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Measured Radio Frequency Emissions
From

TRW Transmitter
Model(s): 42607-0C030 (20 degree bend), 42607-0C040 (40 degree bend)

Report No. 415031-310
June 26, 2006

For:
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Summary

Tests for compliance with FCC Regulations Part 15, Subpart C, and Industry Canada RSS-210, were performed on TRW model(s) 42607-0C030 (20 degree), 42607-0C040 (40 degree). This device is subject to the Rules and Regulations as a Transmitter.

In testing completed on June 21, 2006, the device tested in the worst case met the allowed FCC specifications for radiated emissions by 2.8 dB (see p. 6). Besides harmonics, there were no other significant spurious emissions found; emissions from digital circuitry were negligible. The conducted emission tests do not apply, since the device is powered from a 12 VDC battery.

1. Introduction

TRW model 42607-0C030 (20 degree), 42607-0C040 (40 degree) was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989 as subsequently amended, and with Industry Canada RSS-210/Gen, Issue 6, September 2005. The tests were performed at the University of Michigan Radiation Laboratory Willow Run Test Range following the procedures described in ANSI C63.4-2003 "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 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)		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 Box		University of Michigan
Signal Generator		Hewlett-Packard 8657B

3. Configuration and Identification of Device Under Test

The DUT is a 315 MHz TPMS, Tire Pressure Monitor Sensor (transmitter), 2.5 x 0.75 x 3 inches in size, and is FSK modulated. The transmitter consists of an RF MMIC that is stabilized by a 9.84 MHz crystal. The stem and PCB are used as the antenna. The DUT periodically transmits tire pressure data and is subject to FCC part 15.231(e) emissions limits. The device is also capable of being automatically actuated (via LF interrogation) by trained service personnel, and (per FCC correspondence) those modes fall under FCC part 15.231(a)(5). The DUT was designed and manufactured by TRW, 24175 Research Drive, Farmington Hills, MI 48335-2642. It is identified as:

TRW TPMS Transmitter
Model(s): 42607-0C030, 42607-0C040
FCC ID: GQ4-32T
IC: 1470A-13

There are two versions of the DUT, one with a 20 degree bend between the tire stem and the PCB and one with a 40 degree bend between the stem and the PCB. All electronic components are identical. The DUT with the 20 degree stem demonstrated the highest fundamental output power, and was fully tested. The worst case emissions from the other model are reported. Figure 6.1 demonstrates compliance with 15.231(a)(2) and (5); the transmission protocol in both modes is the same.

3.1 Modifications Made

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

4. 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.

4.1 Radiated Emission Limits

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(e), 15.205(a); IC: RSS-210; 2.7 Table 5). (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	1500-5000*		150-500	
315.0	2418	67.7	241.8	47.7
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 = -2833.2 + 16.67*f (MHz)
** Measure up to tenth harmonic; 120 kHz RBW up to 1 GHz, 1 MHz RBW above 1 GHz

4.3 Conducted Emissions Limits
The conductive emission limits and tests do not apply here, since the DUT is powered by a 12 VDC battery.

5. Radiated Emission Tests and Results

5.1 Semi-Anechoic Chamber Measurements
To familiarize with the radiated emission behavior of the DUT, the DUT was first studied and measured in a shielded semi-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, a transmitter was provided by the manufacturer that is capable of repeated pulse emissions. 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 4.5 GHz using Bicone and the ridge horn antennas, there were no other significant spurious emissions observed.

5.2 Open Site Radiated Emission Tests
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 included in this filing show the DUT on the Open Area Test Site (OATS).

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 2.8 dB.

5.4 Conducted Emission Tests
These tests do not apply, since the DUT is powered from a 12 VDC battery.

6. Other Measurements

6.1 Correction For Pulse Operation
When the transmitter is activated (either by LF pulse or motion), it can, in the worst case, transmit two 7.95 ms pulses of encoded FSK data in any given 100 ms window. See Figure 6.1. Computing the duty factor results in:

$$K_E = (2 \times 7.95 \text{ ms}) / 100 \text{ ms} = 0.159 \text{ or } -16.0 \text{ dB}.$$

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 MHz, or 787.25 kHz. From the plot we see that the -20 dB bandwidth is 133 kHz, and the center frequency is 315 MHz.

6.4 Effect of Supply Voltage Variation
The DUT has been designed to be powered by a 12 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 to 4 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage at Battery Terminals

Batteries:	before testing	V_{oc} =	3.2 V
	after testing	V_{oc} =	3.0 V
Ave. current from batteries		I =	8.5 mA (cw)

Table 5.1 Highest Emissions Measured

Radiated Emission - RF											TRW Toyota TPM; 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	-28.1	Pk	18.9	22.6	59.2	67.7	**8.5**	flat (20 deg. stem)
2	315.0	Dip	V	-33.1	Pk	18.9	22.6	54.2	67.7	13.5	end
3	630.0	Dip	H	-58.9	Pk	25.2	19.6	37.7	47.7	10.0	flat
4	630.0	Dip	V	-56.8	Pk	25.2	19.6	39.8	47.7	7.9	end
5	945.0	Dip	H	-74.3	Pk	28.9	17.7	27.9	47.7	19.8	flat
6	945.0	Dip	V	-74.2	Pk	28.9	17.7	28.0	47.7	19.7	end
7	1260.0	Horn	H	-44.7	Pk	20.6	28.0	38.9	54.0	15.1	flat
8	1575.0	Horn	H	-42.7	Pk	21.5	28.0	41.8	54.0	12.2	end
9	1890.0	Horn	H	-34.1	Pk	22.2	28.0	51.1	54.0	**2.9**	flat
10	2205.0	Horn	H	-39.3	Pk	23.0	28.1	46.6	54.0	7.4	end
11	2520.0	Horn	H	-41.4	Pk	23.9	28.3	45.2	54.0	8.8	flat
12	2835.0	Horn	H	-54.1	Pk	24.8	28.2	33.5	54.0	20.5	flat
13	3150.0	Horn	H	-59.2	Pk	25.8	27.9	29.7	54.0	24.3	flat
14											
15											
16											
17	1890.0	Horn	H	-34.0	Pk	22.2	28.0	51.2	54.0	**2.8**	flat (40 deg. stem)
18											
19											
20											
21											
22											
23											
24	* Includes 16.0 dB duty factor										
25											
26	Digital emissions more than 20 dB below FCC/IC Class B Limit.										
27											

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

Meas. 05/05,10/2006; U of Mich.

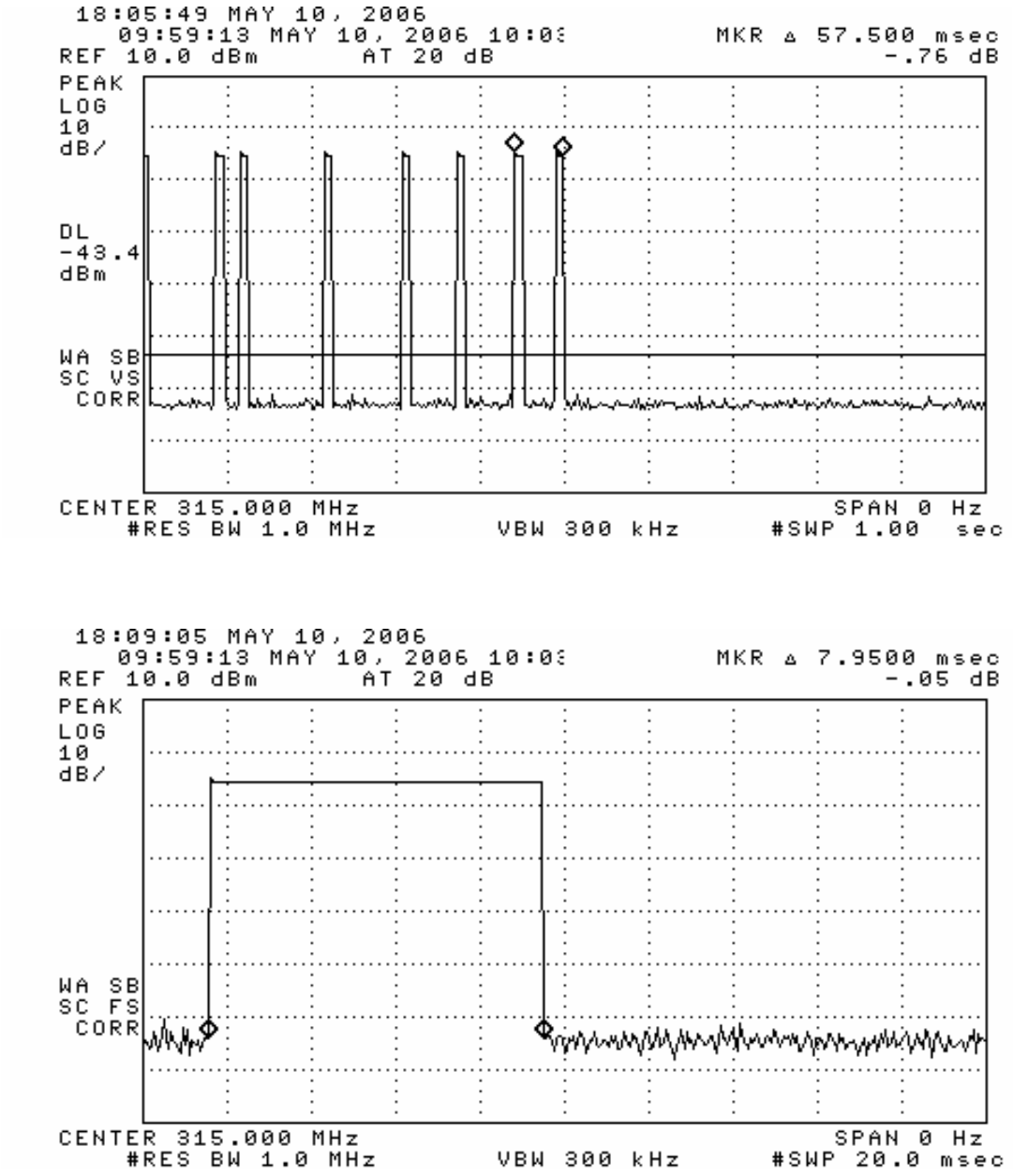


Figure 6.1. Transmissions modulation characteristics: (top) complete transmission, (bottom) expanded FSK word.

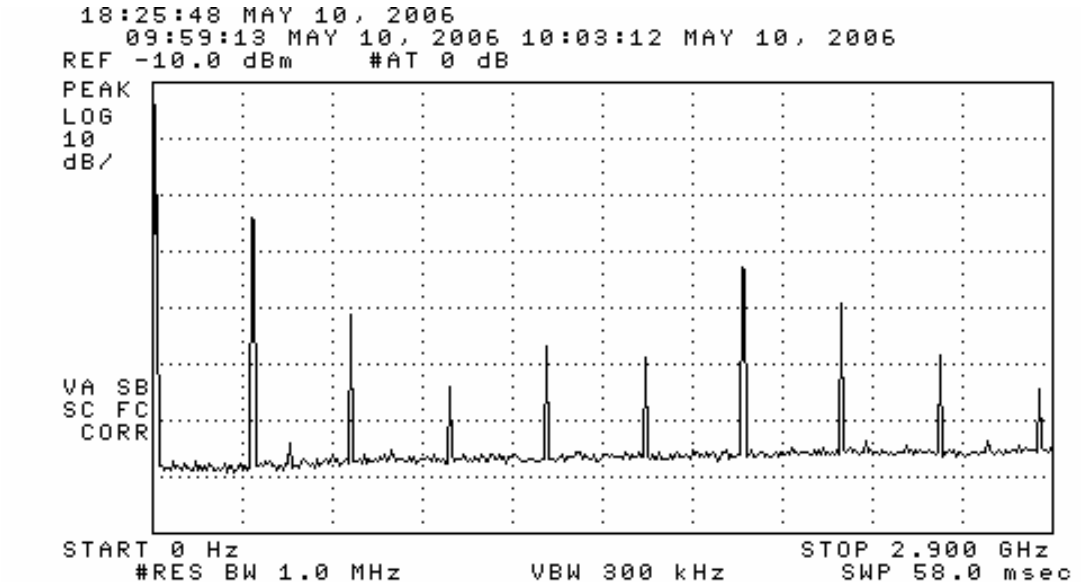


Figure 6.2. Emission spectrum of the DUT (pulsed emission).
The amplitudes are only indicative (not calibrated).

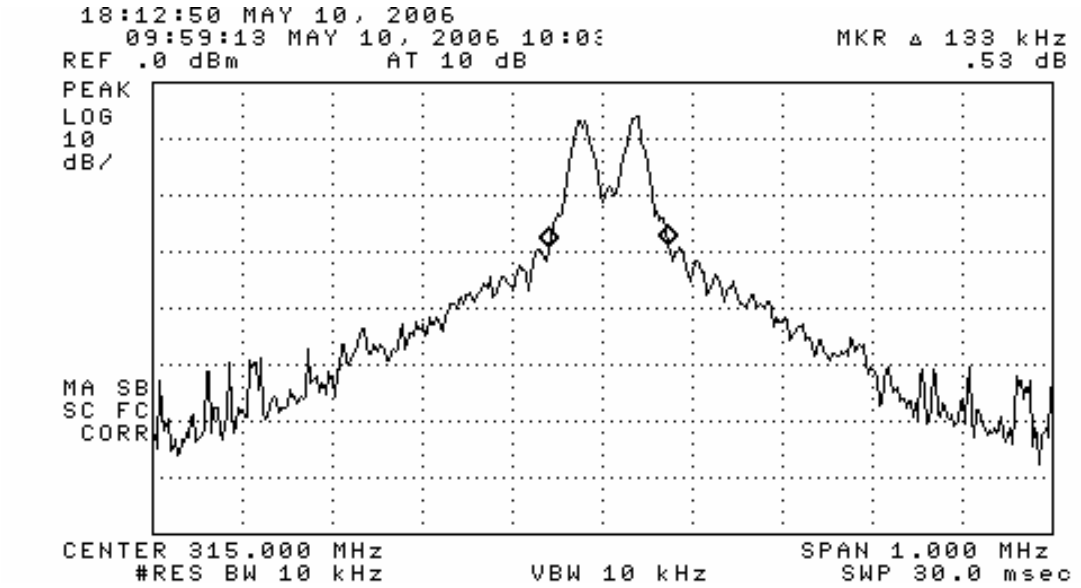


Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

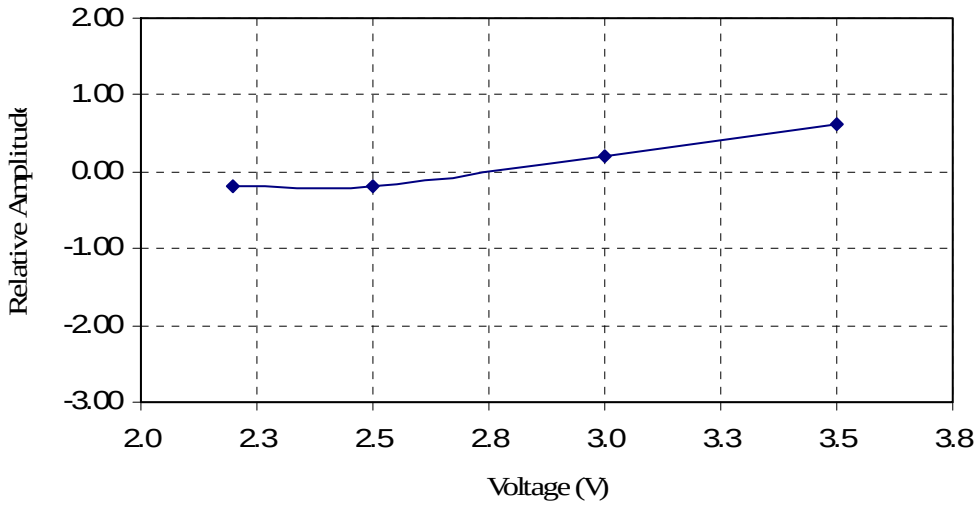
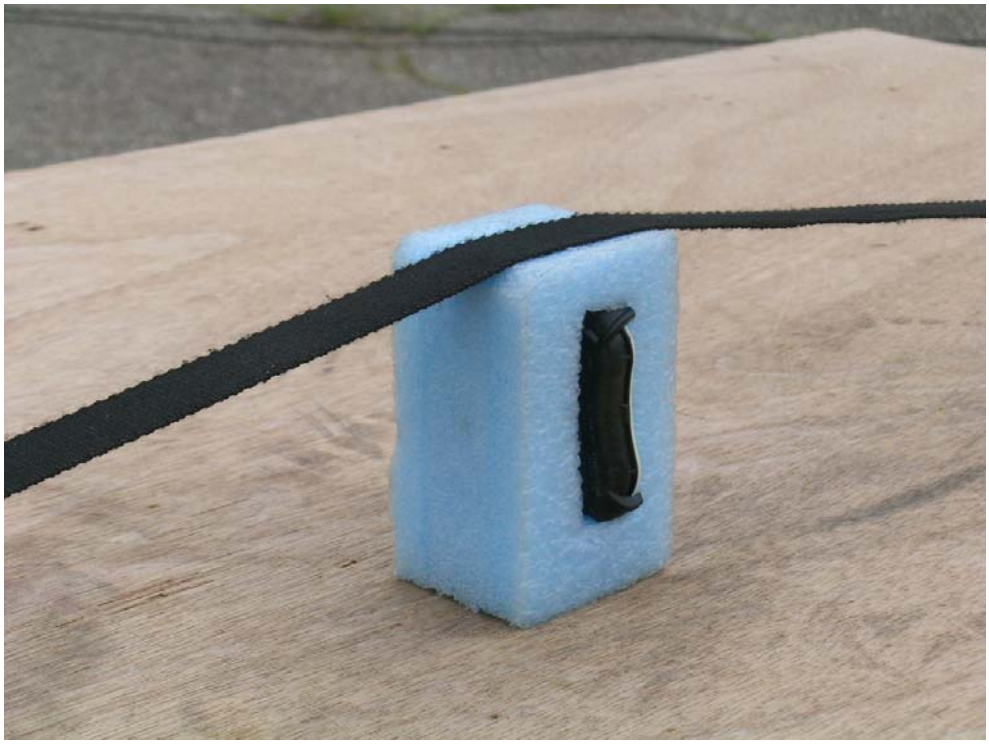


Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage (cw emission).

DUT on OATS



DUT on OATS (close-up)