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Measured Radio Frequency Emissions
From

Lionel L.L.C. Transmitter
FCC ID: LIV-PMBR
Model/PN(s): #996 BRIDGE

Report No. 415031-464
October 18, 2008

For:
Lionel L.L.C.
26750 23 Mile Road,
Chesterfield, Michigan 48051

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Summary

Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-310/Gen, were performed on Lionel L.L.C. Transmitter, model/PN(s) #996 BRIDGE. This device is subject to Rules and Regulations as a Transmitter.

In testing completed September 25, 2008, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 3.5 dB (see p. 7); Class B digital emissions limits by 0.5 dB, and Class B power line conducted emissions limits by 3.6 dB.

1. Introduction

Lionel L.L.C. model #996 BRIDGE was(were) tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as subsequently amended, and with Industry Canada RSS-210/Gen, Issue 7, June 2007. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2003 "Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz". The Site description and attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland (FCC Reg. No: 91050) and with Industry Canada, Ottawa, ON (File Ref. No: IC 2057A-1).

2. Test Procedures and Equipment Used

The pertinent test equipment commonly used in our facility for measurements is listed in Table 2.1 below. The middle column identifies the specific equipment used in these tests. The quality system employed at the University of Michigan Radiation Laboratory Willow Run Test Range has been established to ensure all equipment has a clearly identifiable classification, calibration expiry date, and that all calibrations are traceable to national standards.

Table 2.1 Test Equipment.

Test Instrument	Used	Manufacturer/Model	Q Number
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E, SN: 3412A01131	HP8593E1
Spectrum Analyzer (9kHz-6.5GHz)	X	Hewlett-Packard 8595E, SN: 3543A01546	JDB8595E
Power Meter		Hewlett-Packard, 432A	HP432A1
Harmonic Mixer (26-40 GHz)		Hewlett-Packard 11970A, SN: 3003A08327	HP11970A1
Harmonic Mixer (40-60 GHz)		Hewlett-Packard 11970U, SN: 2332A00500	HP11970U1
Harmonic Mixer (75-110 GHz)		Hewlett-Packard 11970W, SN: 2521A00179	HP11970W1
Harmonic Mixer (140-220 GHz)		Pacific Millimeter Prod., GMA, SN: 26	PMPGMA1
S-Band Std. Gain Horn		S/A, Model SGH-2.6	SBAND1
C-Band Std. Gain Horn		University of Michigan, NRL design	CBAND1
XN-Band Std. Gain Horn		University of Michigan, NRL design	XNBAND1
X-Band Std. Gain Horn		S/A, Model 12-8.2	XBAND1
X-band horn (8.2- 12.4 GHz)		Narda 640	XBAND2
X-band horn (8.2- 12.4 GHz)		Scientific Atlanta , 12-8.2, SN: 730	XBAND3
K-band horn (18-26.5 GHz)		FXR, Inc., K638KF	KBAND1
Ka-band horn (26.5-40 GHz)		FXR, Inc., U638A	KABAND1
U-band horn (40-60 GHz)		Custom Microwave, HO19	UBAND1
W-band horn(75-110 GHz)		Custom Microwave, HO10	WBAND1
G-band horn (140-220 GHz)		Custom Microwave, HO5R	GBAND1
Bicone Antenna (30-250 MHz)	X	University of Michigan, RLBC-1	LBBIC1
Bicone Antenna (200-1000 MHz)	X	University of Michigan, RLBC-2	HBBIC1
Dipole Antenna Set (30-1000 MHz)	X	University of Michigan, RLDP-1,-2,-3	UMDIP1
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C, SN: 992 (Ref. Antennas)	EMDIP1
Active Rod Antenna (30 Hz-50 MHz)		EMCO 3301B, SN: 3223	EMROD1
Active Loop Antenna (30 Hz-50 MHz)	X	EMCO 6502, SN:2855	EMLOOP1
Ridge-horn Antenna (300-5000 MHz)	X	University of Michigan	UMRH1
Amplifier (5-1000 MHz)	X	Avantek, A11-1, A25-1S	AVAMP1
Amplifier (5-4500 MHz)	X	Avantek	AVAMP2
Amplifier (4.5-13 GHz)		Avantek, AFT-12665	AVAMP3
Amplifier (6-16 GHz)		Trek	TRAMP1
Amplifier (16-26 GHz)		Avantek	AVAMP4
LISN Box	X	University of Michigan	UMLISN1
Signal Generator		Hewlett-Packard 8657B	HPSG1

3. Device Under Test

3.1 Identification

The device under test is a 27.5 MHz Transmitter designed for communicating with existing toy trains controlled by 27.5 MHz receivers. The device is powered from the 115 VAC mains power and receives commands from an associated command unit via a digital interface cable It is housed in a plastic case approximately 3 by 2.5 by 12 inches. Transmitting coil is internal. The DUT was designed and manufactured by Lionel L.L.C., 26750 23 Mile Road, Chesterfield, Michigan 48051. It is identified as:

Lionel L.L.C. Transmitter
Model/PN(s): #996 BRIDGE
FCC ID: LIV-PMBR
IC: 7032A-PMBR

3.2 Variants

There is only a single variant of this device, as tested herein.

3.3 Modes of Operation

The device is capable of only a single mode of operation. Data is sent to the DUT via a digital interface cable from a command unit. This data is then transmitted at a fixed data rate by the DUT for reception by a toy train system. For AC mains conducted emissions measurements the antenna was replaced with a 51 Ohm resistor.

3.4 EMI Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices, subject to Subpart C, Section 15.227; and Subpart B, Section 15.109 (transmitter generated signals excluded); and Subpart A, Section 15.33. The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, it is exempt.

Table 4.1. Radiated Emission Limits (FCC: 15.227, 15.35; IC: RSS-310, 3.7)
(Transmitter)

Frequency (MHz)		Fundamental and Spurious* (μV/m)
26.96-27.28		10,000 (3 meters)
0.090-0.110 0.49-0.51 2.1735-2.190 3.020-3.026 (IC) 4.125-4.128 4.17725-4.17775 4.20725-4.20775 5.677-5.683 (IC) 6.215-6.218 6.26775-6.26825 6.31175-6.31225	8.291-8.294 8.37625 - 8.38675 8.41425 - 8.41475 12.29 - 12.293 12.51975 - 12.52025 12.57675 - 12.57725 13.36 - 13.41 16.42 - 16.423 16.69475 - 16.69525 16.80425 - 16.80475 25.5 - 25.67	Restricted Bands

* Harmonics must be below the fundamental.

Table 4.2. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; IC: RSS-310, Table 3)
(Digital Class B)

Freq. (MHz)	E_{lim} (3m) μV/m	E_{lim} dB(μV/m)
30-88	100	40.0
88-216	150	43.5
216-960	200	46.0
> 960	500	54.0

Note: Average readings apply above 1000 MHz (1 MHz BW)
Quasi-Peak readings apply to 1000 MHz (120 kHz BW)

4.2 Power Line Conducted Emission Limits

Table 4.3 Conducted Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 Table 2).

Frequency MHz	Class A (dBμV)		Class B (dBμV)	
	Quasi-peak	Average	Quasi-peak	Average
.150 - 0.50	79	66	66 - 56*	56 - 46*
0.50 - 5	73	60	56	46
5 - 30	73	60	60	50

Notes:
1. The lower limit shall apply at the transition frequency
2. The limit decreases linearly with the logarithm of the frequency in the range 0.15-0.50 MHz:

*Class B Quasi-peak: dBμV = 50.25 - 19.12*log(f)
*Class B Average: dBμV = 40.25 - 19.12*log(f)

3. 9 kHz RBW

5. Radiated Emission Tests and Results

5.1 Semi-Anechoic Chamber Measurements

To become familiar with the radiated emission behavior of the DUT, the DUT was first studied and measured in a shielded semi-anechoic chamber. In the chamber there is a set-up similar to that of an outdoor 3-meter site, with a turntable, an antenna mast, and a ground plane. Instrumentation includes spectrum analyzers and other equipment as needed. In this case, the receiving antenna was an active loop, placed on a tripod, approximately 1.5 meters above ground.

The DUT was laid on the test table as seen in the included photos. Using the loop antenna we studied emissions up to 30 MHz. The spectrum analyzer resolution and video bandwidths were so as to measure the DUT emission without decreasing the EBW (emission bandwidth) of the device. Emissions were studied for all orientations of the DUT and loop antenna. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections.

5.2 Outdoor Measurements
After the chamber measurements, the emissions on our outdoor 3-meter site were measured. For transmitter emissions a loop antenna was used; the resolution bandwidth maintained at such a level that the EBW (emission bandwidth) of the DUT was not reduced. See the attachment Test Setup Photos for measurement set-up. For digital emissions, bicone and dipole antennas were used. See Section 6.6 for low frequency field extrapolation of transmitter data from 3 m to 300 m.

5.3 Computations and Results
To convert the dBm measured on the spectrum analyzer to dB(μV/m), we use expression

$$E_3(\text{dB}\mu\text{V/m}) = 107 + P_R + K_A - K_G + K_E - C_F$$

where P_R = power recorded on spectrum analyzer, dB, measured at 3 m
K_A = antenna factor, dB/m
K_G = pre-amplifier gain, including cable loss, dB
K_E = pulse operation correction factor, dB (see 6.1)
C_F = 3/300 m or 3/30 m conversion factor, dB

When presenting the data, at each frequency the highest measured emission under all of the possible orientations is given. Computations and results are given in Table 5.1. There we see that as a transmitter, the DUT meets the limit by 3.5 dB.

6. Other Measurements and Computations

6.1 Correction for Pulse Operation
The transmitter sends train set commands via a pulse position modulated 27.5 MHz carrier. The minimum pulse period is 85.0 ms. In any given 100 ms window there may be, in the worst case, two 7.00 ms wide pulses. See Figure 6.1. The duty factor is computed to be:

$$K_E = (2 \times 7.00\text{ ms}) / 100.0\text{ ms} = 0.140 = 17.1\text{ dB.}$$

6.2 Emission Spectrum
Using the loop antenna, the emission spectrum was recorded and is shown in Figure 6.2.

6.3 Bandwidth of the Emission Spectrum
The measured spectrum of the signal is shown in Figure 6.3. From the plot we see that the -20 dB bandwidth is 12.7 kHz and the band edge emission is 50.2 dBc.

6.4 Effect of Supply Voltage Variation
For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 60.0 to 140.0 volts AC. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 115.0 V AC

I = 20 mA AC (pulsed emission)

6.6 AC Mains Conducted Emissions

AC mains conducted emissions are shown in Figure 6.5 and tabulated in table 5.2.

Table 5.1 Highest Radiated Emissions Measured

Radiated Emission (Fundamental+Harmonics)											Lionel Bridge Tx; FCC/IC
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3* dBμV/m	E3lim dBμV/m	Pass dB	Comments
1	27.3	Loop	perp	-19.6	Pk	7.6	24.7	53.2	80.0	26.8	
2	27.3	Loop	para	-12.7	Pk	7.6	24.7	60.1	80.0	19.9	
3	27.3	Loop	horiz	-21.6	Pk	7.6	24.7	51.2	80.0	28.8	
4	54.5	Bic	H	-60.1	Pk	8.6	24.4	31.1	40.0	8.9	
5	54.5	Bic	V	-54.7	Pk	8.6	24.4	36.5	40.0	**3.5**	
6	81.8	Bic	H	-58.7	Pk	7.6	24.0	31.9	40.0	8.1	
7	81.8	Bic	V	-60.3	Pk	7.6	24.0	30.3	40.0	9.7	
8	109.0	Bic	H	-79.1	Pk	9.1	23.6	13.4	43.5	30.1	
9	109.0	Bic	V	-67.4	Pk	9.1	23.6	25.1	43.5	18.4	
10	136.3	Bic	H	-82.8	Pk	11.4	23.2	12.3	43.5	31.2	
11	136.3	Bic	V	-81.5	Pk	11.4	23.2	13.6	43.5	29.9	
12	163.5	Bic	H	-74.4	Pk	13.4	22.9	23.1	43.5	20.4	
13	163.5	Bic	V	-80.4	Pk	13.4	22.9	17.1	43.5	26.4	
14	190.8	Bic	H	-78.9	Pk	14.5	22.5	20.1	43.5	23.4	
15	190.8	Bic	V	-78.3	Pk	14.5	22.5	20.7	43.5	22.8	
16	218.1	Bic	H	-84.6	Pk	14.8	22.2	15.0	46.0	31.0	
17	218.1	Bic	V	-82.6	Pk	14.8	22.2	17.0	46.0	29.0	
18	245.3	Bic	H	-84.6	Pk	14.6	21.8	15.2	46.0	30.8	
19	245.3	Bic	V	-87.4	Pk	14.6	21.8	12.4	46.0	33.6	
20	272.6	SBic	H	-88.2	Pk	16.7	21.5	14.0	46.0	32.0	
21	272.6	SBic	V	-90.2	Pk	16.7	21.5	12.0	46.0	34.0	
22											
23	*Duty factor of 17.1 dB applied to fundamental only.										

Digital Radiated Emissions											
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
24	32.2	Bic	V	-68.8	Pk	12.6	24.7	26.1	40.0	13.9	
25	36.2	Bic	H	-72.4	Pk	11.6	24.7	21.5	40.0	18.5	
26	36.2	Bic	V	-65.4	Pk	11.6	24.7	28.5	40.0	11.5	
27	44.2	Bic	V	-62.4	Pk	10.0	24.6	30.0	40.0	10.0	
28	48.2	Bic	V	-61.3	Pk	9.3	24.5	30.5	40.0	9.5	
29	52.2	Bic	H	-66.3	Pk	8.8	24.5	25.1	40.0	14.9	
30	52.2	Bic	V	-51.9	Pk	8.8	24.5	39.5	40.0	**0.5**	
31	56.2	Bic	V	-60.1	Pk	8.4	24.4	30.9	40.0	9.1	
32	64.2	Bic	V	-66.8	Pk	7.8	24.3	23.7	40.0	16.3	
33	68.2	Bic	H	-61.4	Pk	7.7	24.2	29.0	40.0	11.0	
34	76.2	Bic	H	-65.3	Pk	7.5	24.1	25.1	40.0	14.9	
35	80.2	Bic	H	-68.6	Pk	7.6	24.1	21.9	40.0	18.1	
36	116.3	Bic	V	-73.5	Pk	9.7	23.5	19.7	43.5	23.8	
37	124.3	Bic	V	-78.2	Pk	10.3	23.4	15.8	43.5	27.7	
38	260.0	Sbic	H	-85.5	Pk	14.7	21.6	14.6	46.0	31.4	noise
39											
40											

Meas.09/25/08; U of Mich.

Table 5.2 Highest Conducted Emissions Measured

Lionel Bridge Tx; FCC/CISPR B												
	Freq.	Line	Peak Det., dBµV		Pass	QP Det., dBµV		Pass	Ave. Det., dBµV		Pass	
#	MHz	Side	Vtest	Vlim*	dB*	Vtest	Vlim	dB	Vtest	Vlim	dB	Comments
1	0.25	Hi	27.7	51.6	23.9		61.7			51.6		
2	0.28	Hi	27.8	50.9	23.1		60.9			50.9		
3	0.42	Hi	29.0	47.4	18.4		57.5			47.4		
4	0.79	Hi	28.1	46.0	17.9		56.0			46.0		
5	1.50	Hi	29.2	46.0	16.8		56.0			46.0		
6	11.90	Hi	34.4	50.0	15.6		60.0			50.0		
7	12.10	Hi	33.8	50.0	16.2		60.0			50.0		
8	27.30	Hi	47.9	50.0	2.1	46.2	60.0	13.8		50.0	3.8	
9	27.60	Hi	36.4	50.0	13.6		60.0			50.0		
10	28.10	Hi	34.8	50.0	15.2		60.0			50.0		
11												
12	0.54	Lo	29.4	46.0	16.6		56.0			46.0		
13	1.50	Lo	28.7	46.0	17.3		56.0			46.0		
14	12.10	Lo	29.8	50.0	20.2		60.0			50.0		
15	27.30	Lo	29.4	50.0	20.6		60.0			50.0		
16	27.60	Lo	48.2	50.0	1.8	46.4	60.0	13.6		50.0	**3.6**	
17	28.10	Lo	35.4	50.0	14.6		60.0			50.0		
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**Average limit* — Meas. 09/25/2008; U of Mich.

Since Vpeak >= Vqp >= Vave and if Vtestpeak < Vavelim, then Vqplim and Vavelim are met.

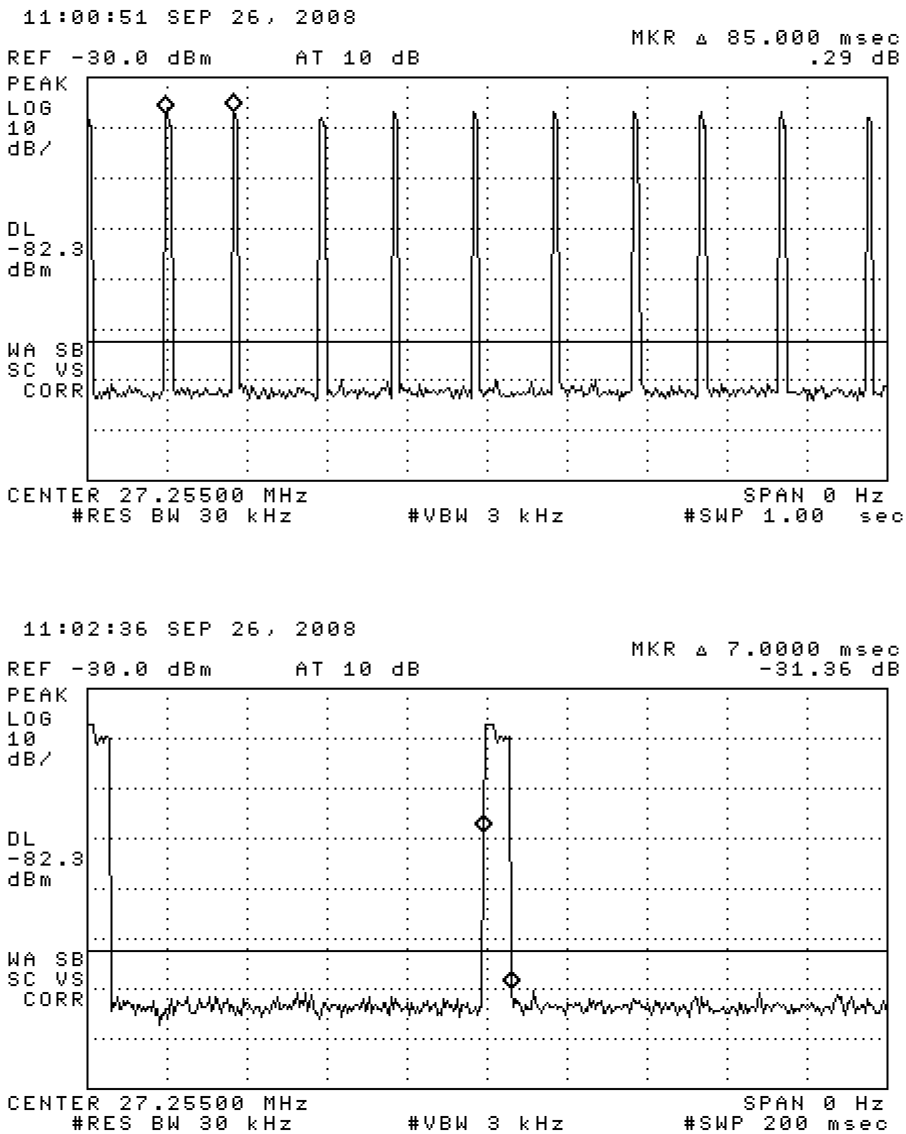


Figure 6.1. Transmission modulation characteristics.
(top) minimum pulse period, (bottom) maximum pulse width.

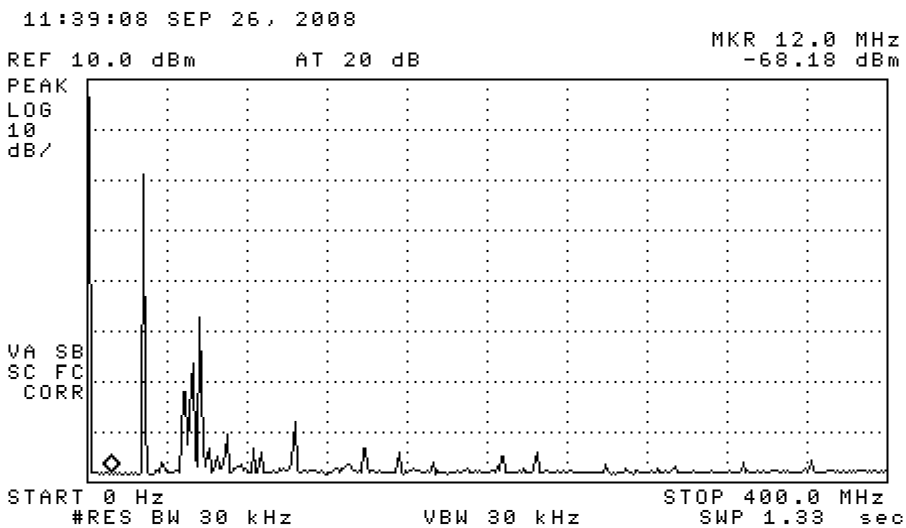


Figure 6.2. Emission spectrum of the DUT. The amplitudes are only indicative (not calibrated).

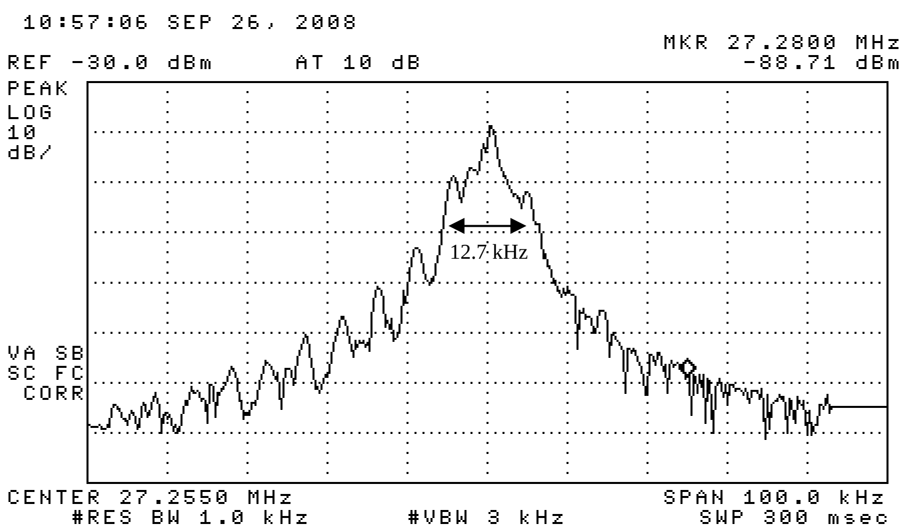


Figure 6.3.Measured 20 dB (99%) bandwidth of the DUT. (pulsed)

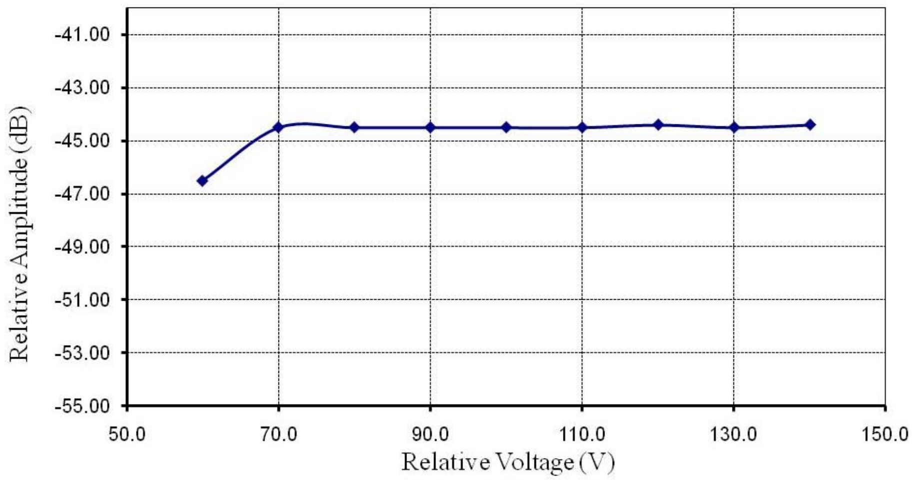


Figure 6.4. Relative emission at 27.5 MHz vs. supply voltage.

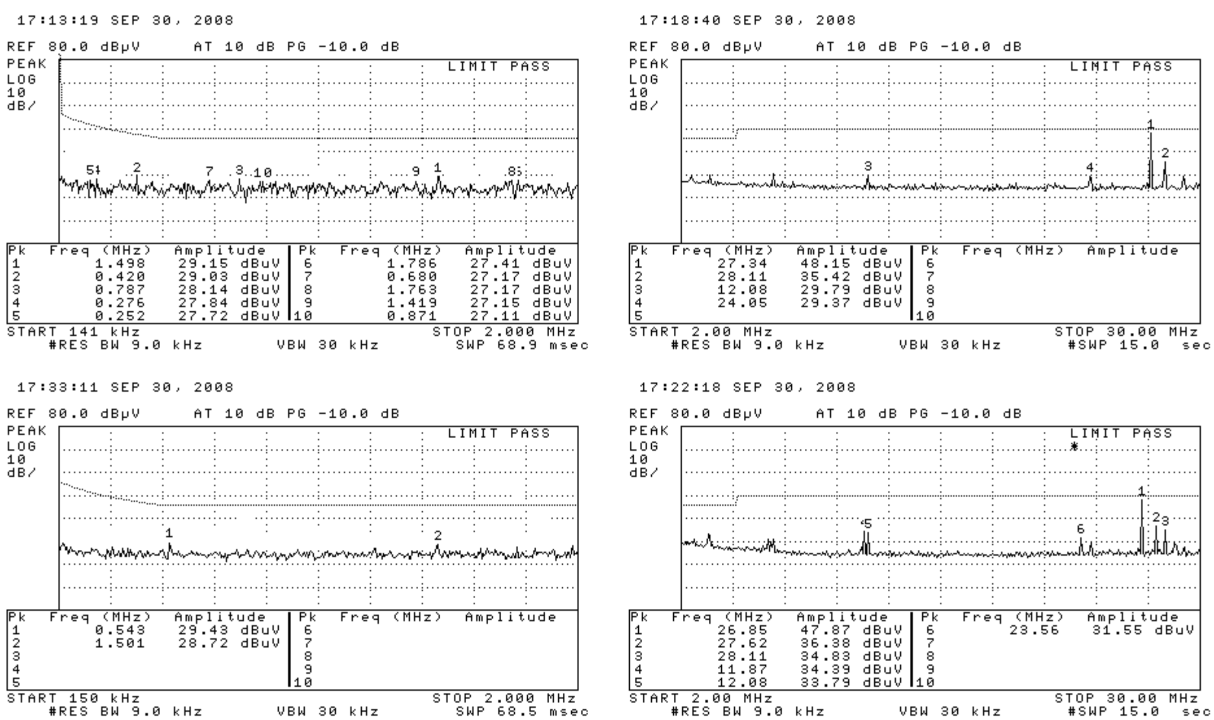
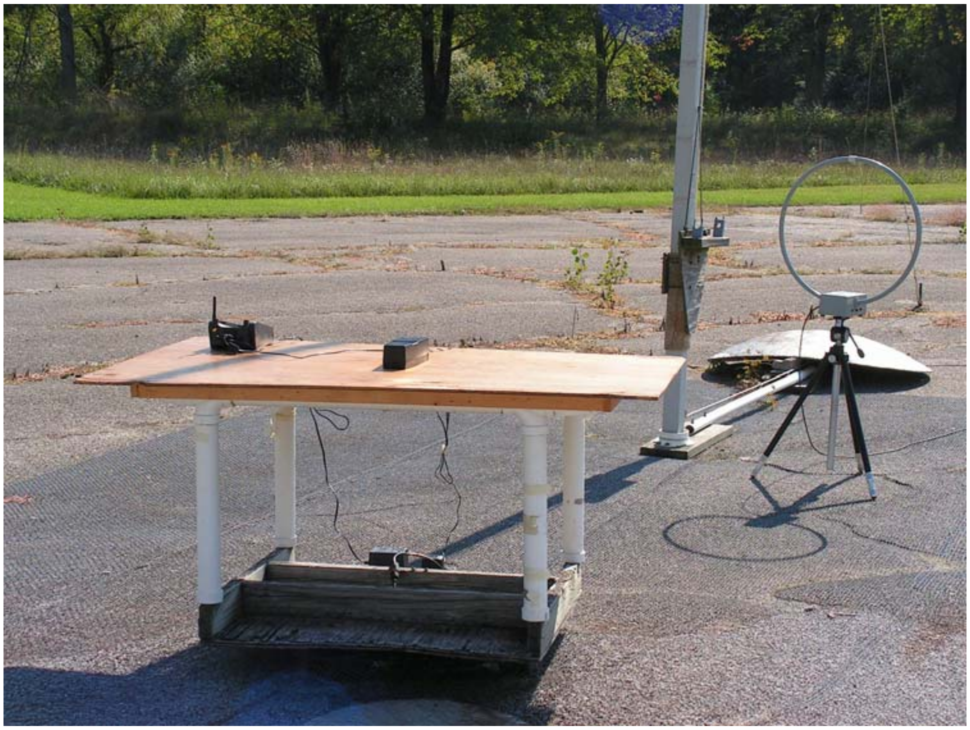


Figure 6.5. AC Mains Conducted Emissions. (top) Hi Line, (bottom) Lo Line.



DUT on OATS – one of three antenna axes tested

DUT on OATS (close-up) – one of three antenna axes tested