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Measured Radio Frequency Emissions
From

TRW LF Transmitter (TPM Initiator)
Model: 39360-S9V-A0

Report No. 415031-213
May 20, 2004

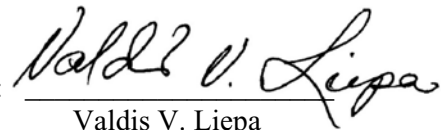
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Summary

Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-210, were performed on TRW, Inc. transmitter, model 39360-S9V-A0. This device is subject to Rules and Regulations as a transmitter.

In testing completed 20-May-04, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 51.9 dB (see p. 7); digital emissions, Class B, were met by at least 20 dB. The conducted emissions tests do not apply, since the device is powered from a 12 VDC system.

1. Introduction

TRW model 39360-S9V-A0 was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210, Issue 5, November, 2001. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-1992 "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 2057).

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.

Table 2.1 Test Equipment.

Test Instrument	Eqpt. Used	Manufacturer/Model
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard, 182T/8558B
Spectrum Analyzer (9kHz-22GHz)	X	Hewlett-Packard 8593A SN: 3107A01358
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E, SN: 3412A01131
Spectrum Analyzer (9kHz-26GHz)		Hewlett-Packard 8563E, SN: 3310A01174
Spectrum Analyzer (9kHz-40GHz)		Hewlett-Packard 8564E, SN: 3745A01031
Power Meter		Hewlett-Packard, 432A
Power Meter		Anritsu, ML4803A/MP
Harmonic Mixer (26-40 GHz)		Hewlett-Packard 11970A, SN: 3003A08327
Harmonic Mixer (40-60 GHz)		Hewlett-Packard 11970U, SN: 2332A00500
Harmonic Mixer (75-110 GHz)		Hewlett-Packard 11970W, SN: 2521A00179
Harmonic Mixer (140-220 GHz)		Pacific Millimeter Prod., GMA, SN: 26
S-Band Std. Gain Horn		S/A, Model SGH-2.6
C-Band Std. Gain Horn		University of Michigan, NRL design
XN-Band Std. Gain Horn		University of Michigan, NRL design
X-Band Std. Gain Horn		S/A, Model 12-8.2
X-band horn (8.2- 12.4 GHz)		Narda 640
X-band horn (8.2- 12.4 GHz)		Scientific Atlanta , 12-8.2, SN: 730
K-band horn (18-26.5 GHz)		FXR, Inc., K638KF
Ka-band horn (26.5-40 GHz)		FXR, Inc., U638A
U-band horn (40-60 GHz)		Custom Microwave, HO19
W-band horn(75-110 GHz)		Custom Microwave, HO10
G-band horn (140-220 GHz)		Custom Microwave, HO5R
Bicone Antenna (30-250 MHz)	X	University of Michigan, RLBC-1
Bicone Antenna (200-1000 MHz)	X	University of Michigan, RLBC-2
Dipole Antenna Set (30-1000 MHz)	X	University of Michigan, RLDP-1,-2,-3
Dipole Antenna Set (30-1000 MHz)		EMCO 2131C, SN: 992
Active Rod Antenna (30 Hz-50 MHz)		EMCO 3301B, SN: 3223
Active Loop Antenna (30 Hz-50 MHz)	X	EMCO 6502, SN:2855
Ridge-horn Antenna (300-5000 MHz)	X	University of Michigan
Amplifier (5-1000 MHz)	X	Avantek, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	Avantek
Amplifier (4.5-13 GHz)		Avantek, AFT-12665
Amplifier (6-16 GHz)		Trek
Amplifier (16-26 GHz)		Avantek
LISN Box		University of Michigan
Signal Generator		Hewlett-Packard 8657B

3. Configurations and Identification of Device Under Test

The DUT is a 135 kHz LF transmitter designed for an onboard automobile Tire Pressure Monitoring System (TPMS), and as such, it is powered from an automotive 12 VDC source. It consists of two parts. The modulation and 125 kHz RF circuitry is located in the control module, 7 by 3 by 1.5 inches, and the drivers and coil antenna are housed in a plastic case, approximately 3 by 2 by 1.5 inches. The control module also contains a 315 MHz receiver (FCC ID: GQ4-3QR, IC: 1470A-2R) and automobile body module functions. For testing, a generic harness was provided by the manufacturer.

The DUT was designed by TRW, Inc., 24175 Research Drive, Farmington Hills, MI 48335-2642. It is identified as:

TRW, Inc. Transmitter
Model: 39360-S9V-A0
FCC ID: GQ4-27T
CANADA: 1470A-8T

3.1 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 15.209; 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: 15.205, 15.35; IC: RSS-210 (6.2.2(r), 6.3)).
(Transmitter)

Frequency (MHz)	Fundamental and Spurious* (μ V/m)
0.009-0.490	2400/F(kHz), 300m
0.490-1.705	24,000/F(kHz), 30m
0.090-0.110 0.49-0.51	Restricted Bands

* Harmonics must be below the fundamental.

For extrapolation to other distances, see Section 6.6.

Table 4.2. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; IC: RSS-210, 6.2.2(r)).
(Digital Class B)

Freq. (MHz)	E _{lim} (3m) μ V/m	E _{lim} dB(μ 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 BW)

4.2 Conductive Emission Limits

Table 4.3 Conducted Emission Limits (FCC:15.107 (CISPR); IC: RSS-210, 6.6).

Frequency MHz	Class A (dB μ V)		Class B (dB μ V)	
	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: dB μ V = 50.25 - 19.12*log(f)

*Class B Average: dB μ V = 40.25 - 19.12*log(f)

3. 9 kHz RBW

5. Radiated Emission Tests and Results

5.1 Anechoic Chamber Measurements

To become familiar with the radiated emission behavior of the DUT, the DUT was first studied and measured in a shielded 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 Attachment-Test Setup Photos. Using the loop antenna we studied emissions up to 2 MHz. The spectrum analyzer resolution and video bandwidths were usually set to 1 kHz, and sometimes to 300 Hz. Emissions were studied with the plane of the loop perpendicular and parallel to the direction of propagation from the DUT. 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 was usually 9 kHz, but reduced when ambient noise is present. See Appendix for measurement set-up. For digital emissions bicone and dipole antennas were used. See Section 6.6 for field extrapolation of LF transmitter data from 3 m to 300 m.

5.3 Computations and Results

To convert the dBm measured on the spectrum analyzer to dB(μ V/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 51.9 dB. The digital emissions, Class B, were met by 20 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

Under normal operation the transmitter produces a continuous pulse for 660.0 ms. See Figure 6.1. Since the DUT operates in CW mode for more than 100 ms, no duty factor is applied.

The duty factor is:

$$K_E = 100 \text{ ms} / 100 \text{ ms} = 1.0 \text{ or } 0.0 \text{ dB}$$

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 and Its Level in 110 kHz Restricted Band

The measured spectrum of the signal at the lowest operation channel is shown in Figure 6.3. From the plot we see that the -20 dB bandwidth is 24 kHz, and the highest sidelobe in the restricted band is 26.7 dB below the center frequency.

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 6.0 to 17.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

$$V = 14.1 \text{ V}$$

$$I = 192 \text{ mA (CW emission)}$$

6.6 Field Behavior at 135 kHz

Because at the specified 300/30 m measurement distance the signal is too small to measure, measurements were made at 3 m. To translate the measurement from 3 m to the 300/30 m distance, we computed the field behavior for a Hertzian (small loop) dipole using equations found in most antenna books, such as, Balanis Antenna Theory Analysis and Design, 1997 John Wiley & Sons, 2nd Edition, pg. 207-208. The applicable results that we need are:

Freq (kHz)	H-component	Extrapolated Position	Correction (dB)	Notes
135	Vertical – Radial	3m/300m	117.1 dB	Axial coupling
135	Vertical –Transverse	3m/300m	121.0 dB	Planar coupling
135	Horizontal –Transverse	3m/300m	121.0 dB	Planar coupling
270	Vertical – Radial	3m/300m	114.1 dB	Axial coupling
270	Vertical –Transverse	3m/300m	111.9 dB	Planar coupling
270	Horizontal –Transverse	3m/300m	111.9 dB	Planar coupling
405	Vertical – Radial	3m/300m	111.3 dB	Axial coupling
405	Vertical –Transverse	3m/300m	104.4 dB	Planar coupling
405	Horizontal –Transverse	3m/300m	104.4 dB	Planar coupling
540	Vertical – Radial	3m/30m	59.5 dB	Axial coupling
540	Vertical –Transverse	3m/30m	60.5 dB	Planar coupling
540	Horizontal –Transverse	3m/30m	60.5 dB	Planar coupling
675	Vertical – Radial	3m/30m	59.3 dB	Axial coupling
675	Vertical –Transverse	3m/30m	60.7 dB	Planar coupling
675	Horizontal –Transverse	3m/30m	60.7 dB	Planar coupling
810	Vertical – Radial	3m/30m	59.0 dB	Axial coupling
810	Vertical –Transverse	3m/30m	60.9 dB	Planar coupling
810	Horizontal –Transverse	3m/30m	60.9 dB	Planar coupling
945	Vertical – Radial	3m/30m	58.7 dB	Axial coupling
945	Vertical –Transverse	3m/30m	61.1 dB	Planar coupling
945	Horizontal –Transverse	3m/30m	61.1 dB	Planar coupling
1080	Vertical – Radial	3m/30m	58.4 dB	Axial coupling
1080	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1080	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1215	Vertical – Radial	3m/30m	58.0 dB	Axial coupling
1215	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1215	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1350	Vertical – Radial	3m/30m	57.7 dB	Axial coupling
1350	Vertical –Transverse	3m/30m	61.0 dB	Planar coupling
1350	Horizontal –Transverse	3m/30m	61.0 dB	Planar coupling

In the data table, Table 5.1, the measured field is decreased by the dB values given above to represent the field at 300m or 30m, which ever is applicable.

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Table 5.1 Highest Emissions Measured

Transmitter Radiated Emissions												TRW LF Initiator; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 3/300 m	E* dBμV/m	Elim dBμV/m	Pass dB	Comments
1	137.3	Loop	V/perp	-26.2	Pk	9.9	0.0	117.7	-27.0	24.9	51.9	loop perp. (axis in dir. of prop.)
2	137.3	Loop	V/par	-30.8	Pk	9.9	0.0	121.0	-34.9	24.9	59.8	loop paral. (loop in dir. of prop.)
3	137.3	Loop	H, CP	-28.0	Pk	9.9	0.0	121.0	-32.1	24.9	57.0	loop horiz. (loop in horiz. plane)
4	274.5	Loop	V/perp	-66.3	Pk	9.8	0.0	114.1	-63.6	18.8	82.4	loop perp. (axis in dir. of prop.)
5	274.5	Loop	V/par	-69.9	Pk	9.8	0.0	111.9	-65.0	18.8	83.8	loop paral. (loop in dir. of prop.)
6	274.5	Loop	H, CP	-68.4	Pk	9.8	0.0	111.9	-63.5	18.8	82.3	loop horiz. (loop in horiz. plane)
7	411.8	Loop	V/perp	-73.8	Pk	9.8	0.0	111.3	-68.3	15.3	83.6	
8	411.8	Loop	V/par	-75.9	Pk	9.8	0.0	104.4	-63.5	15.3	78.8	
9	411.8	Loop	H, CP	-75.1	Pk	9.8	0.0	104.4	-62.7	15.3	78.0	
10	549.0	Loop	V/perp	-77.4	Pk	9.8	0.0	59.5	-20.1	32.8	52.9	background
11	549.0	Loop	V/par	-76.3	Pk	9.8	0.0	60.5	-20.0	32.8	52.8	background
12	549.0	Loop	H, CP	-84.1	Pk	9.8	0.0	60.5	-27.8	32.8	60.6	noise
13	686.3	Loop	V/perp	-76.2	Pk	9.8	0.0	59.3	-18.7	30.9	49.6	background
14	686.3	Loop	V/par	-77.5	Pk	9.8	0.0	60.7	-21.4	30.9	52.3	background
15	686.3	Loop	H, CP	-81.4	Pk	9.8	0.0	60.7	-25.3	30.9	56.2	noise
16	823.5	Loop	All	-85.6	Pk	9.8	0.0	59.0	-27.8	29.3	57.1	noise
17	960.8	Loop	All	-74.5	Pk	9.8	0.0	58.7	-16.4	28.0	44.4	background
18	1098.0	Loop	All	-83.4	Pk	9.8	0.0	58.4	-25.0	26.8	51.8	background
19	1235.3	Loop	All	-89.4	Pk	9.8	0.0	58.0	-30.6	25.8	56.4	noise
20	1372.5	Loop	All	-86.5	Pk	9.8	0.0	57.7	-27.4	24.9	52.3	background
21												
22	* Averaging applies up to 490 kHz, 0.0 dB in this case											
23	Limit at 300m for f<0.490MHz; 30m for f>0.490MHz											
24	Measurements made at 3 m, see Sec. 6.6 for extrapolation information											
25	Usually, 9 kHz RBW is used, sometimes lower to reduce ambient and instrument noise											
26												
Digital Radiated Emissions, Class B												
#	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												
2	Digital emission were > 20 dB below the Class B limit											
3												
4												
5												
6												
7												
8												
9												
10												
11												

Meas.05/20/2004; U of Mich.

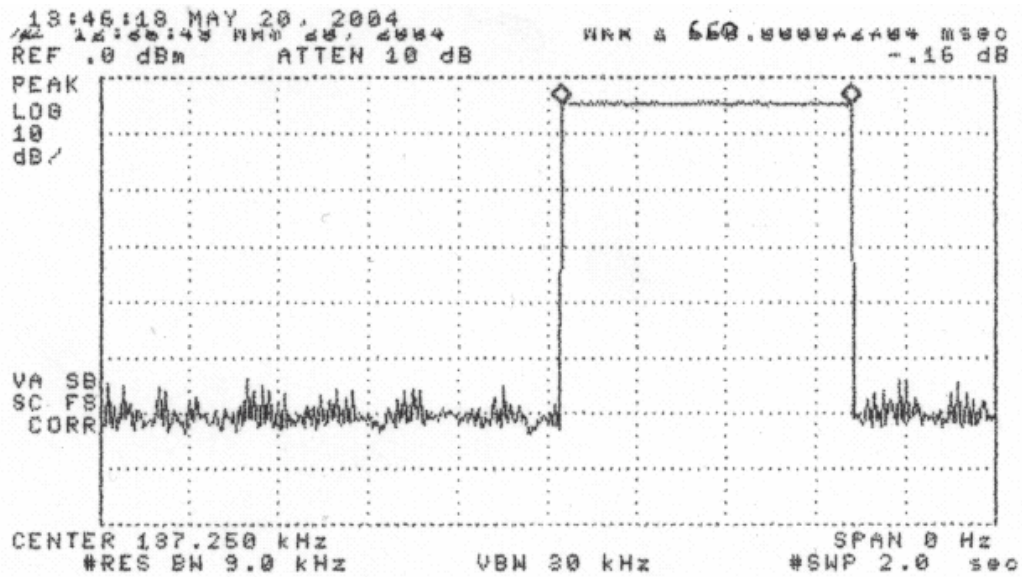


Figure 6.1. Transmission modulation characteristics.

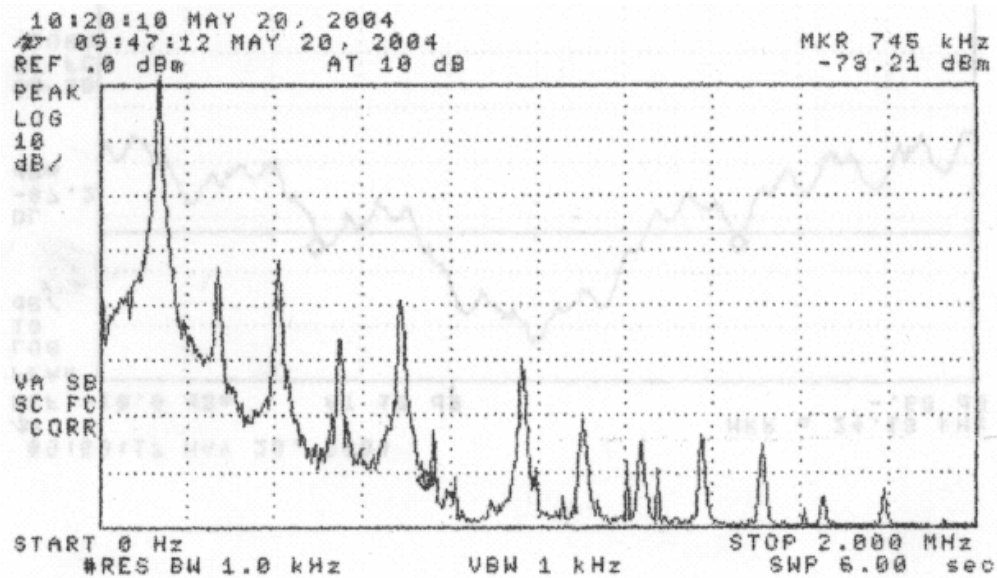


Figure 6.2. Emission spectrum of the DUT. The amplitudes are only indicative (not calibrated).

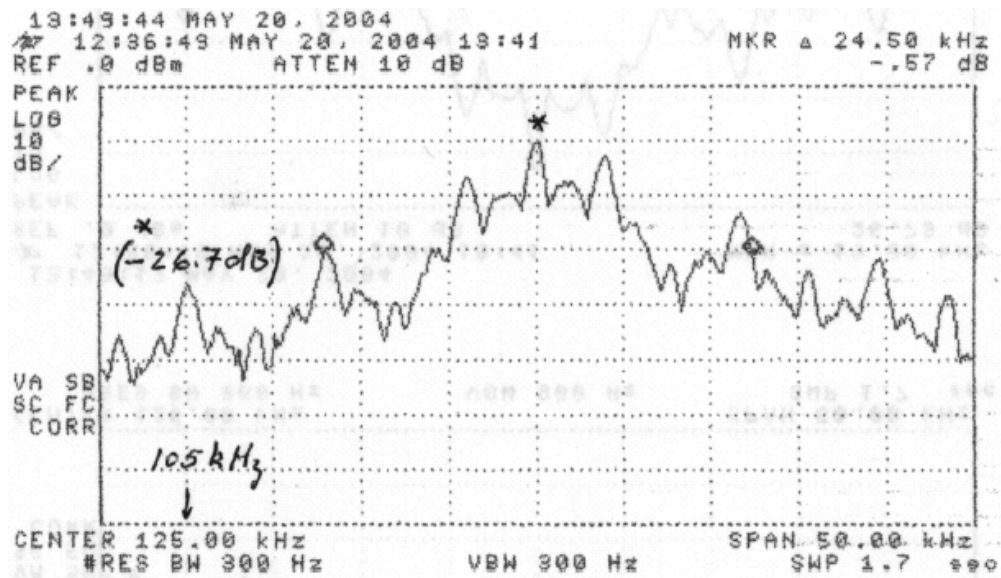


Figure 6.3. Measured bandwidth of the DUT at 125 kHz. (pulsed)

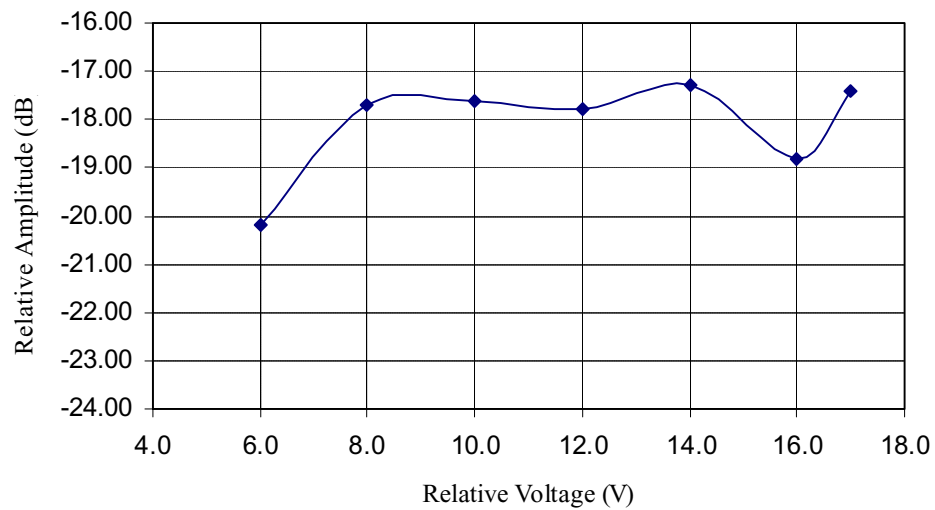
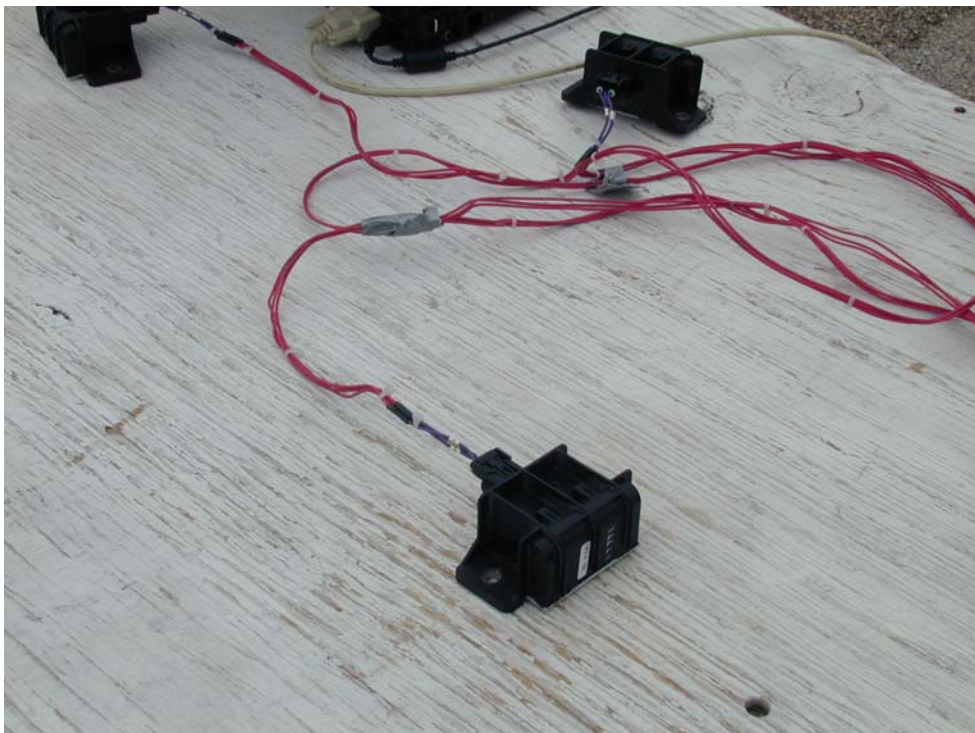


Figure 6.4. Relative emission at 135 kHz vs. supply voltage.



Appendix: DUT on OATS



Appendix: Close-up of the DUT on OATS