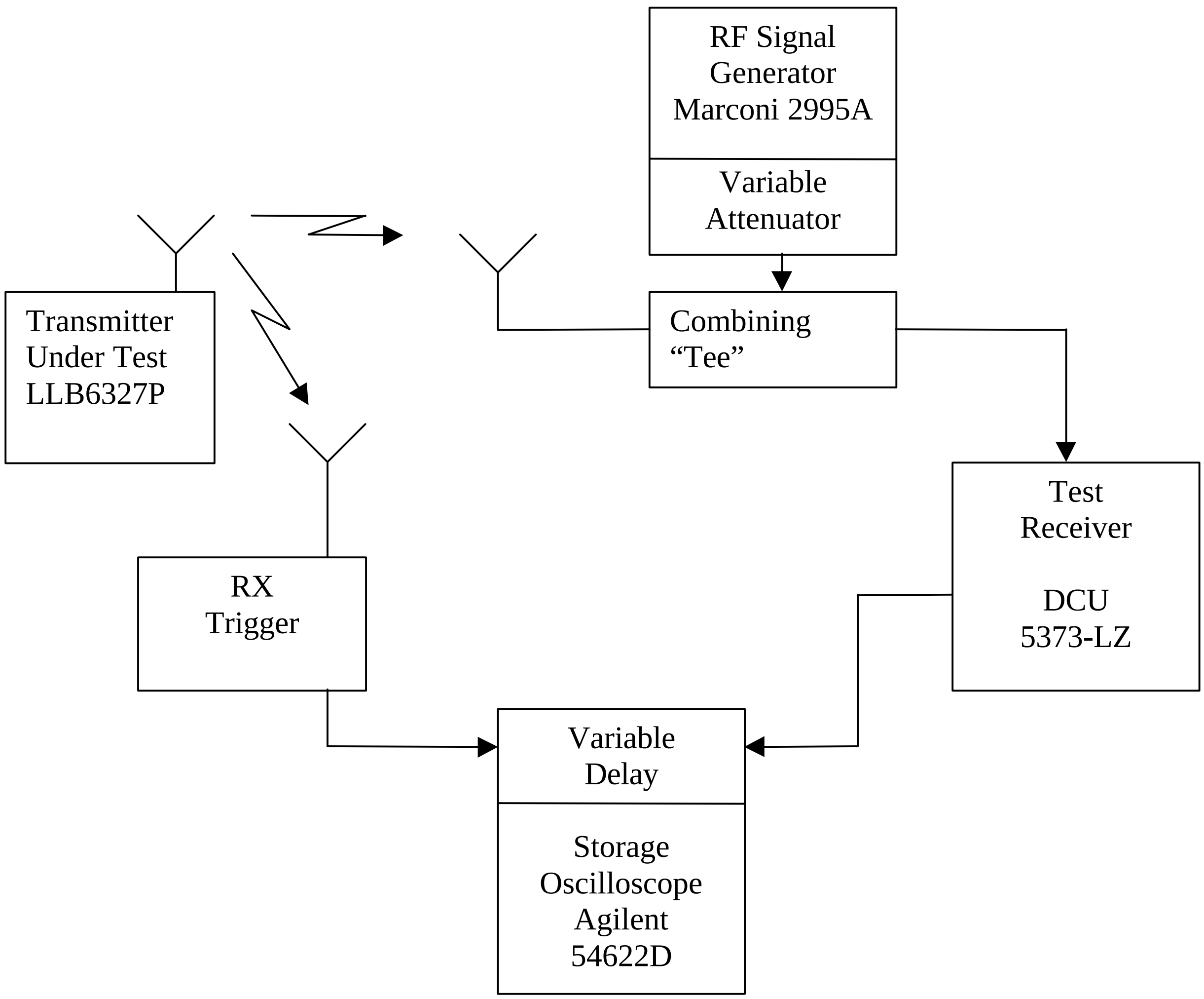

Fig. 2
Transient Frequency Behavior
Test Setup

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 6 show the Model 6327P's transient frequency characteristics. The limit masks are overlaid or indicated on each of the figures.

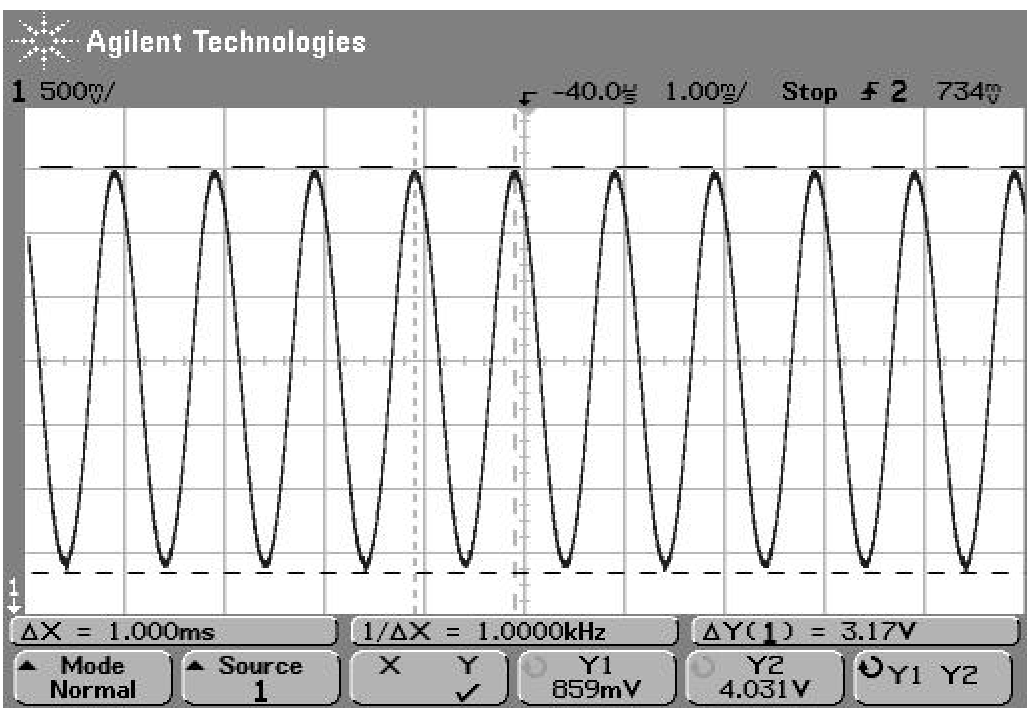

Fig. 3 ±12.5 kHz Signal

±12.5 kHz = ±1.59 V = 3.17 V
±6.25 kHz = ±0.80 V = 1.60 V
±1150 Hz = ±146 mV = 292 mV

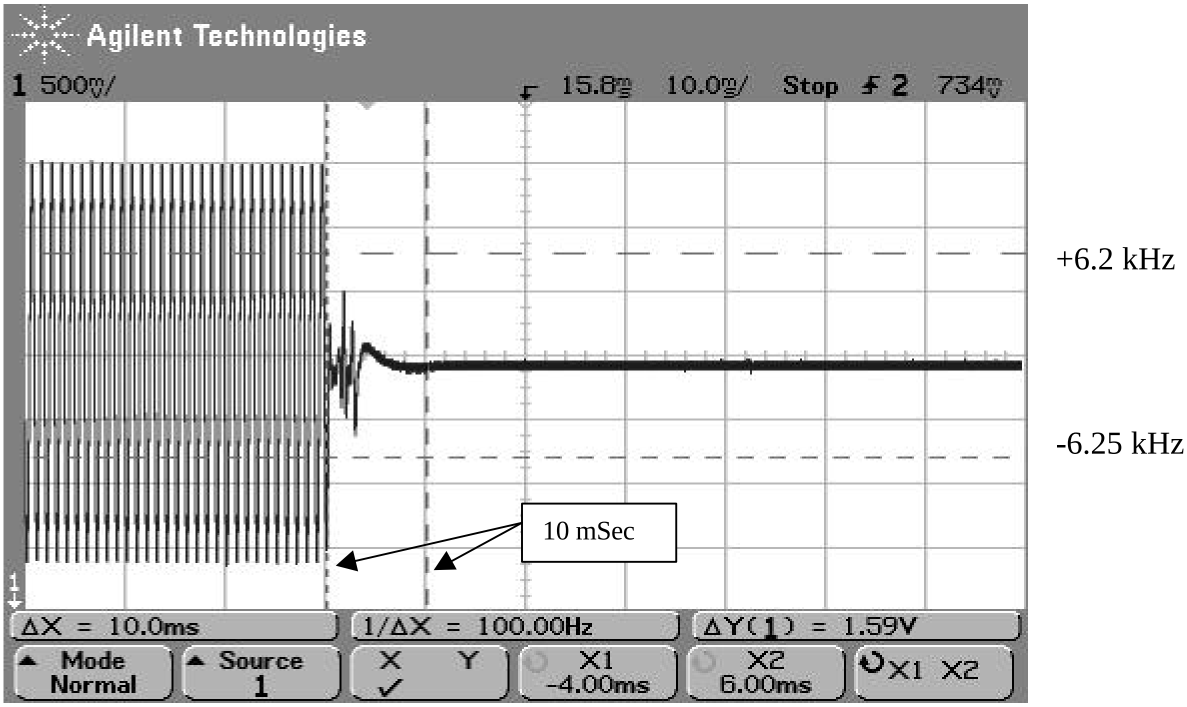

Fig. 4 Transmission Start-up

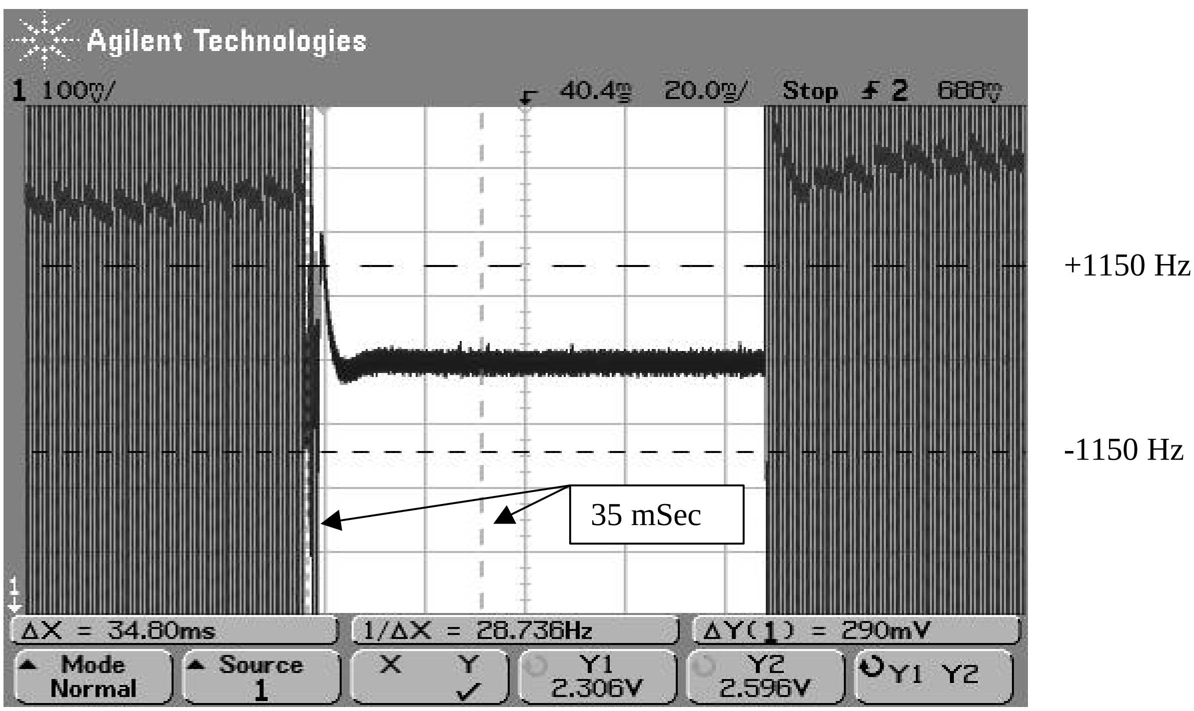

Fig. 5 Complete Transmission

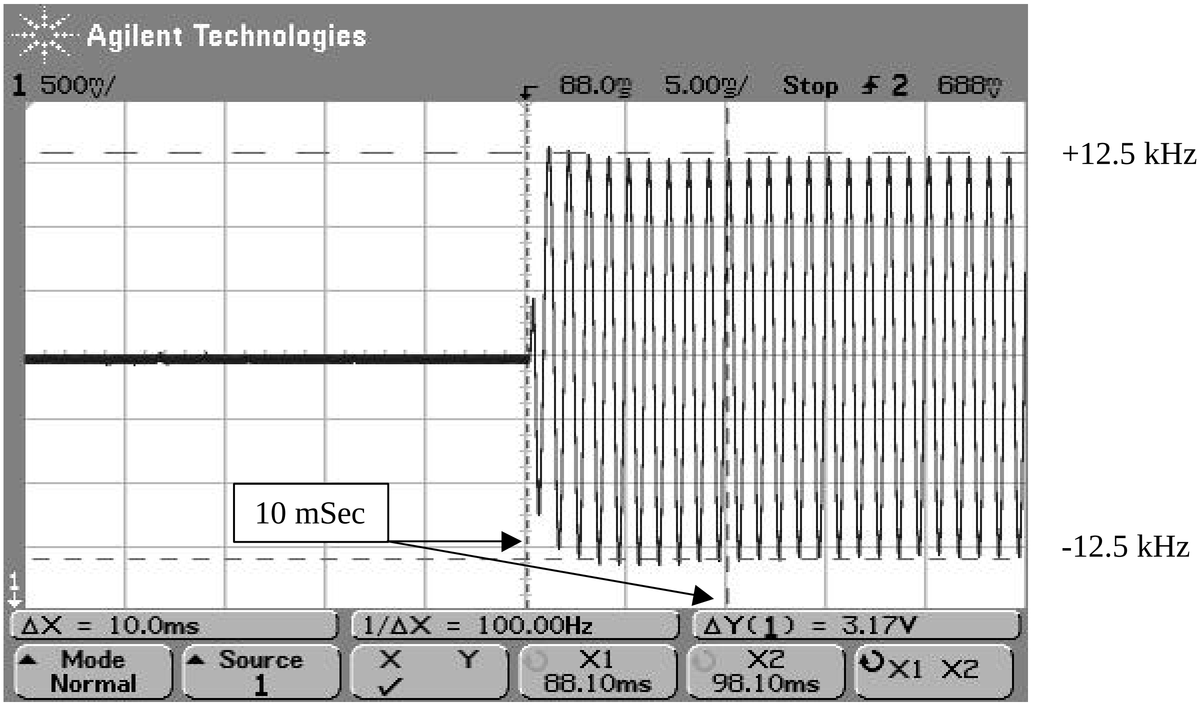

Fig. 6 End of Transmission

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TEST EQUIPMENT USED

Signal Generator	Marconi Model 2955A Calibration 11/06
Test Receiver	Hexagram DCU-1 (Modified)
Oscilloscope	Agilent Model 54622D S/N MY40006228 Calibration 11/06
RF Trigger	Hexagram Detector Circuit

TEST INFORMATION

SUMMARY

The Hexagram Meter Transmitting Unit transmitter, Model 6327P, 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	Meter Transmitter Unit, Model 6327P
MANUFACTURER	Hexagram, Inc. 23905 Mercantile Road Cleveland, OH 44122
TEST DATES	May 14 – May 23, 2007
TEST LABORATORY	Smith Electronics, Inc. 8200 Snowville Road Cleveland, OH 44141 (440)526-4386