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Measured Radio Frequency Emissions
From

Siemens TG1A+ Tire Pressure Monitoring Transmitter
Model: S120092001

Report No. 415031-166
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For:
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Summary

Tests for compliance with FCC Regulations, Part 15, and with Industry Canada, RSS-210, were performed on Siemens Tire Pressure Monitoring Transmitter. This device is subject to Rules and Regulations as a low power (data) transmitter. As a Digital Device it is exempt, but such measurements we routinely perform to assess the transmitters's overall emissions.

The Sensor was tested "in free space", i.e., without a tire and off the rim. In testing performed on April 14 and 29, 2003, the device tested in the worst case met the limits for radiated emissions by 6.2 dB (see p. 6). Besides harmonics there were no other significant spurious emissions found.

No conductive emission tests were made, since the transmitter is powered by a 3V internal lithium battery.

1. Introduction

Siemens Tire Pressure Monitoring 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. 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 (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)	X	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 6.0 x 7.0 x 1.5 cm in size (including valve stem) potted tire pressure sensor/transmitter that mounts on a rim inside the tire. When the vehicle is in motion, it transmits the tire pressure information to the receiver in the vehicle. Normal transmission consists of four encoded words, lasting about 0.55 s, and repeated typically every 60 seconds. For this the wheel must be rotating and the device pressurized. For factory testing, installation testing, etc., the device has been designed to be activated also by a 125 kHz signal. In the transmission, the first word is wake-up and is ASK modulated; the next three words are repeated data id/words and are FSK modulated.

The DUT was designed and manufactured by Siemens. It is identified as:

Siemens Tire Pressure Monitoring Transmitter
Model: S120092001
Type: TG1A+
FCC ID: KR5S120092001
IC: 267T-20092001

Two devices were provided. Both were modified for testing in software and are activated by application of 125 kHz signal. One sample was modified for CW emission (SN: 073775) that last about 2 min. after activation with LF. This device was used for emission measurements. The other sample was for normal transmission (four words) after activation with LF. This was used for duty factor and occupied bandwidth measurements.

3.1 EMI Relevant Modifications

There were no modifications 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 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 a Class B device.

Table 4.1 Radiated Emission Limits (FCC: 15.231(e); IC: RSS-210; 6.1, 6.3, Table 4). Data transmission.

Frequency (MHz)	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
260-470	1500-5000*		150-500	
315	2418	67.7	241.8	47.7

* Linear interpolation, formula: E = -2833.2 + 16.67*f (MHz)
** Measure up to tenth harmonic; 120 kHz BW up to 1 GHz, 1 MHz BW above 1 GHz

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

4.2 Conductive Emission Limits

The conductive emission limits and tests do not apply here, since the DUT is powered by a 3 V internal lithium battery.

5. Radiated Emission Tests and Results

5.1 Anechoic Chamber Measurements

To familiarize with the radiated emission behavior of the DUT, the DUT was first studied and measured in a semi-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 the chamber we studied and recorded all the emissions using a ridged horn antenna up to 3.15 GHz. The measurements made in the chamber below 1 GHz are used for pre-test evaluation only. The measurements made above 1 GHz are also used in pre-test evaluation and in 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). 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 3.15 GHz, 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 in site test 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 6.2 dB at fundamental and by 15.8 dB at harmonics.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

Normally the transmitter is activated by rotation of the wheel and transmits approximately once every minute. The transmission consists of an ASK wake-up, followed by three FSK data words. The transmission lasts about 55 ms. Each of the words lie in its own 100 ms window; we shall analyze the wake-up and the data word for the duty factors. The wake-up is 45 ms long, consisting of 12 pulses that have 16 pulses within the pulse. The first of the 12 pulses has a wider first pulse (0.1075 ms), then all are followed by 0.055 ms pulses. Thus the duty factor for the wake-up is:

$$((1 \times 0.1075 + 15 \times 0.055) + 11 \times (16 \times 0.055))/100 = 0.09769 \text{ or } -20.2 \text{ dB}$$

For the FSK 10.5 ms data word the duty factor is:

$$10.5/100 = 0.105 \text{ or } -19.6 \text{ dB}$$

Use −19.6 dB for compliance computations.

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 315.0 MHz, or 786 kHz, and from the plot we see that the -20 dB bandwidth is 170.0 kHz, and the center frequency is 314.990 MHz.

6.4 Effect of Supply Voltage Variation

The DUT has been designed to be powered by a single 3 V battery. For this test, the battery was parallelled by a laboratory variable power supply and relative power radiated was measured at the fundamental as the voltage was varied from 2.0 to 3.6 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current at Battery Terminals

V start = 3.03V

V stop = 2.94V

I = 3.5 mA at 3.0V (CW)

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Siemens/Mazda TPS; 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	-25.2	Pk	18.9	19.6	61.5	67.7	**6.2**	flat
2	315.0	Dip	V	-30.0	Pk	18.9	19.6	56.7	67.7	11.0	end
3	630.0	Dip	H	-74.1	Pk	25.2	16.2	22.3	47.7	25.4	flat
4	630.0	Dip	V	-73.6	Pk	25.2	16.2	22.8	47.7	24.9	end
5	945.0	Dip	H	-77.0	Pk	28.9	13.8	25.4	47.7	22.3	flat
6	945.0	Dip	V	-78.6	Pk	28.9	13.8	23.8	47.7	23.9	side
7	1260.0	Horn	H	-55.9	Pk	20.4	28.1	23.8	54.0	30.2	end
8	1575.0	Horn	H	-58.8	Pk	21.4	28.2	21.8	54.0	32.2	flat
9	1890.0	Horn	H	-43.2	Pk	22.1	28.1	38.2	54.0	15.8	flat
10	2205.0	Horn	H	-45.8	Pk	22.9	27.0	37.5	54.0	16.5	flat
11	2520.0	Horn	H	-64.1	Pk	24.0	26.6	20.7	54.0	33.3	side
12	2835.0	Horn	H	-59.4	Pk	24.9	25.4	27.5	54.0	26.5	flat
13	3150.0	Horn	H	-64.8	Pk	25.2	24.8	23.0	54.0	31.0	end
14											
15											
16											
17											
18			* Used -19.6 dB duty factor								
19			Measurements made in CW mode.								
20											
21											
22											
23			Digital emissions more than 20 dB below Class B limit								
24											
25											
26											
27											

Conducted Emissions							
#	Freq. MHz	Line Side	Det. Used	Vtest dBµV	Vlim dBµV	Pass dB	Comments
1							
2	Not applicable						
3							
4							
5							
6							
7							

Meas. 04/14/03 U of Mich.

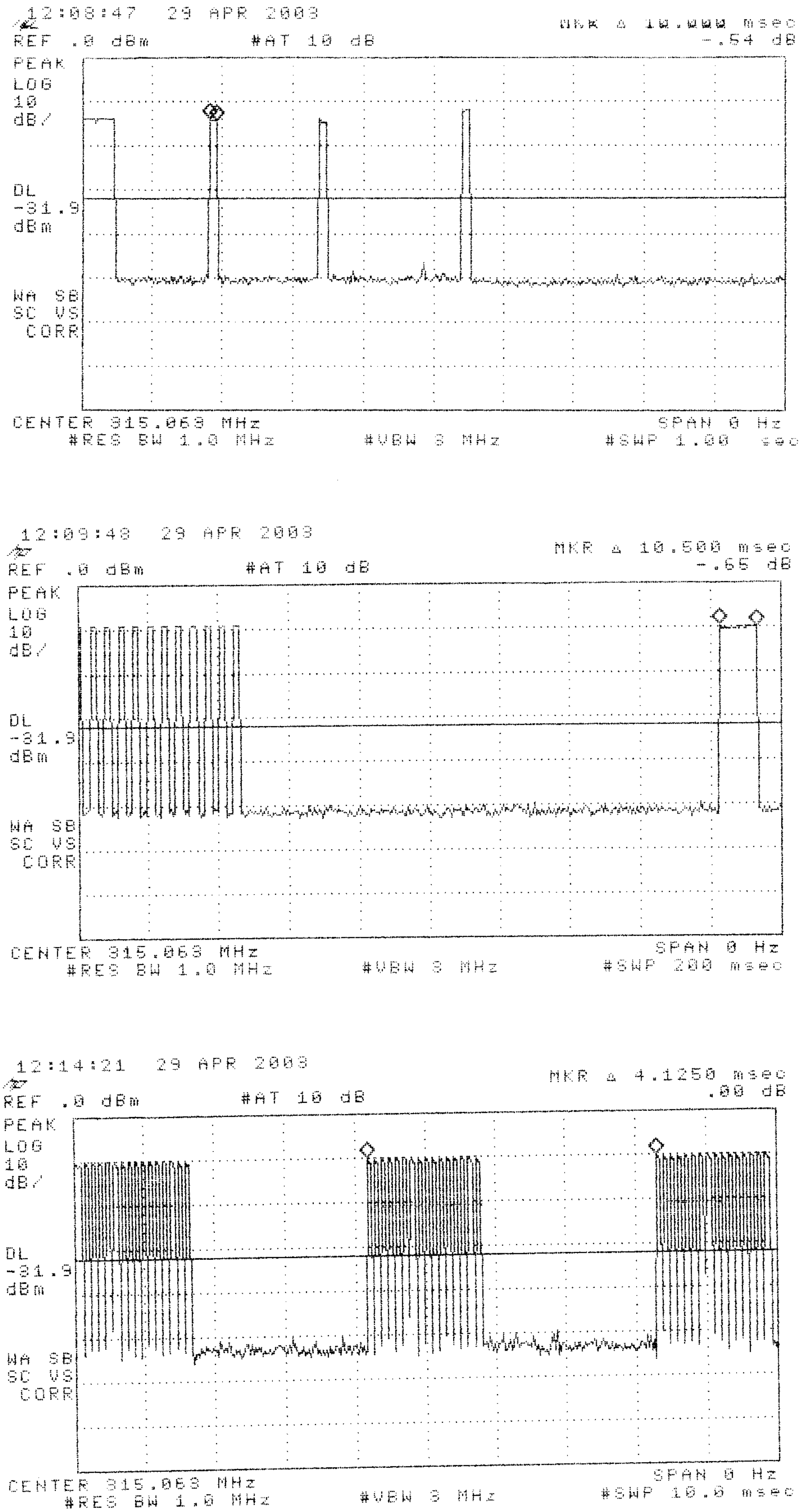


Figure 6.1. Transmissions modulation characteristics: (top) total transmission, (center) wake-up and data, (bottom) expanded wake-up.

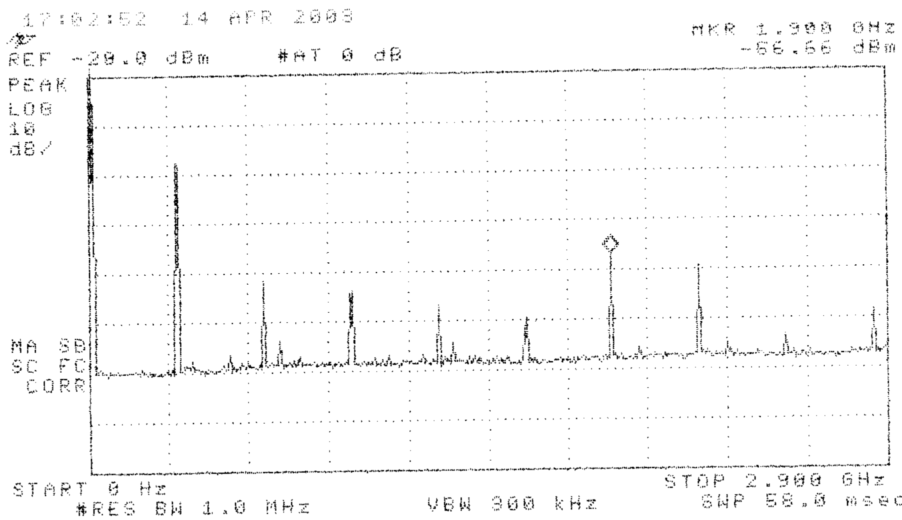


Figure 6.2. Emission spectrum of the DUT in free space (CW emission). The amplitudes are only indicative (not calibrated).

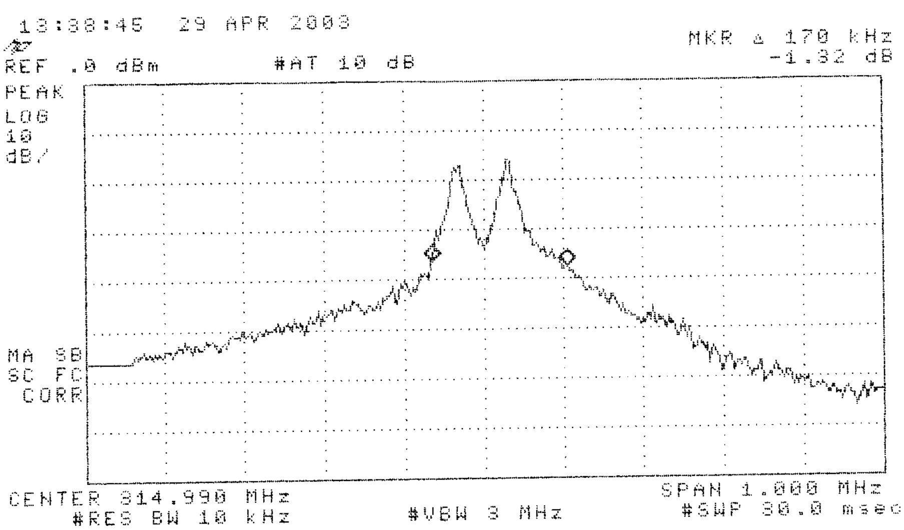


Figure 6.3. Measured bandwidth of the DUT (repeated pulsed emission).

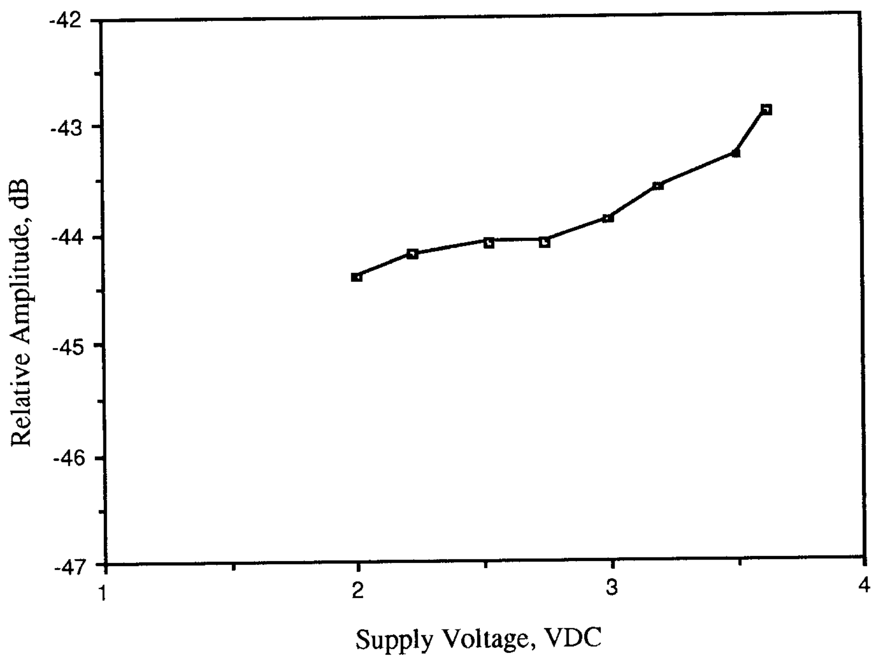
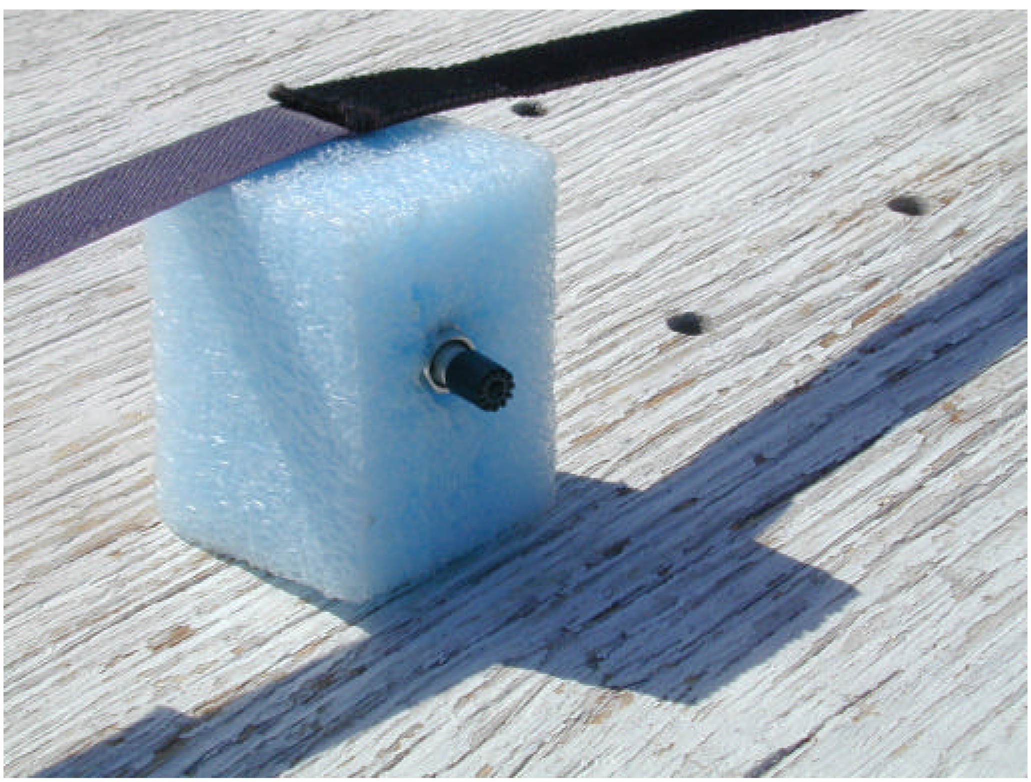


Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage. (CW emission)

Appendix: DUT on OATS



Appendix: Close-up of the DUT on OATS