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

Measured Radio Frequency Emissions From

Lear SKREEM 315 MHz RKE Transmitter

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

Contact:
Jason Summerford
e-mail: jsummerford@lear.com
Tel: 313-593-9293
Fax: 313-240-9306
PO: verbal

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 C, and for compliance with Industry Canada RSS-210, were performed on Lear RKE transmitter. This device is subject to the Rules and Regulations as a transmitter and as a digital device.

In testing performed on January 28 and February 5, 2003, the device tested in the worst case met the allowed specifications for radiated emissions by 1.0 dB at the fundamental and by 2.2 dB at the harmonics (see p. 6). Besides harmonics, there were no other significant spurious emissions found; emissions from digital circuitry were negligible. The line conducted emission tests do not apply, since the device is powered by a 3-volt battery.

1. Introduction

Lear RKE Skreem Transmitter 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)	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)		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)		Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard

3. Configuration and Identification of Device Under Test

The DUT is a hand held push-button low power RKE transmitter designed to send identification and control signals to a companion receiver. It also contains a "passive" 125 kHz Immobilizer transponder circuit used for identification, though there is also a depopulated version without the transponder. The transponder uses energy from the incident LF field, and does not generate new frequencies. The DUT is activated by depressing any of the buttons. When the transmitter is activated by momentary push, it transmits five words for about 560 ms. If the button is kept depressed, it will transmit up to 15 seconds. The emission is Manchester encoded format, ASK modulated on a 315.0 MHz carrier. The DUT was designed and manufactured by Lear Corporation, 5200 Auto Club Drive, Dearborn, MI 48126. It is identified as:

Lear Skreem RKE Transmitter
Model: Skreem (for IC use P/Ns)
S/N: none
FCC ID: KOBDT04A
IC: 3521A-T04B

There are a number of variants in the DUT. The same PCB is used on all. The variations are:

(1) Three and four button versions. The difference is only in the plastic and the number of push-buttons, (Three button was tested completely, four button for fundamental and the worst harmonic.)
(2) To avoid an unavailability of parts, three different SAW manufacturers are used. (Murata device was tested completely, Kyocera and Epcos for fundamental and the worst harmonic.)
(3) Version will be sold with depopulated LF transponder coil, i.e., no identifier function (A version was tested for fundamental and the worst harmonic.)

For harmonic emission measurements the devices were modified for CW operation by jumping pins 4 and 16 on the micro.

3.1 EMI Relevant Modifications

No modifications were made to the DUT by this laboratory.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices. For FCC, it is subject to Part 15, Subpart C, (Section 15.231), Subpart B, (Section 15.109), and Subpart A, (Section 15.33). For Industry Canada it is subject to RSS-210, (Sections 6.1 and 6.3). The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, the DUT is considered as a Class B device.

Table 4.1. 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)

Table 4.2. Radiated Emission Limits (FCC: 15.231(b), 15.205(a); IC: RSS-210; 6.1, 6.3). (Transmitter)

Frequency (MHz)	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
260.0-470.0	3750-12500*		375-1250	
322-335.4 399.9-410 608-614	Restricted Bands		200	46.0
960-1240 1300-1427 1435-1626.5 1660-1710 1718.9-1722.2 2200-2300	Restricted Bands		500	54.0

* Linear interpolation, formula: E = -7083 + 41.67*f (MHz)
** Measure up to tenth harmonic; 120 kHz BW up to 1 GHz, 1 MHz BW above 1 GHz

4.2 Conductive Emission Limits

The conductive emission limits and tests do not apply here, since the DUT is powered by one internal 3-volt battery.

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 testing for radiated emissions, the transmitter was modified for CW emission. It was placed on the test table flat, on its side, or on its end.

In the chamber we studied and recorded all the emissions using a bicone antenna up to 300 MHz and a ridged horn antenna above 200 MHz. The measurements made in the chamber below 1 GHz are used for pre-test evaluation only. The measurements made above 1 GHz are used in pre-test evaluation and in the final compliance assessment. We note that for the horn antenna, the antenna pattern is more directive and hence the measurement is essentially that of free space (no ground reflection). Consequently it is not essential to measure the DUT for both antenna polarizations, as long as the DUT is measured on all three of its major axis. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections. We also note that in scanning from 30 MHz to 4.4 GHz using bicone and the ridge horn antennas, there were no other significant spurious emissions observed.

5.2 Outdoor Measurements

After the chamber measurements, the emissions were re-measured on the outdoor 3-meter site at fundamental and harmonics up to 1 GHz using tuned dipoles and/or the high frequency bicone.

Photographs in Appendix (at end of this report) show the DUT on the open-site table (OATS).

5.3 Computations and Results

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

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

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
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 the DUT meets the limits by 1.0 dB at fundamental and by 2.2 dB at harmonics.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

When the transmitter is activated by a momentary push, it transmits five ASK encoded words. The first one is 120 bit pre-amble, followed by 112 bit (repeated) ID/control words. When a button is kept depressed, it transmits repeated words for up to 15 seconds. Manchester format coding is used: ones and zeros are encoded as low-high, high-low transitions. Thus all the bits are of same width. When a pulse appears wide, that is a result of two adjacent highs. See Fig. 6.1. Each bit is 0.2225 ms. The duty factor is thus,

$$K_E = (120 \times 0.2225\text{ms})/100\text{ms} = 0.267 \text{ or } -11.5 \text{ dB}.$$

6.2 Emission Spectrum

Using the ridge-horn antenna and DUT placed in its aperture, 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. The allowed (-20 dB) bandwidth is 0.25% of 315 MHz, or 787.25 KHz. From the plot we see that the -20 dB bandwidth is 65.0 kHz, and the center frequency is 315.02 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by 3 VDC battery. For this test, the battery was replaced by a laboratory variable power supply. Relative power radiated was measured at the fundamental as the voltage was varied from 2.0 to 3.5 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage at Battery Terminals

Batteries:	before testing	V_{oc}	=	3.215 V
	after testing	V_{oc}	=	3.091V
Ave. current from batteries		I	=	6.5 mA (CW)

6.6 Verification for Deactivation Within 5 Seconds

When a button is depressed, the DUT transmits up to about 15 seconds. When the button is released, the transmission essentially ceases at that time. Figure 6.5 shows emission when the DUT button is depressed and released; the emission is less than five seconds.

Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Lear Skreem 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	315.0	Dip	H	-19.3	Pk	18.9	21.3	73.8	75.6	1.8	flat; 3-button with LF, Murata
2	315.0	Dip	V	-22.4	Pk	18.9	21.7	70.3	75.6	5.3	side
3	630.0	Dip	H	-69.3	Pk	25.2	18.4	33.0	55.6	22.6	flat
4	630.0	Dip	V	-75.0	Pk	25.2	18.4	27.3	55.6	28.3	side
5	945.0	Dip	H	-73.9	Pk	28.9	16.0	34.5	55.6	21.1	side
6	945.0	Dip	V	-77.0	Pk	28.9	16.0	31.4	55.6	24.2	end
7	1260.0	Horn	H	-36.3	Pk	20.4	28.1	51.5	55.6	4.1	flat
8	1575.0	Horn	H	-49.2	Pk	21.4	28.2	39.5	54.0	14.5	flat
9	1890.0	Horn	H	-44.2	Pk	22.1	28.1	45.3	55.6	10.3	flat
10	2205.0	Horn	H	-65.9	Pk	22.9	27.0	25.5	54.0	28.5	flat
11	2520.0	Horn	H	-57.8	Pk	24.0	26.6	35.1	55.6	20.5	flat
12	2835.0	Horn	H	-56.6	Pk	24.9	25.4	38.4	54.0	15.6	end
13	3150.0	Horn	H	-56.0	Pk	25.2	24.8	39.9	55.6	15.7	flat
14											
15											
16	Other variations of DUT (see Sec. 3)										
17	315.0	Dip	H	-20.6	Pk	18.9	21.3	72.5	75.6	3.1	flat; 3-button w/ LF, Kyocera
18	1260.0	Horn	H	-36.0	Pk	20.4	28.1	51.8	55.6	3.8	flat
19	315.0	Dip	H	-18.8	Pk	18.9	21.3	74.3	75.6	1.3	flat; 3-button w/ LF, Epcos
20	1260.0	Horn	H	-36.1	Pk	20.4	28.1	51.7	55.6	3.9	flat
21	315.0	Dip	H	-18.5	Pk	18.9	21.3	74.6	75.6	1.0	flat; 3-button w/o LF, Murata
22	1260.0	Horn	H	-34.4	Pk	20.4	28.1	53.4	55.6	2.2	flat
23	315.0	Dip	H	-18.7	Pk	18.9	21.3	74.4	75.6	1.2	flat; 4-button w/ LF, Murata
24	1260.0	Horn	H	-37.2	Pk	20.4	28.1	50.6	55.6	5.0	flat
25		* Includes 11.5 dB duty factor									

Digital 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
1			Digital emissions are more than 20 dB below FCC Class B limit								
2											

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

Meas. 01/28,02/05/03; U of Mich.

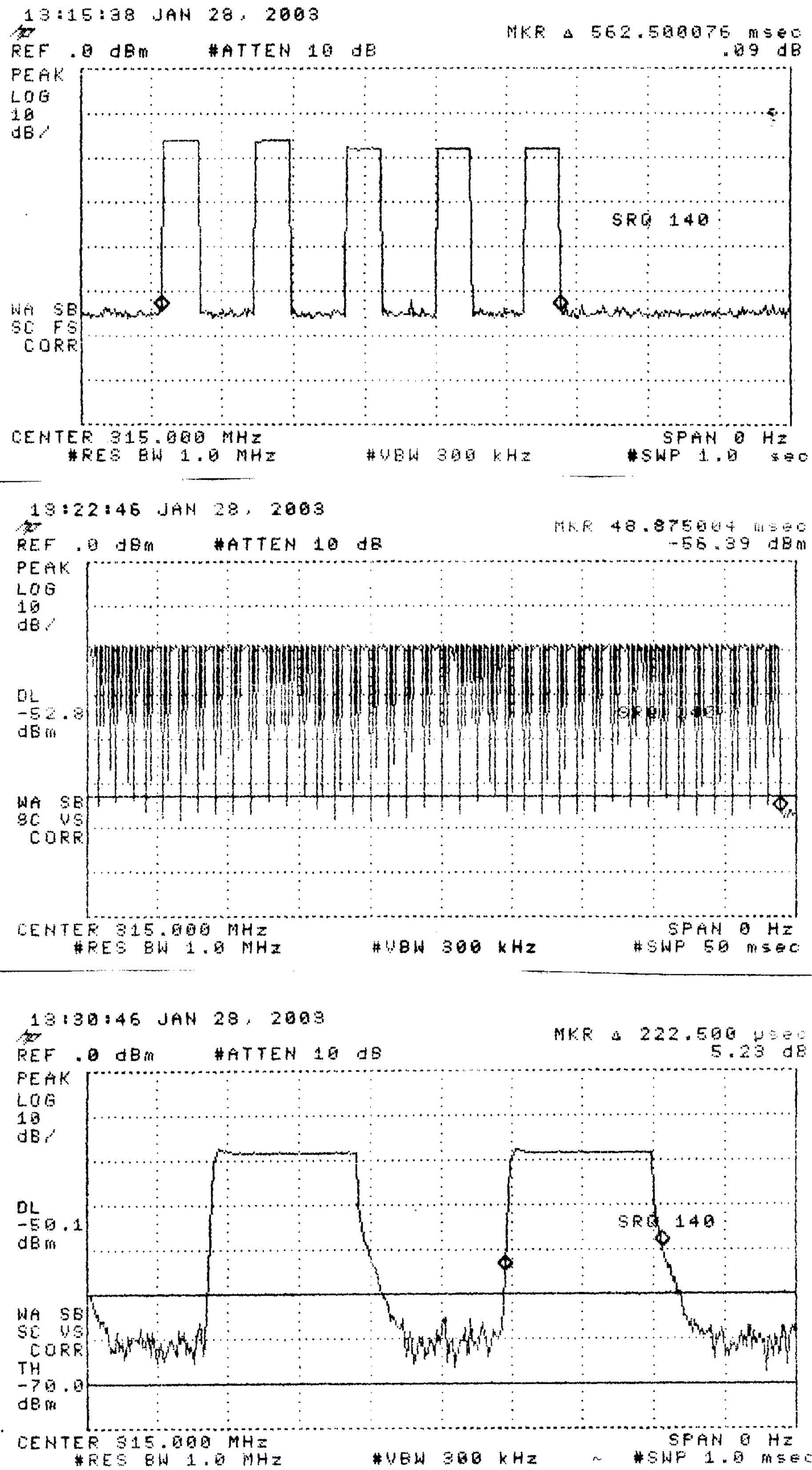


Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (center) expanded word, (bottom) expanded bits.

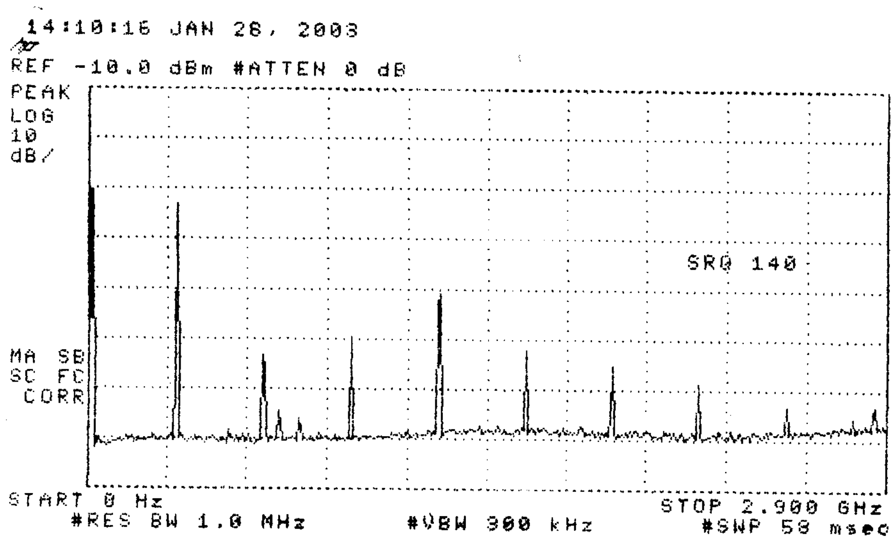


Figure 6.2. Emission spectrum of the DUT (CW emission).
The amplitudes are only indicative (not calibrated).

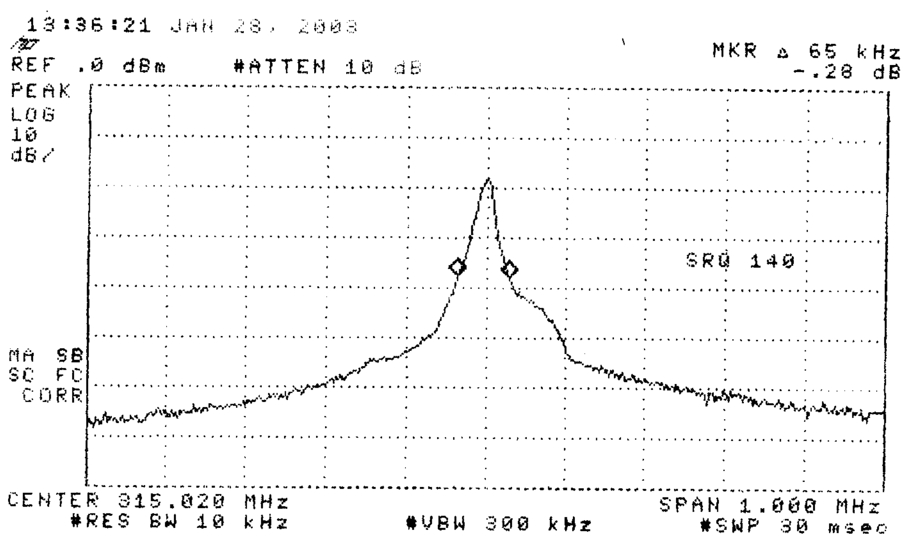


Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

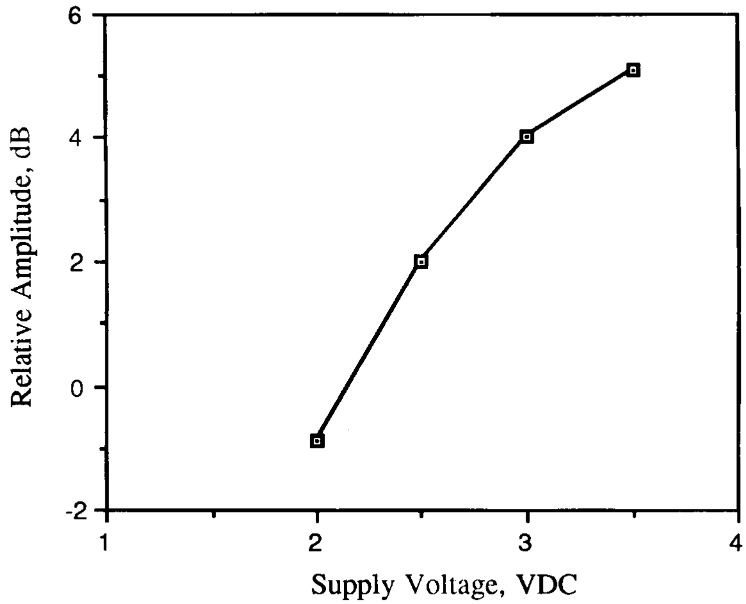


Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage (CW emission).

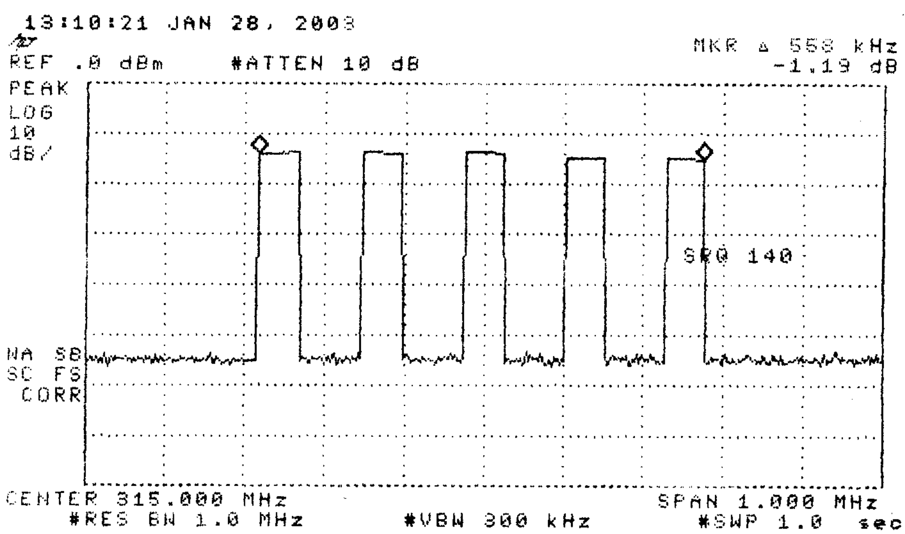
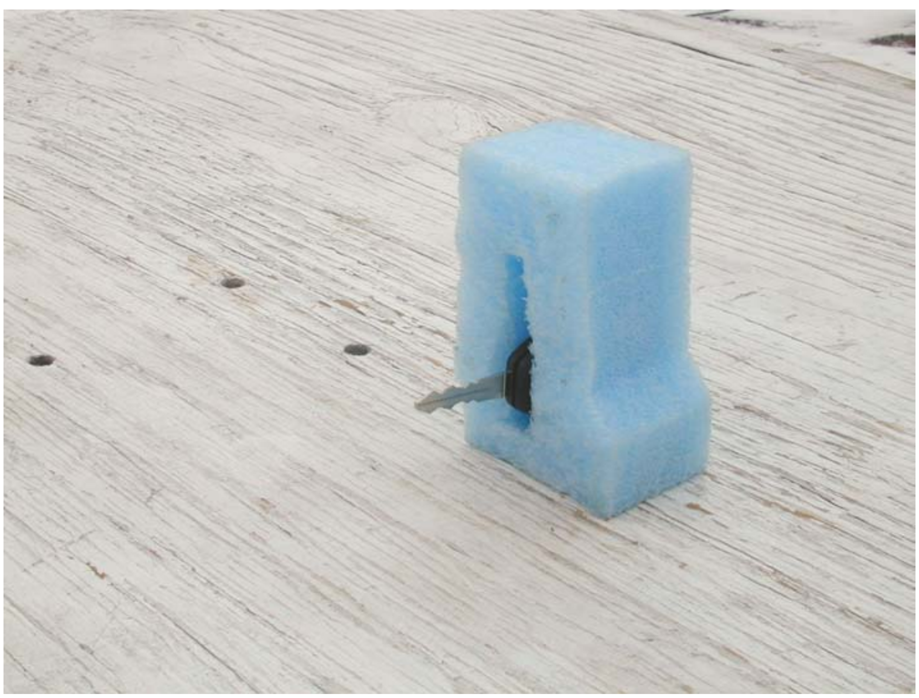


Figure 6.5. Emission after the DUT button is released.

Appendix: DUT on OATS



Appendix: Close-up on the DUT on OATS