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

Measured Radio Frequency Emissions
From

Lear RFA-X-05 315 MHz RKE Receiver

Report No. 415031-218
May 28, 2004

For:
Lear Corporation
5200 Auto Club Drive
Dearborn, Michigan 48126-9982

Contact:
Bruce Conner
e-mail: bconner@lear.com
Tel: 313-593-9801
Fax: 734-484-1389
PO: 167061

Measurements made by: Valdis V. Liepa

Tests supervised by:
Report approved by: Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations Part 15, Subpart B, and with Industry Canada Regulations, RSS-210, were performed on Lear 315 MHz Receiver. The device is subject to the Rules and Regulations as a Receiver. As a Digital Device it is exempt, but such measurements were made to assess the receiver's overall emissions.

In testing performed on May 18 and 28, 2004, the device tested in the worst case met the specifications for antenna conducted emissions by 37.8 dB (see p. 5) and for radiated emissions by 18.4 dB (see p. 6). Since the device is powered from an automotive 12-volt system, the line conductive regulation tests do not apply.

1. Introduction

Lear 315 MHz Receiver , Model RFA-X-05 , 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 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 Millimiter 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)		EMCO 6502, SN:2855
Ridge-horn Antenna (300-5000 MHz)		University of Michigan
Amplifier (5-1000 MHz)	X	Avantak, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	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)	X	Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard

3. Configuration and Identification of Device Under Test

The DUT is a 315.0 MHz superheterodyne receiver, designed for onboard automobile security/convenience applications, and as such, it is powered from an automotive 12-volt source. It is housed in a plastic case approximately 3 x 2 x 0.75 inches, having one multi-pin connector for power input and digital signal output, and another connector for an external antenna. Antenna conducted emission procedure was used for compliance determination. When testing for radiated emissions, a 3-meter long bundle of wires was used, containing power and control/signal lines. The receiver is IC based, having a synthesized VCO with the reference crystal frequency of 10.178 MHz, the VCO frequency of 651.4 MHz, and the LO frequency at 325.7 MHz. It was powered by a 12-volt laboratory power supply at 13.2 volts.

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

Lear RKE Receiver
Model: RFA-X-05
S/N: 040427GMX365RFI
FCC ID: KOBGR05A
IC: 3521A-R05A

In the production version of the Rx, the LO is pulsed to conserve the power consumption. The measurements were made in a pulsed mode; it just took longer to acquire the signal amplitudes.

3.1 Modifications Made

There were no modifications made to the DUT by this laboratory.

4. Emission Limits

For FCC the DUT falls under Part 15, Subpart B, "Unintentional Radiators". For Industry Canada the DUT falls under Receiver category and is subject to technical requirement of sections 7.1 to 7.4 in RSS-210. The pertinent test frequencies, with corresponding emission limits, are given in Tables 4.1 and 4.2 below.

4.1 Radiated Emission Limits

Table 4.1. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; IC: RSS-210, 7.3).

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

4.2 Conducted Emission Limits

Do not apply.

4.3 AntennaPower Conduction Limits
Pmax = 2 nW; for requency range see Table 4.1. (FCC: 15.111(a); IC: RSS-210, 7.2).

5. Emission Tests and Results

5.1 Anechoic Chamber Radiated Emission Tests
To familiarize with the radiated emission behavior of the DUT, it was studied and measured in the shielded anechoic chamber. In the chamber there is a set-up similar to that of an outdoor 3-meter site, with turntable, antenna mast, and a ground plane. Instrumentation includes spectrum analyzers and other equipment as needed.

To study and test for radiated emissions, the DUT was powered by a laboratory power supply. A 315 MHz CW signal was injected (radiated) from a nearby signal generator using a short wire antenna. The DUT was placed on the test table on each of its three axis. For each placement, the table was rotated to obtain maximum signal for vertical and horizontal emission polarizations. This sequence was repeated throughout the required frequency range.

In the chamber we studied and recorded all the emissions using a ridge-horn antenna, which covers 200 MHz to 5000 MHz, up to 2 GHz. In scanning from 30 MHz to 2.0 GHz, there were no spurious emissions observed other than the LO, the injection signal, and the LO harmonics. Figures 5.1 and 5.2 show emissions measured 0-1000 MHz and 1000-2000 MHz, respectively. These measurements are made with a ridge-horn antenna at 3m, with spectrum analyzer in peak hold mode and the receiver rotated in all orientations. The measurements up to 1000 MHz (Fig. 5.1) are used for initial evaluation only, but those above 1000 MHz (Fig. 5.2) are used in final assessment for the compliance.

5.2 Open Site Radiated Emission Tests
The DUT was then moved to the 3-meter Open Field Test Site where measurements were repeated up to 1000 MHz using a small bicone, or dipoles when the measurement is near the limit. The DUT was exercised as described in Sec. 5.1 above. The measurements were made with a spectrum analyzer using 120 kHz IF bandwidth and peak detection mode, and, when appropriate, using Quasi-Peak or average detection. When emissions are narrow band, as in a case of an LO, measurements may be made with a reduced RBW to help discriminate the emissions from ambient signals and noise. Test set-up photographs are in the Appendix (i.e., end of this report).

The emissions from digital circuitry were measured using a standard bicone. These results are noted in Table 5.1.

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

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

where P_R = power recorded on spectrum analyzer, dB, measured at 3m
K_A = antenna factor, dB/m
K_G = pre-amplifier gain, including cable loss, 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 the DUT meets the limit by 18.4 dB.

5.4 Conducted Emission Tests
These tests do not apply, since the DUT is powered from a 12-volt automotive system.

6. Other Measurements

6.1 Emission Spectrum Near Fundamental

The LO emissions are measured typically over 1 MHz span with and without injection signal. Here data were taken at antenna connector. A plot is shown in Figure 6.1.

6.2 Effect of Supply Voltage Variation

The DUT has been designed to operate from 12 VDC power. Using a spectrum analyzer, relative antenna conducted emissions were recorded at the LO frequency (651.4 MHz) as voltage was varied from 6.0 to 18.0 VDC. Figure 6.2 shows the emission variation.

6.3 Operating Voltage and Current

V = 12.3 VDC
I = 10.2 mADC

6.4 Antenna RF Power Conducted Measurements

These measurements are made by connecting a spectrum analyzer directly to the DUT antenna terminal and recording, in this case, the LO signal, its harmonics, and any other spurious signals. Using an LNA and some creative measuring techniques we were able to detect:

LO	325.70 MHz	-122.6 dBm	0.00000055 nW
2xLO	651.40 MHz	- 95.4 dBm	0.00028800 nW
3xLO	977.10 MHz	-124.4 dBm (noise)	0.00000037 nW
4xLO	1302.80 MHz	-104.7 dBm	0.00003400 nW
5xLO	1528.50 MHz	-117.8 dBm (noise)	0.00000170 nW
6xLO	1954.20 MHz	-114.1 dBm (noise)	0.00000390 nW
		Total	0. 00033 nW

This meets the 2nW limit by 37.8 dB. See Figure 6.1 for measurement example.

Table 5.1 Highest Emissions Measured

Radiated Emission - RF

Lear RFA-X-05 Rx; 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	325.7	SBic	H	-80.0	Pk	19.2	21.8	24.5	46.0	21.5	max. of all, noise floor
2	325.7	SBic	V	-79.7	Pk	19.2	21.8	24.8	46.0	21.2	max. of all, noise floor
3	651.4	SBic	H	-85.0	Pk	25.5	19.9	27.6	46.0	**18.4**	max. of all, noise; 10 kHz BW
4	651.4	SBic	V	-90.0	Pk	25.5	19.9	22.6	46.0	23.4	max. of all, noise; 10 kHz BW
5	977.1	SBic	H	-88.3	Pk	29.2	17.7	30.1	54.0	23.9	max. of all, noise; 10 kHz BW
6	977.1	SBic	V	-89.1	Pk	29.2	17.7	29.3	54.0	24.7	max. of all, noise; 10 kHz BW
7	1302.8	Horn	H	-71.0	Ave	20.4	28.0	28.4	54.0	25.6	max. of all, noise floor
8	1628.5	Horn	H	-70.0	Ave	20.6	28.0	29.6	54.0	24.4	max. of all, noise floor
9	1954.2	Horn	H	-70.5	Ave	20.8	28.2	29.1	54.0	24.9	max. of all, noise floor
10											
11											
12											
13											
14											
15											
16											
17											
18											

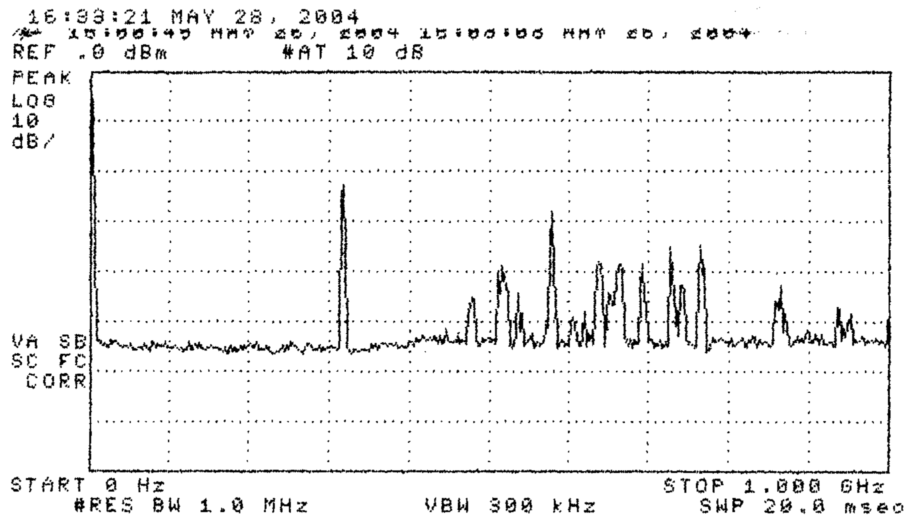
Radiated Emission - Digital (Class B)

#											
1											
2											
3	Digital Emissions more than 20 dB below FCC Class B limits										
4											
5											
6											
7											
8											
9											
10											
11											
12											

Conducted Emissions

#	Freq. MHz	Line Side	Det. Used	Vtest dBµV	Vlim dBµV	Pass dB	Comments
1							
2	Not applicable						
3							

Meas. 05/18, 28/04; U of Mich.



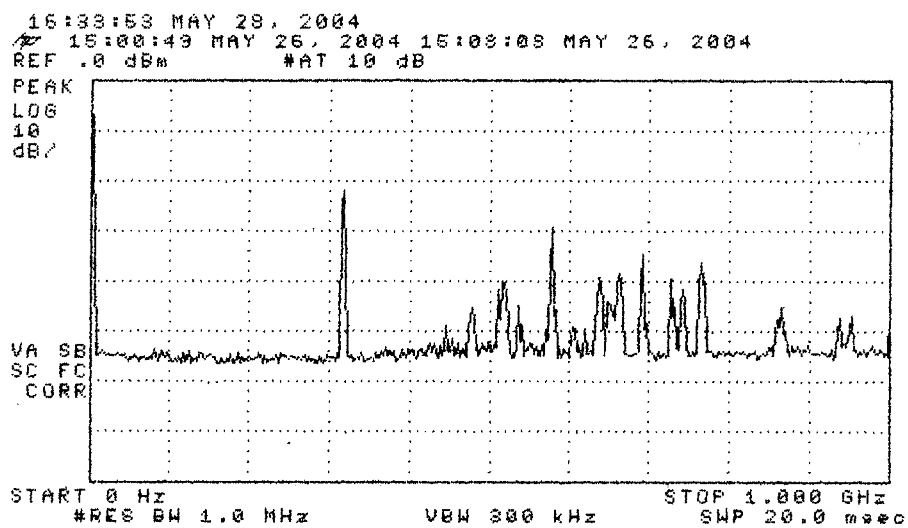
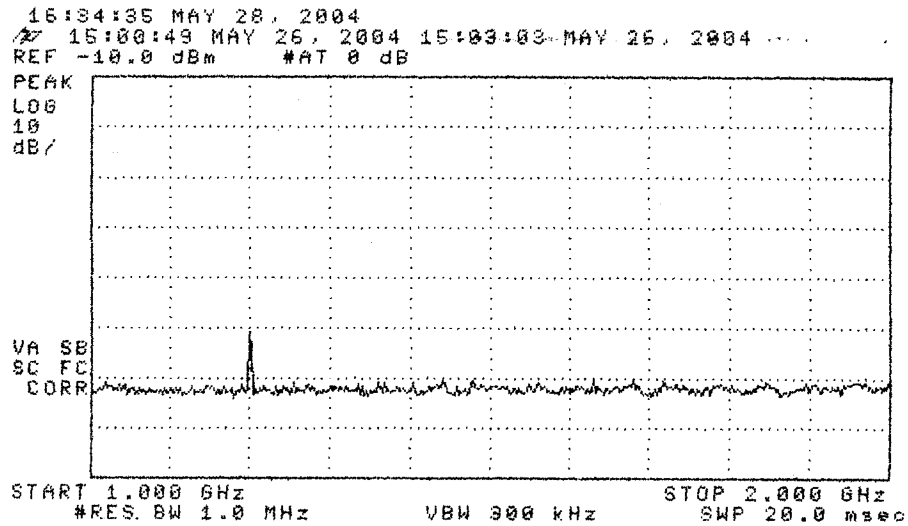


Figure 5.1. Emissions measured at 3 meters in anechoic chamber, 0-1000 MHz.
(top) Receiver plus ambient
(bottom) Ambient



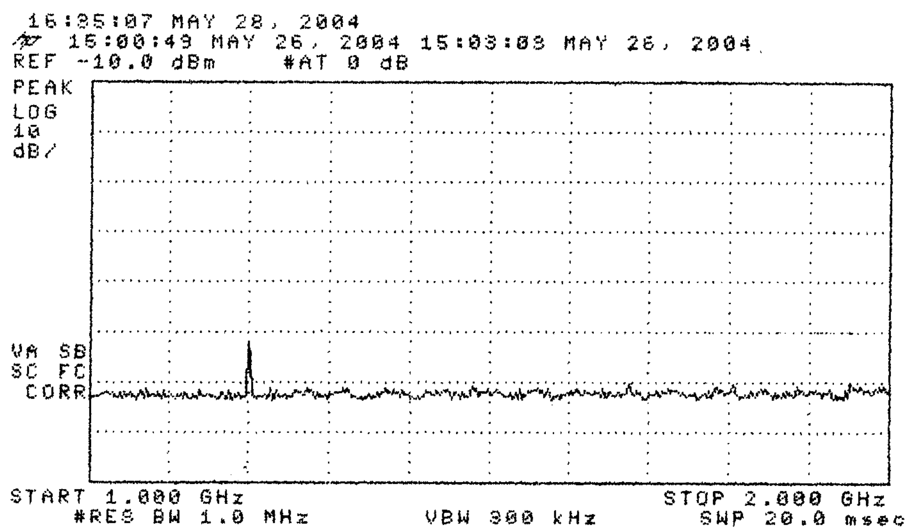


Figure 5.2. Emissions measured at 3 meters in anechoic chamber, 1000-2000 MHz.
(top) Receiver plus ambient
(bottom) Ambient

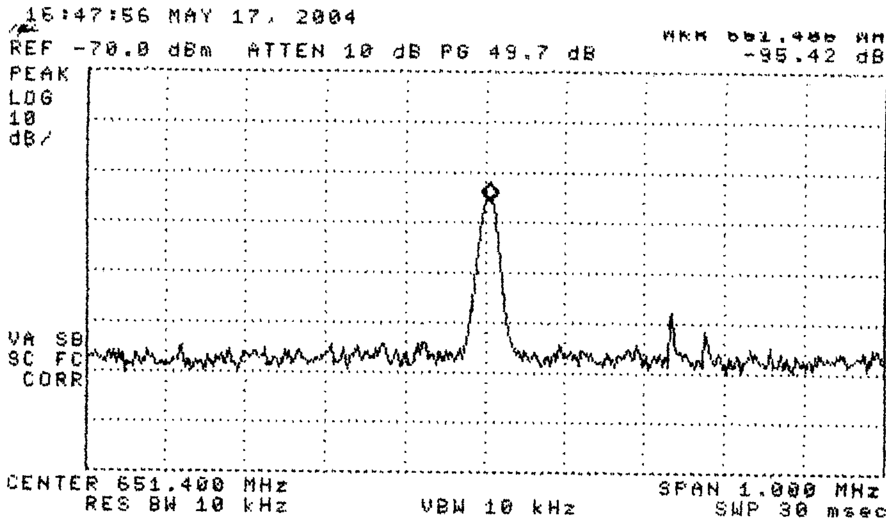


Figure 6.1. Receiver emission at VCO (2xLO). Conductive measurement.

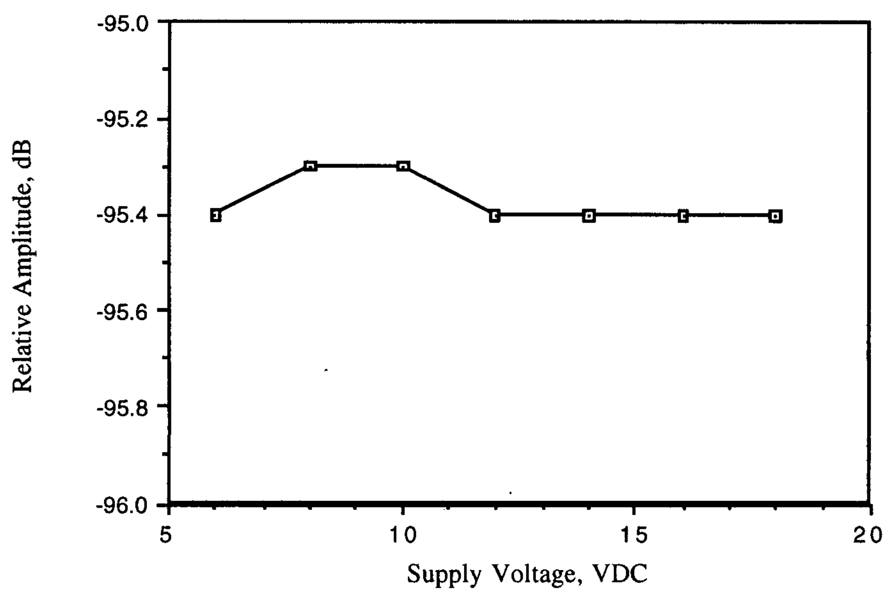
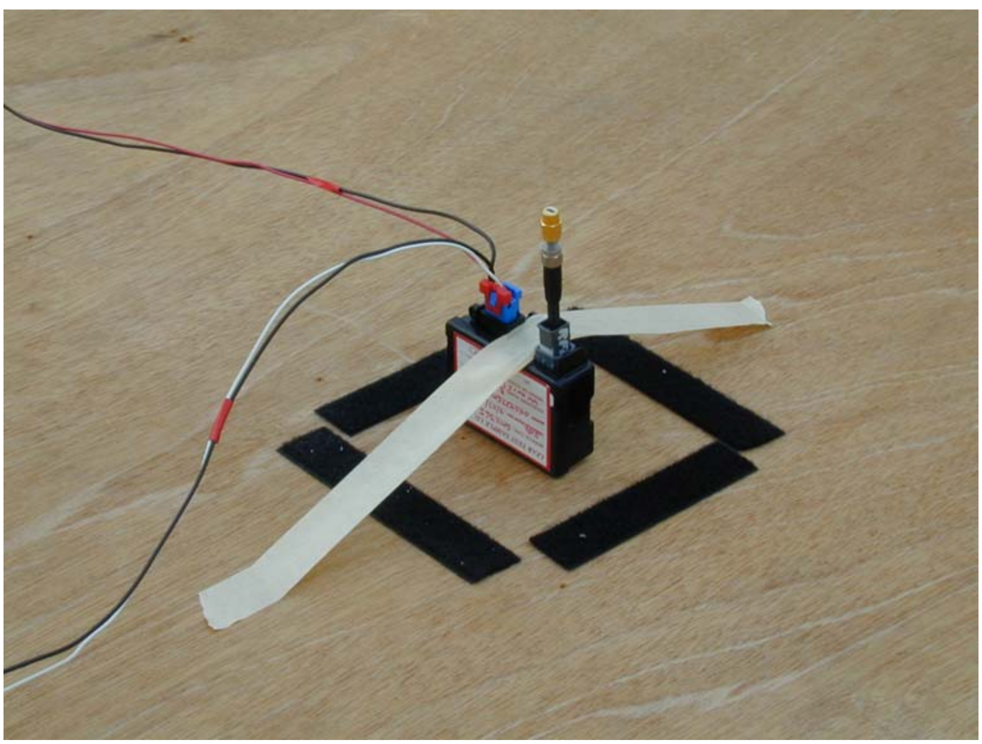


Figure 6.2. Relative emission at VCO (2xLO) vs. supply voltage.

Appendix: DUT on OATS



Appendix: Close-up of the DUT on OATS