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Measured Radio Frequency Emissions
From

Lear Daimler-Chrysler WCM Immobilizer HB and LX Series

Report No. 415031-208
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For:
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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 Lear WCM HB and LX Immobilizer. This device is subject to Rules and Regulations as a transmitter. As a digital device it is exempt.

In testing performed March 18, 2004, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 24.5 dB (see p. 6).

The conductive emission tests do not apply, since the device is powered from an automotive 12-volt battery.

1. Introduction

Lear WCM Immobilizer 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, dated November 1, 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 Procedure and Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1 below. The second column identifies the specific equipment used in these tests. The HP 8593E spectrum analyzer is used for primary amplitude and frequency reference.

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)		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)		University of Michigan
Amplifier (5-1000 MHz)		Avantak, A11-1, A25-1S
Amplifier (5-4500 MHz)		Avantak
Amplifier (4.5-13 GHz)		Avantek, AFT-12665
Amplifier (6-16 GHz)		Trek
Amplifier (16-26 GHz)		Avantek
LISN (50 μH)		University of Michigan
Signal Generator (0.1-2060 MHz)		Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard

3. Configuration and Identification of Device Under Test

The DUT is a car security system that electronically identifies the "real" ignition key for the car. The system tested consisted of a T/R module (including coupling coil antenna) and a "passive" transponder imbedded in the key. The transponder in the key is considered passive because it uses the energy supplied by the transmitter coil to operate its micro and, hence, is not subject to the regulations. Also, the module contains a 315 MHz RKE receiver; this was tested and results reported in a separate report. The DUT was mounted on aluminum lock housing and its 0.5 m harness connected to a control/junction box. The 12-volt power supply was placed under the test table. A remote laptop was connected to the junction box to put the DUT in appropriate test mode.

The DUT was designed and manufactured by Lear Corporation, 5200 Auto Club Drive, Dearborn, MI 48126. It is identified as:

Lear WCM Immobilizer
Lear P/N: L0020343 AB (HB), L0020342 AB (LX), L0020359 AB (LX)
S/N: TGOCH283300326, TGTCH2273300460, TGSCH290300178, resp.
FCC ID: KOBDR05A
IC: 3521A-R05B

The HB and LX versions use the same PCB and electronics. Differences are only in plastic and lock housings. The HB version was tested completely; for LX version only the fundamental emission was measured.

3.1 EMI Relevant Modifications

None.

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* (μV/m)
0.009-0.490 0.490-1.705	2400/F(kHz), 300m 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) μV/m	E_{lim} dB(μV/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

The conductive emission limits and tests do not apply here, since the DUT is powered from an automobile 12VDC system.

5. Radiated Emission Tests and Results

5.1 Anechonic Chamber Measurements

To familiarize 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 Appendix Setup Photos. Using the loop antenna we studied emissions up to 2 MHz. The spectrum analyzer resolution and video bandwidths were set to 9 kHz/200 Hz, depending on measurement frequency. Emissions were studied with the plane of the loop perpendicular, parallel, and horizontal to the direction of propagation from the DUT. Usually larger emissions were observed when the loop was perpendicular. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections. In scanning from 0.0-2.0 MHz there were no spurious emissions observed, other than harmonics. In some instances, it was difficult to separate the DUT emissions from AM-band signals.

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 and video bandwidths were set to 9 kHz/200 Hz, depending on measurement frequency as defined in ANSI 63.4. See Appendix for photographs of measurement set-up. For digital emissions bicone or dipole antennas were used. See Section 6.6 for field extrapolation of data measured at 3 meters to 30 and 300 merer limits.

5.3 Computations and Results

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

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

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
C_F = conversion factor from measurement distance to limit distance, dB
K_E = pulse operation correction factor, dB (see 6.1)

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 24.5 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

In normal a operation the transmitter is activated when the ignition key is first turned on. The device then transmitts for about 478 ms. See Figure 6.1. The "worst case" avering factor occurs when the last pulse is included. The off time is 9 ms. The averaging factor for such is

$$K_E = 91 \text{ ms} / 100 \text{ ms} = 0.91 \text{ or } -0.8 \text{ dB}$$

6.2 Emission Spectrum

Using the loop antenna, the emission spectrum was recorded and is shown in Figure 6.2. Unfortunately, the measurement is contaminated by AM stations.

6.3 Bandwidth of the Emission Spectrum and Emissions in 0.090 – 0.110 MHz Restricted Band.

The measured spectrum of the signal is shown in Figure 6.3. From the plot we see that the -20 dB bandwidth is 7 kHz, the center requency is about 125.15 kHz, and the level in the Restricted Band is 36 dB below the peak.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be operated from an automobile 12VDC system. For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 5.5 to 18.0 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 12.3 V
I = 100 mA (during transmission)

6.6 Field Behavior from 125 kHz to 1.25 MHz

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 Analysys and Design, 1997 John Wiley & Sons, 2nd Edition, pg. 207-208. The applicable results that we need are:

Freq (kHz)	H-component	Extrap positions	Correction (dB)	Notes
125	Radial	3m/300m	117.9 dB	Axial coupling
125	Transverse	3m/300m	121.2 dB	Planar coupling
250	Radial	3m/300m	114.6 dB	Axial coupling
250	Transverse	3m/300m	113.4 dB	Planar coupling
375	Radial	3m/300m	111.9 dB	Axial coupling
375	Transverse	3m/300m	105.6 dB	Planar coupling
500	Radial	3m/30m	59.6 dB	Axial coupling
500	Transverse	3m/30m	60.6 dB	Planar coupling
625	Radial	3m/30m	59.4 dB	Axial coupling
625	Transverse	3m/30m	60.6 dB	Planar coupling
750	Radial	3m/30m	59.1 dB	Axial coupling
750	Transverse	3m/30m	60.8 dB	Planar coupling
875	Radial	3m/30m	58.9 dB	Axial coupling
875	Transverse	3m/30m	61.0 dB	Planar coupling
1000	Radial	3m/30m	58.6 dB	Axial coupling
1000	Transverse	3m/30m	61.2 dB	Planar coupling
1125	Radial	3m/30m	58.3 dB	Axial coupling
1125	Transverse	3m/30m	61.2 dB	Planar coupling
1250	Radial	3m/30m	57.9 dB	Axial coupling
1250	Transverse	3m/30m	61.2 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, whichever is applicable.

Table 5.1 Highest Emissions Measured

Transmitter Radiated Emissions											Lear WCM LX and HB Immob.; FCC/IC
N	Freq. MHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	E* dBμV/m	Elim* dBμV/m	Pass dB	Comments
1	0.1252	Loop	V/perp	-32.1	Pk	9.9	0.0	-33.9	25.7	59.6	loop perp. (axis in dir. of prop.)
1	0.1252	Loop	V/par	-32.8	Pk	9.9	0.0	-37.8	25.7	63.5	loop paral (loop in dir. of prop.)
1	0.1252	Loop	H	-31.9	Pk	9.9	0.0	-36.9	25.7	62.6	loop horiz (loop in horizontal plane)
2	0.2503	Loop	V/perp	-67.5	Pk	9.8	0.0	-66.1	19.6	85.7	background noise
2	0.2503	Loop	V/par	-76.7	Pk	9.8	0.0	-74.1	19.6	93.7	background noise
2	0.2503	Loop	H	-68.7	Pk	9.8	0.0	-66.1	19.6	85.7	background noise
3	0.3755	Loop	V/perp	-62.8	Pk	9.8	0.0	-58.7	16.1	74.8	signal
3	0.3755	Loop	V/par	-68.4	Pk	9.8	0.0	-58.0	16.1	74.1	signal
3	0.3755	Loop	H	-66.8	Pk	9.8	0.0	-56.4	16.1	72.5	signal
4	0.5006	Loop	V/perp	-78.1	Pk	9.8	0.0	-20.9	33.6	54.5	background noise
4	0.5006	Loop	V/par	-74.6	Pk	9.8	0.0	-18.4	33.6	52.0	background noise
4	0.5006	Loop	H	-74.2	Pk	9.8	0.0	-18.0	33.6	51.6	background noise
5	0.6258	Loop	V/perp	-78.2	Pk	9.8	0.0	-20.8	31.7	52.5	noise, background rf
5	0.6258	Loop	V/par	-61	Pk	9.8	0.0	- 4.8	31.7	36.5	noise, background rf
5	0.6258	Loop	H	-74.2	Pk	9.8	0.0	-16.5	31.7	48.2	noise, background rf
6	0.7509	Loop	All	-78.4	Pk	9.8	0.0	-20.7	30.1	50.8	noise, background rf
7	0.8761	Loop	All	-79.4	Pk	9.8	0.0	-21.5	28.8	50.3	noise, background rf
8	1.0012	Loop	All	-68.8	Pk	9.8	0.0	-10.6	27.6	38.2	noise, background rf
9	1.1264	Loop	All	-56.4	Pk	9.8	0.0	2.1	26.6	**24.5**	noise, background rf
10	1.2515	Loop	All	-74.4	Pk	9.8	0.0	-15.5	25.7	41.2	noise, background rf
	HB version:										
1	0.1252	Loop	V/perp	-34.5	Pk	9.9	0.0	-36.3	25.7	62.0	loop perp. (axis in dir. of prop.)
		* Averaging applies up 490 kHz, -0.8 dB in this case									
		Limit at 300m for f<0.490MHz; 30m for f>0.490MHz									
		Measurements made at 3m, see Sec.6.6 for extrapolation values									
		Usually 9kHz RBW used, sometimes lower to reduce ambient and rf noise									

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
		Meets class B limit by more than 20dB									

Meas.03/18/04; U of Mich.

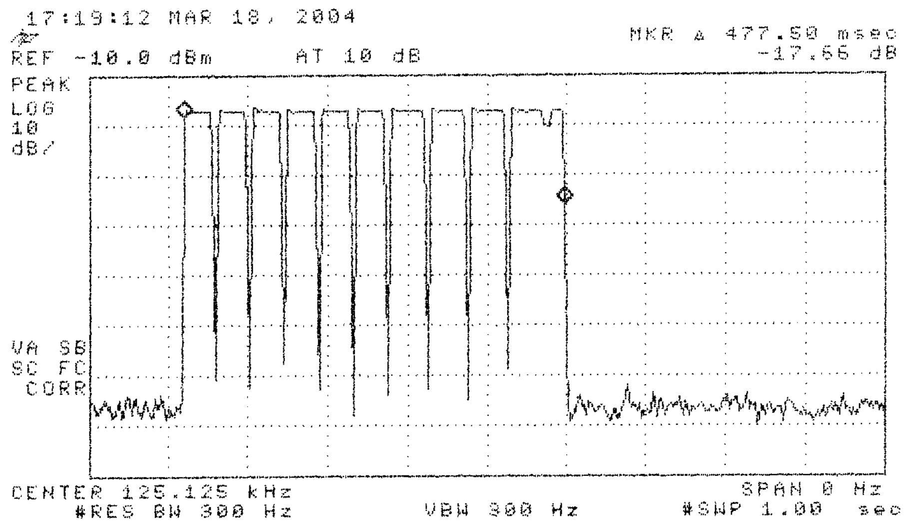


Figure 6.1. Transmission modulation characteristics.

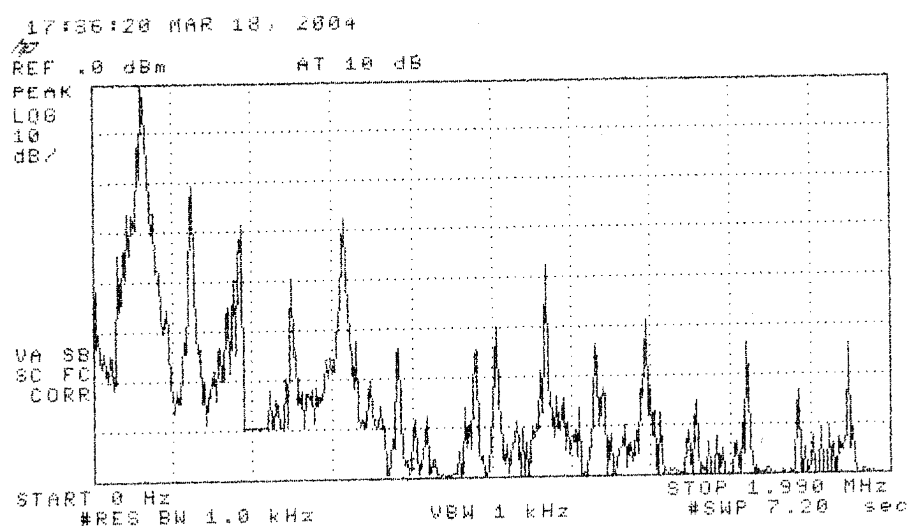


Figure 6.2. Emission spectrum of the DUT.
The amplitudes are only indicative (not calibrated).

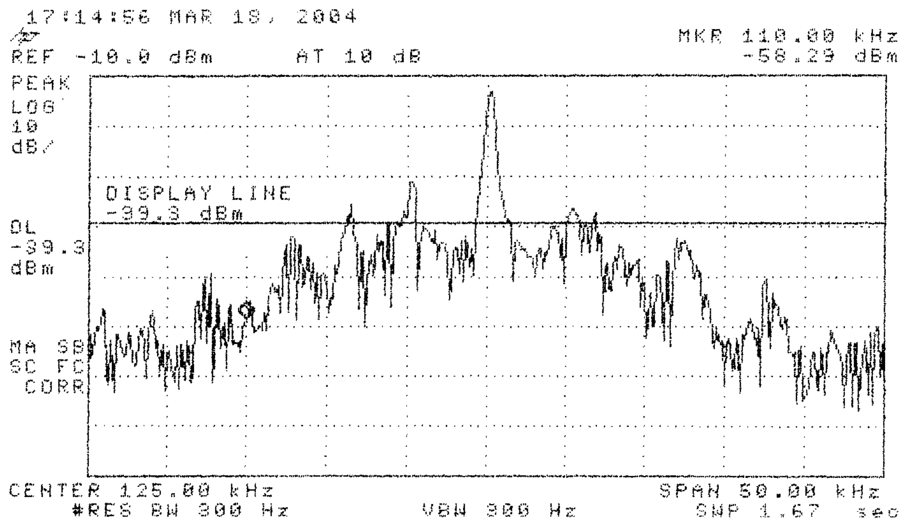


Figure 6.3. Measured bandwidth of the DUT. (repeated pulses)

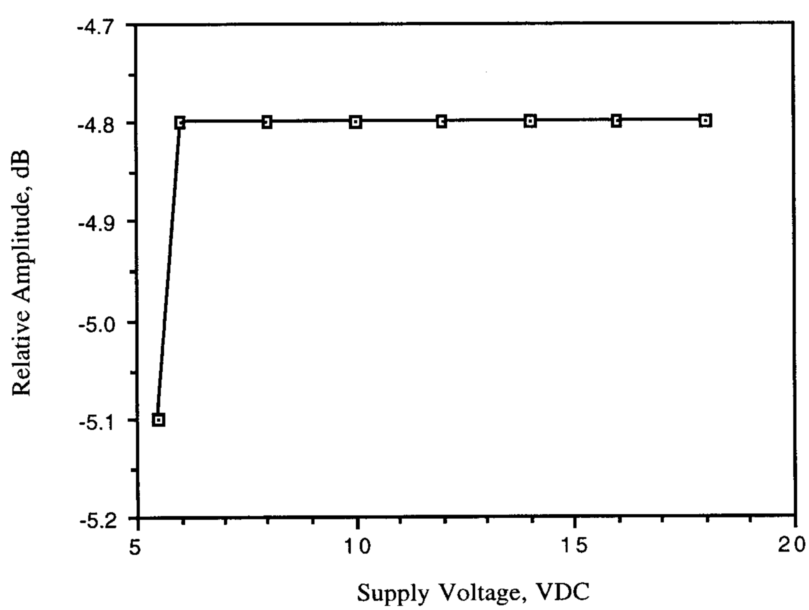
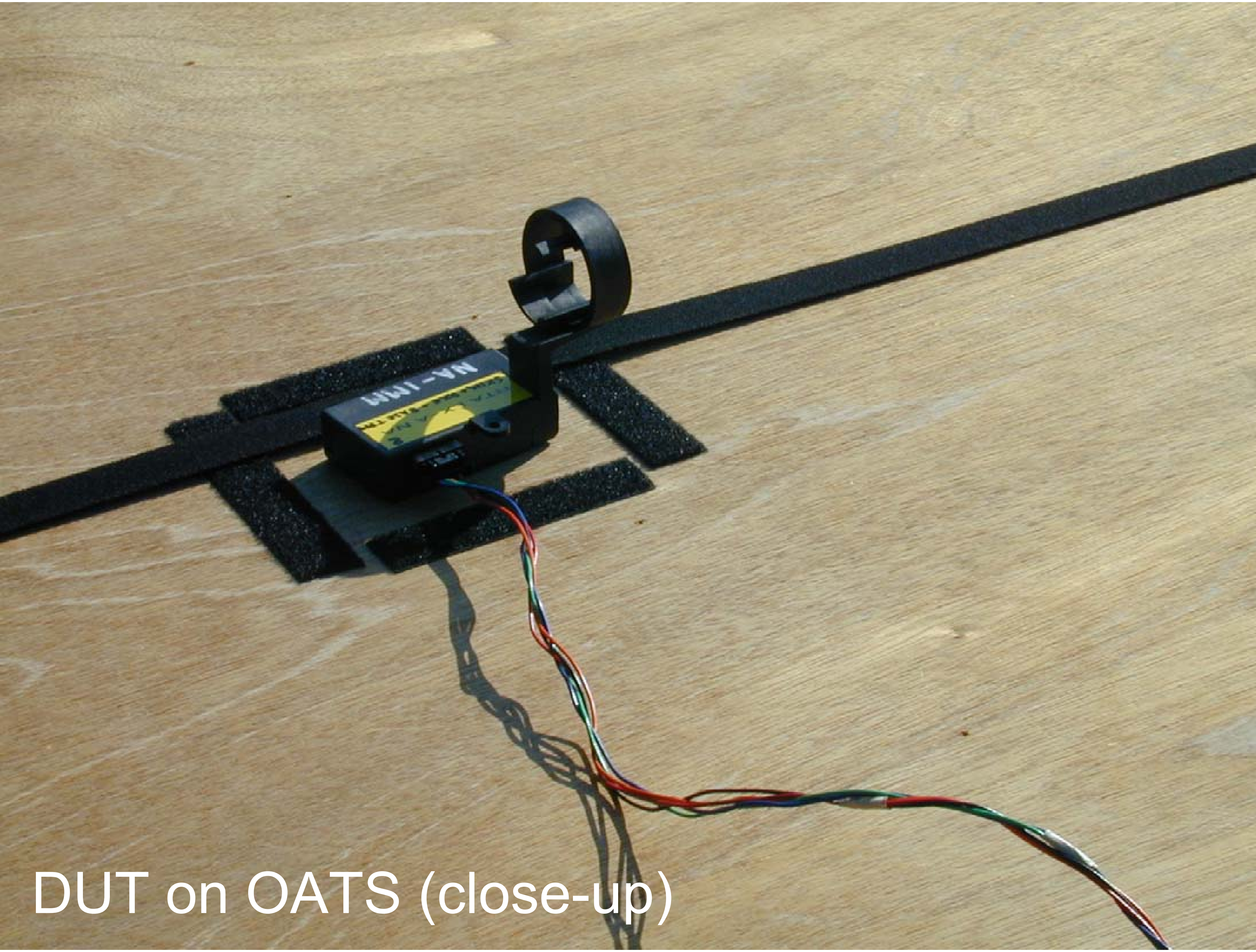


Figure 6.4. Relative emission at 125 kHz vs. supply voltage.


DUT on OATS



DUT on OATS (close-up)