



The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 764-0500
Fax: (734) 647-2106

Measured Radio Frequency Emissions
From

Lear Corporation Transmitter
FCC ID: KOBJBG10A
IC: 3521A-JBG10A

Test Report No. 417124-486
February 18, 2009

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For:
Lear Corporation
21557 Telegraph Rd
Southfield, MI 48033
Contact: Kevin Cotton
kcotton@lear.com
Phone: 248-447-1334
Fax: 248-447-1334

Measurements made by: Joseph D. Brunett

Test report written by: Joseph D. Brunett

Testing supervised by:

Report Approved by:

Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations, CFR 47, Part 15 and with Industry Canada RSS-210/Gen, were performed on a Lear, FCC ID: KOBJBG10A, IC: 3521A-JBG10A. This device under test (DUT) is subject to the rules and regulations as a Transmitter.

In testing completed on February 3, 2009, the DUT tested met the allowed specifications for radiated emissions by 40 dB. Conducted emissions are not subject to regulation as the DUT is powered by a 12 VDC battery.

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1. Introduction

This Lear Transmitter was 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. 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. Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1. Except where indicated as a pre-test, monitoring, or support device; all equipment listed below is a part of the University of Michigan Radiation Laboratory (UMRL) quality system. This quality system 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)	<input checked="" type="checkbox"/>	Hewlett-Packard 8593E, SN: 3412A01131	HP8593E1
Spectrum Analyzer (9kHz-6.5GHz)	<input checked="" type="checkbox"/>	Hewlett-Packard 8595E, SN: 3543A01546	JDB8595E
Power Meter	<input type="checkbox"/>	Hewlett-Packard, 432A	HP432A1
Harmonic Mixer (26-40 GHz)	<input type="checkbox"/>	Hewlett-Packard 11970A, SN: 3003A08327	HP11970A1
Harmonic Mixer (40-60 GHz)	<input type="checkbox"/>	Hewlett-Packard 11970U, SN: 2332A00500	HP11970U1
Harmonic Mixer (75-110 GHz)	<input type="checkbox"/>	Hewlett-Packard 11970W, SN: 2521A00179	HP11970W1
Harmonic Mixer (140-220 GHz)	<input type="checkbox"/>	Pacific Millimeter Prod., GMA, SN: 26	PMPGMA1
S-Band Std. Gain Horn	<input type="checkbox"/>	S/A, Model SGH-2.6	SBAND1
C-Band Std. Gain Horn	<input type="checkbox"/>	University of Michigan, NRL design	CBAND1
XN-Band Std. Gain Horn	<input type="checkbox"/>	University of Michigan, NRL design	XNBAND1
X-Band Std. Gain Horn	<input type="checkbox"/>	S/A, Model 12-8.2	XBAND1
X-band horn (8.2- 12.4 GHz)	<input type="checkbox"/>	Narda 640	XBAND2
X-band horn (8.2- 12.4 GHz)	<input type="checkbox"/>	Scientific Atlanta , 12-8.2, SN: 730	XBAND3
K-band horn (18-26.5 GHz)	<input type="checkbox"/>	FXR, Inc., K638KF	KBAND1
Ka-band horn (26.5-40 GHz)	<input type="checkbox"/>	FXR, Inc., U638A	KABAND1
U-band horn (40-60 GHz)	<input type="checkbox"/>	Custom Microwave, HO19	UBAND1
W-band horn(75-110 GHz)	<input type="checkbox"/>	Custom Microwave, HO10	WBAND1
G-band horn (140-220 GHz)	<input type="checkbox"/>	Custom Microwave, HO5R	GBAND1
Bicone Antenna (30-250 MHz)	<input checked="" type="checkbox"/>	University of Michigan, RLBC-1	LBBIC1
Bicone Antenna (200-1000 MHz)	<input checked="" type="checkbox"/>	University of Michigan, RLBC-2	HBBIC1
Dipole Antenna Set (30-1000 MHz)	<input type="checkbox"/>	University of Michigan, RLDP-1,-2,-3	UMDIP1
Dipole Antenna Set (30-1000 MHz)	<input type="checkbox"/>	EMCO 3121C, SN: 992 (Ref. Antennas)	EMDIP1
Active Rod Antenna (30 Hz-50 MHz)	<input type="checkbox"/>	EMCO 3301B, SN: 3223	EMROD1
Active Loop Antenna (30 Hz-50 MHz)	<input checked="" type="checkbox"/>	EMCO 6502, SN:2855	EMLOOP1
Ridge-horn Antenna (300-5000 MHz)	<input checked="" type="checkbox"/>	University of Michigan	UMRH1
Amplifier (5-1000 MHz)	<input checked="" type="checkbox"/>	Avantek, A11-1, A25-1S	AVAMP1
Amplifier (5-4500 MHz)	<input checked="" type="checkbox"/>	Avantek	AVAMP2
Amplifier (4.5-13 GHz)	<input type="checkbox"/>	Avantek, AFT-12665	AVAMP3
Amplifier (6-16 GHz)	<input type="checkbox"/>	Trek	TRAMP1
Amplifier (16-26 GHz)	<input type="checkbox"/>	Avantek	AVAMP4
LISN Box	<input type="checkbox"/>	University of Michigan	UMLISN1
Signal Generator	<input type="checkbox"/>	Hewlett-Packard 8657B	HPSG1

3. Device Under Test

3.1 Description & Block Diagram

The DUT is a 125 kHz Transmitter designed for automotive/vehicular applications, and as such it is powered by a 12 VDC source. The device is housed in a plastic case approximately 17 x 14 x 4 cm in dimension. For testing, a generic harness and test box were provided by the manufacturer. The DUT is designed and manufactured by Lear Corporation, 21557 Telegraph Rd., Southfield, MI 48033

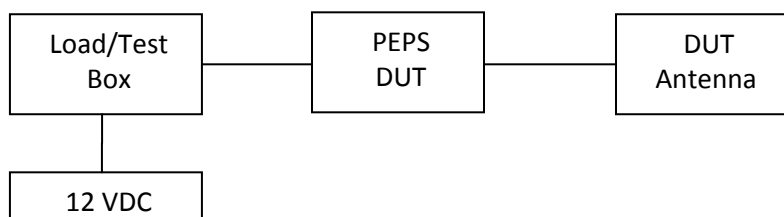


Figure 3.1 Block Diagram

Device	[Make], Model	[S/N],P/N
PEPS DUT (Passive Entry + Passive Start)	[Lear], 5E0770237	H001
DUT Antenna	[Lear], 5E08X0107	-
Load Box	[Lear]	-

3.2 Variants

There are two variants of this device. Model 5E0770237 (PEPS) is the fully populated model, and can employ up to 9 identical LF antenna coils that are distinctly activated (no two antennas are ever actuated at the same time). These antennas are placed at different locations in the vehicle, such as door/trunk handle or dashboard, allowing “Passive Entry and Passive Start”. Model 5E0770337 (PS) is a depopulated version of the previous model that employs only one “Passive Start” antenna. The PEPS version was fully tested, employing a single LF coil antenna with minimum cable length (determined by pre-testing to be the worst case emissions configuration).

3.3 Modes of Operation

The DUT is capable of only a single mode of operation, as reported herein. LF interrogation is initiated by the end user lifting a handle or pressing a button on/in the vehicle.

3.4 Exemptions

- The DUT is permanently installed in a transportation vehicle. As such, digital emissions are exempt (per FCC 15.103(a) and IC correspondence on ICES-003) from regulation.

3.5 EMC Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emissions Limits

4.1 Radiated Emissions Limits

The DUT tested falls under the category of an Intentional Radiator. The applicable testing frequencies and corresponding emission limits set by both the FCC and IC are given in Tables 4.1 and 4.2 below.

Table 4.1. Transmitter Radiated Emission Limits (FCC: 15.205, 15.35; IC: RSS-210, 2.6 Tab. 1,3)

Frequency (MHz)		Fundamental and Spurious* ($\mu\text{V/m}$)
0.009-0.490		2400/F(kHz), 300m
0.490-1.705		24,000/F(kHz), 30m
0.090-0.110	8.291-8.294	Restricted Bands
0.49-0.51	8.37625 - 8.38675	
2.1735-2.190	8.41425 - 8.41475	
3.020-3.026 (IC)	12.29 - 12.293	
4.125-4.128	12.51975 - 12.52025	
4.17725-4.17775	12.57675 - 12.57725	
4.20725-4.20775	13.36 - 13.41	
5.677-5.683 (IC)	16.42 - 16.423	
6.215-6.218	16.69475 - 16.69525	
6.26775-6.26825	16.80425 - 16.80475	
6.31175-6.31225	25.5 - 25.67	

* Harmonics must be below the fundamental. To translate measurements to the 300/30 m distance, we refer to the journal paper: "Extrapolating Near-Field Emissions of Low-Frequency Loop Transmitters," J. D. Brunett, V. V. Liepa, D. L. Sengupta, IEEE Trans. EMC, Vol. 47, No. 3, August 2005.

Table 4.2. Spurious Emission Limits (FCC: 15.33, .35, .109/209; IC: RSS-210 2.7, T2)

Freq. (MHz)	E_{lim} (3m) $\mu\text{V/m}$	E_{lim} dB($\mu\text{V/m}$)
30-88	100	40.0
88-216	150	43.5
216-960	200	46.0
960-2000	500	54.0

Note: Average readings apply above 1000 MHz (1 MHz BW), Quasi-Peak readings apply to 1000 MHz (120 kHz RBW), PRF of intentional emissions > 20 Hz for QPK to apply.

4.2 Power Line Conducted Emissions Limits

Table 4.3 Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 T2).

Frequency (MHz)	Class A (dB μV)		Class B (dB μV)	
	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:

- The lower limit shall apply at the transition frequency
- The limit decreases linearly with the logarithm of the frequency in the range 0.15-0.50 MHz:
 *Class B Quasi-peak: $\text{dB}\mu\text{V} = 50.25 - 19.12 \cdot \log(f)$
 *Class B Average: $\text{dB}\mu\text{V} = 40.25 - 19.12 \cdot \log(f)$
- 9 kHz RBW

5. Measurement Procedures

5.1 Semi-Anechoic Chamber Radiated Emissions

To become familiar with the radiated emission behavior of the DUT, the device is first studied and measured in our 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.

The DUT is laid on the test table as shown in the included block diagram. A shielded loop antenna is employed when studying emissions from 9 kHz to 30 MHz. Above 30 MHz and below 250 MHz a biconical antenna is employed. Above 250 MHz a ridge or standard gain horn antennas are used. The spectrum analyzer resolution and video bandwidths are set so as to measure the DUT emission without decreasing the emission bandwidth (EBW) of the device. Emissions are studied for all orientations (3-axes) of the DUT and all test antenna polarizations. In the chamber spectrum and modulation characteristics of the carrier are recorded. This data is presented in subsequent sections.

5.2 Outdoor Radiated Emissions

After measurements are performed indoors, emissions on our outdoor 3-meter Open Area Test Site (OATS) are made. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration. Any intentionally radiating elements are placed on the test table flat, on their side, and on their end (3-axes) and worst case emissions are recorded. For devices with intentional emissions below 30 MHz, our shielded loop antenna is used and low frequency field extrapolation to the regulatory limit distance is employed as needed. Emissions between 30 MHz and 1 GHz are measured using tuned dipoles and/or biconical antennas. Care is taken to ensure that the RBW and VBW used meet the regulatory requirements, and that the EBW of the DUT is not reduced. The Photographs included in this report show the DUT on the OATS.

5.3 Radiated Field Computations

To convert the dBm values measured on the spectrum analyzer to dB(μ V/m), we use expression

$$E3(\text{dB}\mu\text{V/m}) = 107 + \text{PR} + \text{KA} - \text{KG} + \text{KE} - \text{CF}$$

where

- PR = power recorded on spectrum analyzer, dB, measured at 3 m
- KA = antenna factor, dB/m
- KG = pre-amplifier gain, including cable loss, dB
- KE = duty correction factor, dB
- CF = distance conversion (employed only if limits are specified at alternate distance), dB

When presenting the data at each frequency, the highest measured emission under all of the possible DUT orientations (3-axes) is given.

5.4 Indoor Power Line Conducted Emissions

When applicable, power line conducted emissions are measured in our semi-anechoic chamber. If the DUT connects to auxiliary equipment and is table or floor standing, the configurations prescribed in ANSI C63.4 are employed. Alternatively, an on-table layout more representative of actual use may be employed if the resulting emissions appear to be worst-case in such a configuration.

The conducted emissions measured with the spectrum analyzer and recorded (in dB μ V) from 0-2 MHz and 2-30 MHz for both the ungrounded (Hi) and grounded (Lo) conductors. The spectrum analyzer is set to peak-hold mode in order to record the highest peak throughout the course of functional operation. Only when the emission exceeds or is near the limit are quasi-peak and average detection used.

5.5 Supply Voltage Variation

Measurements of the variation in the fundamental radiated emission were performed with the supply voltage varied by no less than 85% and 115% of the nominal rated value. For battery operated equipment, tests were performed using a new battery, and worst case emissions are re-checked employing a new battery.

6. Test Results

6.1 Radiated Emissions

6.1.1 Correction for Pulse Operation

When the transmitter is manually activated, it can, in the worst case, transmit 31.3 ms long Manchester encoded words with 40.25 ms period. See Figure 6.1. While a duty cycle may be applied to emissions below 490 kHz, encoding is only depicted here to document the modulation employed, as required for authorization.

6.1.2 Emission Spectrum

The relative DUT emission spectrum is recorded and is shown in Figure 6.2.

6.1.3 Emission Bandwidth

The emission bandwidth of the signal is shown in Figure 6.3. From the plot we see that the EBW is 11.38 kHz, and unintentional emissions in the 109 kHz restricted band are 26.7 dBc.

6.1.4 Supply Voltage and Supply Voltage Variation

The DUT has been designed to be powered by a 12 VDC battery. For this test, relative radiated power was measured at the fundamental as the voltage was varied from 6.0 to 18.0 volts. The emission variation is shown in Figure 6.4.

$$\begin{array}{rcl} V & = & 12.0 \text{ V} \\ I & = & 130 \text{ mA (pulsed)} \end{array}$$

6.2 Conducted Emissions

These tests do not apply, since the DUT is powered from a 12 VDC battery.

The University of Michigan
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3228 EECS Building
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Fax: (734) 647-2106

Table 6.1 Highest Emissions Measured

Radiated Emission - LF												Lear, RFA FET; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orient.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv.** 3/30/300 m	E* dB μ V/m	Elim dB μ V/m	Pass dB	Comments
1	125.0	Loop	V/perp	-24.7	Pk	9.9	0.0	114.8	-22.6	25.7	48.3	loop perp. (axis in dir. of prop.)
2	125.0	Loop	V/par	-28.0	Pk	9.9	0.0	114.8	-25.9	25.7	51.6	loop paral. (loop in dir. of prop.)
3	125.0	Loop	H	-31.4	Pk	9.9	0.0	114.8	-29.3	25.7	55.0	loop horiz. (loop in horiz. plane)
4	250.0	Loop	V/perp	-84.1	Pk	9.8	0.0	110.4	-77.7	19.6	97.3	loop perp. (noise)
5	250.0	Loop	V/par	-83.8	Pk	9.8	0.0	110.4	-77.4	19.6	97.0	loop paral. (noise)
6	250.0	Loop	H	-82.5	Pk	9.8	0.0	110.4	-76.1	19.6	95.7	loop horiz. (noise)
7	375.0	Loop	V/perp	-61.6	Pk	9.8	0.0	104.5	-49.3	16.1	65.4	loop perp.
8	375.0	Loop	V/par	-60.7	Pk	9.8	0.0	104.5	-48.4	16.1	64.5	loop paral.
9	375.0	Loop	H	-64.4	Pk	9.8	0.0	104.5	-52.1	16.1	68.2	loop horiz.
10	500.0	Loop	V/perp	-84.8	Pk	9.8	0.0	56.3	-24.3	33.6	57.9	noise
11	625.0	Loop	V/perp	-72.7	Pk	9.8	0.0	56.1	-12.0	31.7	43.7	max all
12	750.0	Loop	All	-84.0	Pk	9.8	0.0	55.9	-23.1	30.1	53.2	noise
13	875.0	Loop	All	-79.3	Pk	9.8	0.0	55.6	-18.1	28.8	46.9	max all
14	1000.0	Loop	All	-81.8	Pk	9.8	0.0	55.4	-20.4	27.6	48.0	background
15	1125.0	Loop	All	-83.9	Pk	9.8	0.0	55.1	-22.2	26.6	48.8	noise
16	1250.0	Loop	All	-89.2	Pk	9.8	0.0	54.8	-27.2	25.7	52.8	background
17												
18												
19												
20												
21												
22	* Averaging applies up to 490 kHz, 0.0 dB employed in this case											
23	Limit at 300m for f<0.490MHz; 30m for f>0.490MHz											
24	Measurements made at 3 m, see Test Report for extrapolation information											
25	9 kHz RBW for f > 150 kHz.											
26	** Represents the worst case conversion factor for all possible orientations and ground m											
27												
28												
Digital Radiated Emissions*												
#	Freq. kHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB		E3 dB μ V/m	E3lim dB μ V/m	Pass dB	Comments
1												
2												
3												
4												
5												
6												
7												
8												
9	* For devices used in transportation vehicles, digital emissions are exempt from FCC regulations per FCC 15.103(a)											

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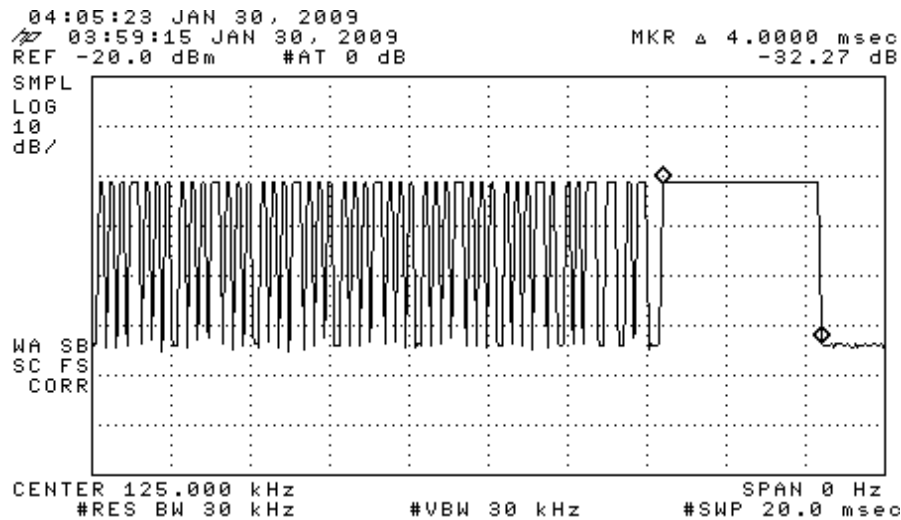
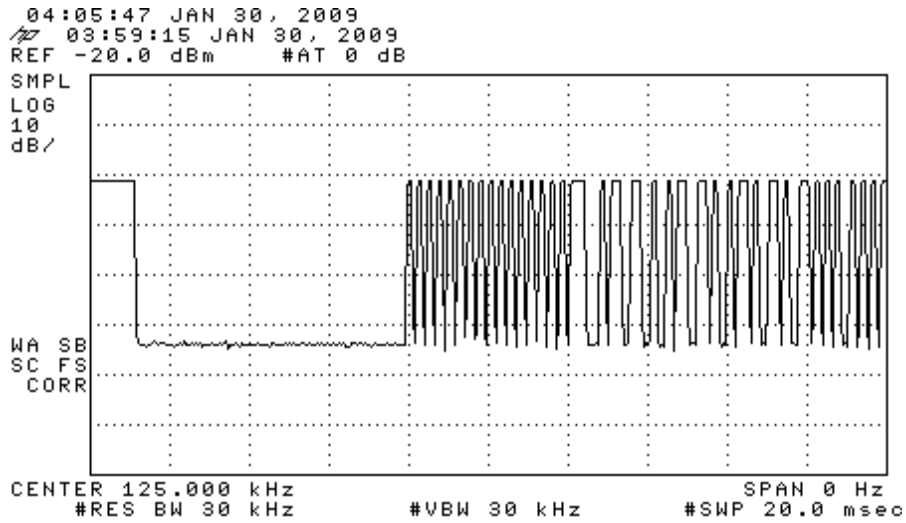
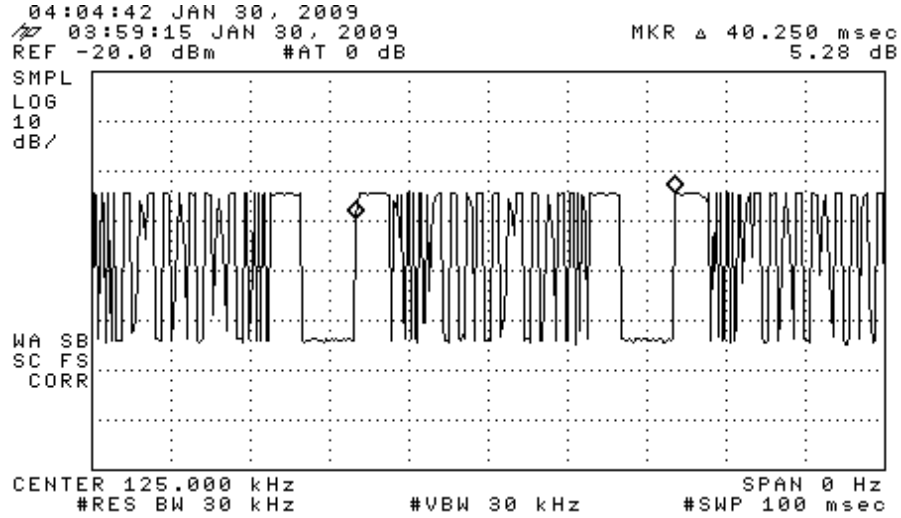


Figure 6.1(a). Transmission modulation characteristics. (top) complete transmission, (center) expanded wake-up, (bottom) expanded end.

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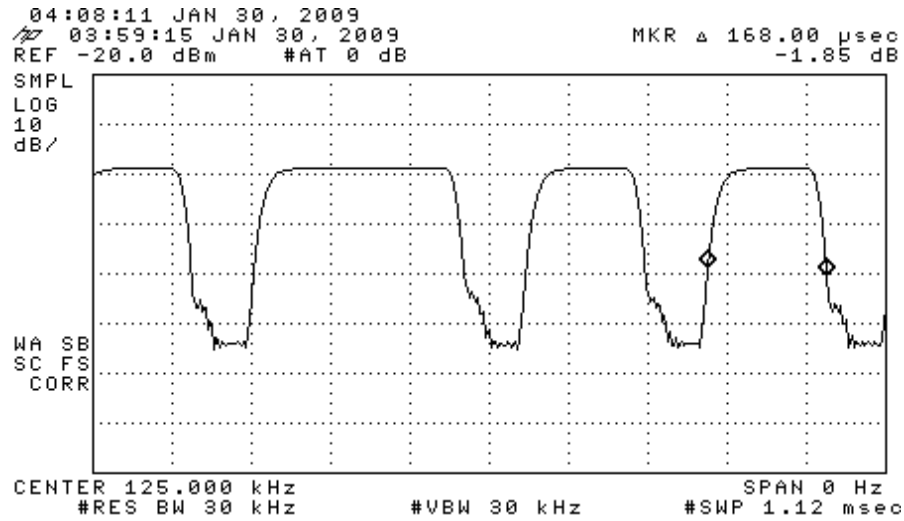
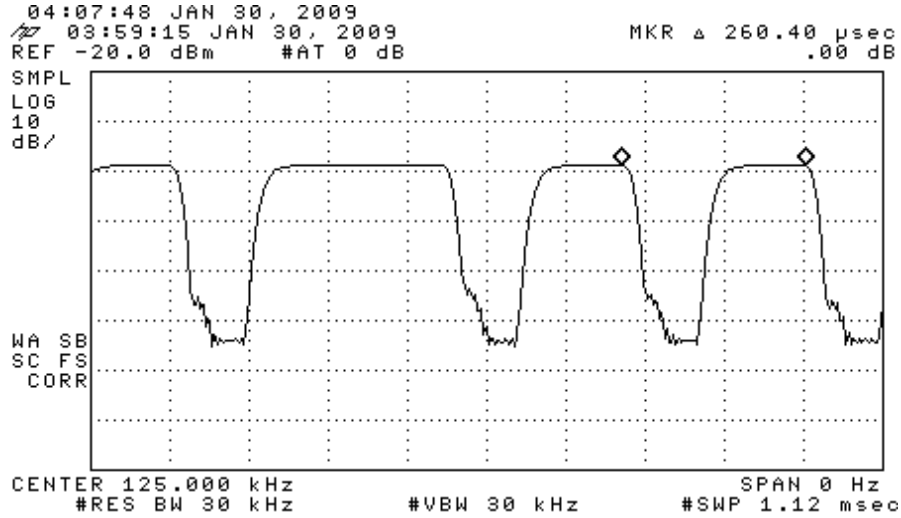


Figure 6.1(b). Manchester modulation characteristics. (top) period, (bottom) pulse-width.

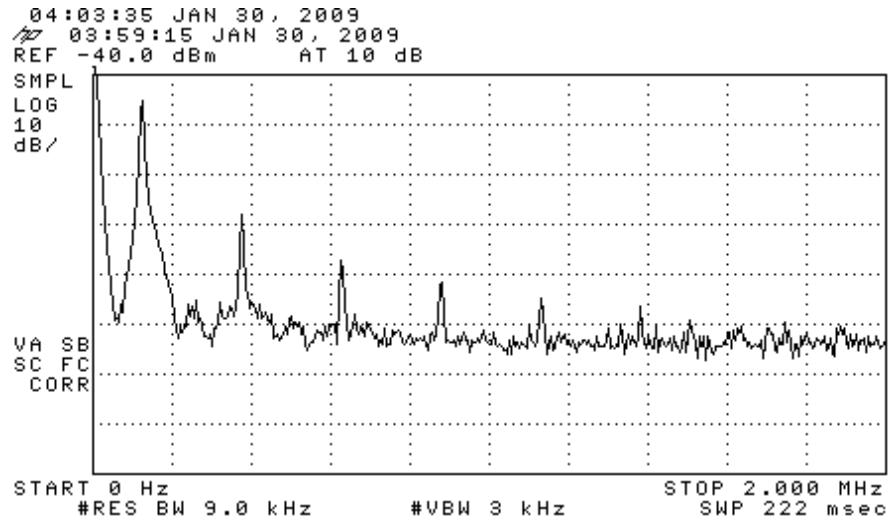


Figure 6.2. Emission spectrum of the DUT (pulsed emission). Amplitudes are only indicative (not calibrated).

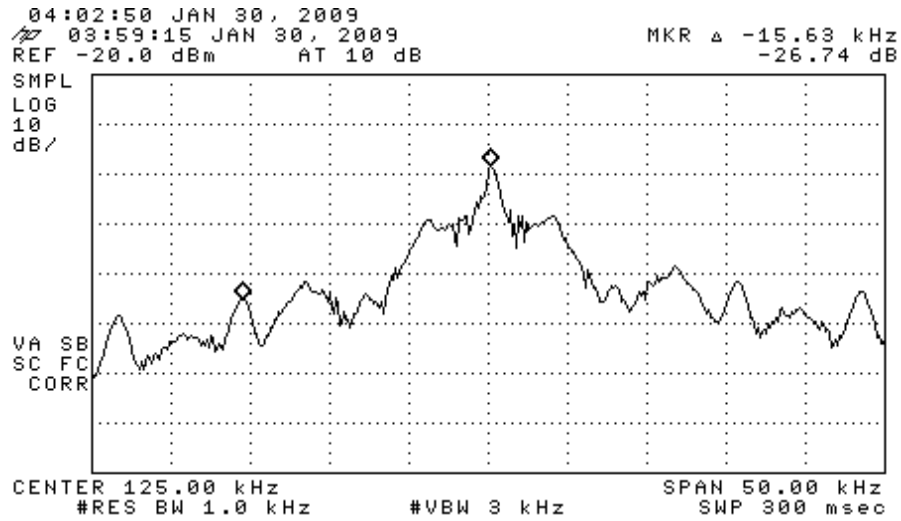
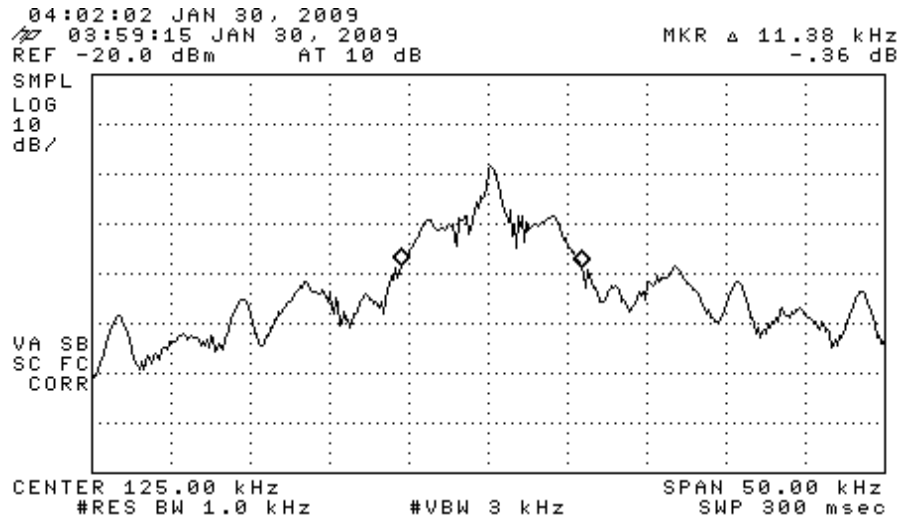


Figure 6.3. Measured emission bandwidth of the DUT (pulsed).

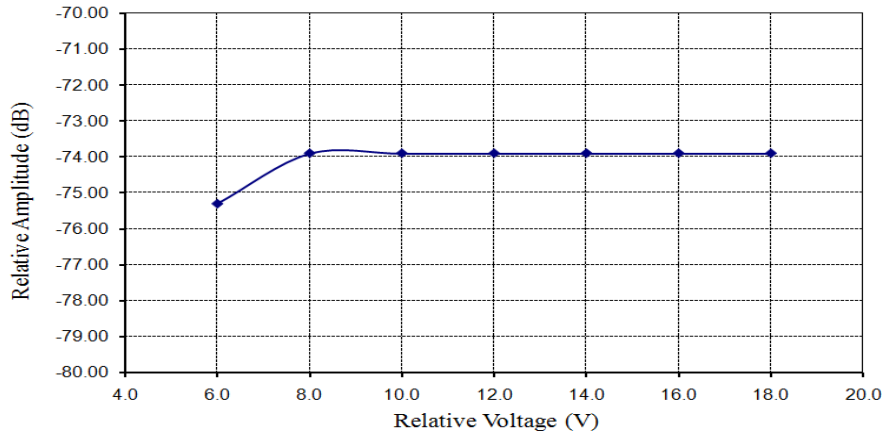
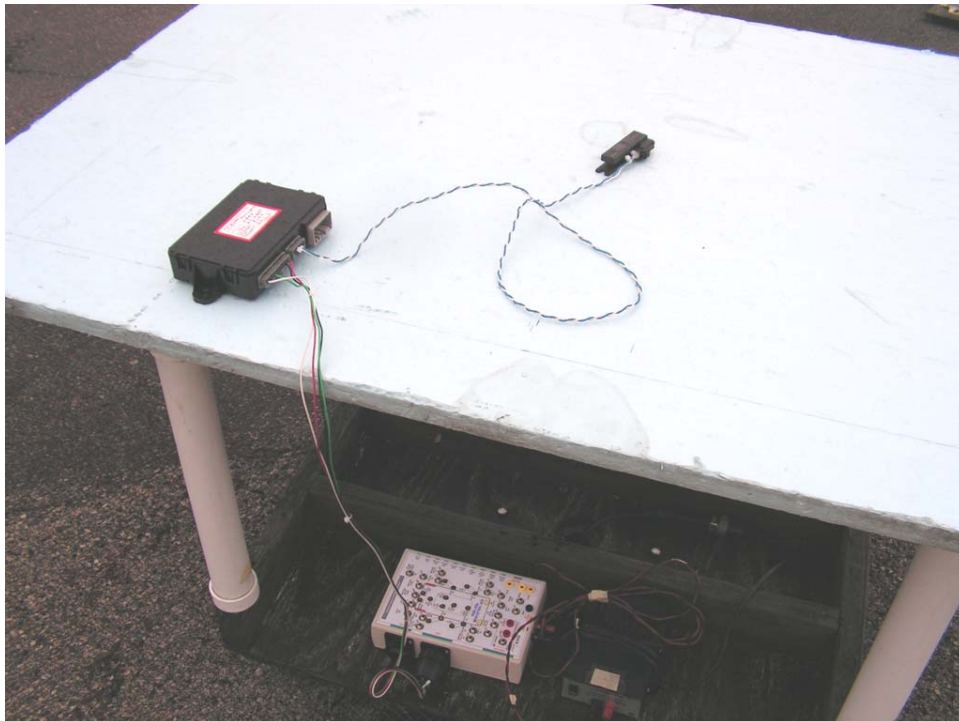


Figure 6.4. Relative emission at fundamental vs. supply voltage (pulsed).



Photograph 6.5. DUT on OATS (one of three axes tested)



Photograph 6.6. Close-up of DUT on OATS (one of three axes tested)