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Measured Radio Frequency Emissions
From

Schrader Electronics TPM Transmitter
Model(s): MRXDCA315TX1

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For:
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Summary

Tests for compliance with FCC Regulations Part 15, Subpart C, and Industry Canada RSS-210/GEN, were performed on Schrader Electronics Limited model(s) MRXDCA315TX1. This device is subject to the Rules and Regulations as a Transmitter.

In testing completed on May 17, 2006, the device tested in the worst case met the allowed FCC specifications for radiated emissions by 6.0 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 3 VDC battery.

1. Introduction

Schrader Electronics Limited model MRXDCA315TX1 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 Area Tes Site 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 (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 (DUT)

3.1 Design and Identification of the Device

The DUT is a 2 x 0.75 x 2.5 inches in size (including valve stem), potted tire pressure transmitter. The 315 MHz carrier is generated by an RFIC stabilized using a 9.84375MHz crystal. The device transmits FSK data with 82 kHz modulation. The DUT was designed and manufactured by Schrader Electronics Limited, 11, Technology Park, Belfast Road,, Antrim BT41 1QS, Northern Ireland. It is identified as:

Schrader Electronics TPMS Transmitter
Model(s): MRXDCA315TX1
FCC ID: MRXDCA315TX1
IC: 2546A-DCATX1

3.2 Models

There is only one model of the DUT. Two versions were provided; one capable of CW transmission and one standard module that could be LF actuated. The CW version was used to measure harmonic emissions, all other tests were performed on the pulsed module.

3.3 Modes of Operation

The DUT periodically transmits tire pressure data. The device is also capable of being automatically actuated (via LF interrogation) either by in-vehicle LF initiators or by trained personnel during servicing. Per FCC correspondence, service modes fall under FCC part 15.231(a)(5). Figure 6.1 demonstrates compliance with both 15.231(a)(2) and (5). A list of all operating modes is included in the Description of Operation exhibit.

3.4 EMI/EMC Relevant Modifications

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

4. Regulatory 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(a),(c), & (e),15.209) and Subpart A (Section 15.33). For Industry Canada it is subject to RSS-210 (2.6, 2.7). The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below.

4.1 Radiated Emission Limits

Table 4.1. General Radiated Emission Limits (FCC: 15.33, 15.35, 15.209; IC: RSS-210, 2.7 Table 2)
(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	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
(MHz)	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
260.0-470.0	1500-5000*		150-500	
315.0	2417	67.7	241.7	47.7
433.9	4399	72.9	439.9	52.9
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 Exemptions
For devices operating in transportation vehicles, digital emissions are exempt (FCC 15.103(a), IC correspondence) and need not be reported.

4.4 Power Line Conducted Emission Limits
The power line conducted emission limits and tests do not apply here, as the DUT is powered by a 3 VDC battery.

4.5 Supply Voltage Variation
Measurements of the variation in the fundamental radiated emission shall be performed with the supply voltage varied between 85% and 115% of the nominal rated value. For battery operated equipment, the equipment tests shall be performed using a new battery.

5. Test Procedures

5.1 Semi-Anechoic Chamber Radiated Emission Testing
To become familiar with the emission behavior of the DUT, the DUT was first studied and measured in a shielded semi-anechoic chamber. In the chamber is set-up similar to that of an outdoor 3-meter site, with a turntable, 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 emissions. It was placed on the test table flat, on its side, and 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 final compliance assessment. We note that for the horn antenna, the antenna pattern is directive and 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.

5.2 Open Area Test Site (OATS) Radiated Emission Testing
After the chamber measurements are complete, emissions are re-measured on the outdoor 3-meter open area test site at the fundamental and harmonics up to 1 GHz using tuned dipoles and/or a high frequency biconical antenna. The DUT is placed on the test table flat, on its side, and on its end, and worst case emissions are recorded. Photographs included in this filing show the DUT on the OATS.

5.3 Field Calculation for Radiated Emission Measurements
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 6.0 dB.

5.4 Power Line Conducted Emission Testing
These tests do not apply, since the DUT is powered from a 3 VDC battery.

6. Test Results

6.1 Correction For Pulse Operation
When the transmitter is activated, it will, in the worst case, transmit one FSK sync word followed by four FSK data words, each separated by more than 100 ms. The 1.7 ms sync word contains one 0.035 ms narrow pulse, followed by 0.053 ms wide pulses. Each data word has an on-time of 11.0 ms in any given 100 ms window. As formulated below, the data words demonstrate the worst case duty cycle. See Figure 6.1. Computing the duty factor results in:

$K_{E(sync)}$ = (1 x 0.035 + 16 x 0.053) / 100 ms = 0.009 or -41 dB (not used)
$K_{E(data)}$ = 11.0 ms / 100 ms = 0.11 or -19.2 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. We 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.

6.3 Bandwidth of the Emission Spectrum
The measured spectrum of the signal is shown in Figure 6.3. The allowed (-20 dB, 99%) bandwidth is 0.25% of 315 MHz, or 787.25 kHz. From the plot we see that the -20 dB bandwidth is 150.0 kHz, and the center frequency is 315.01 MHz.

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

Batteries:	before testing	V_{oc} =	3.3 V
	after testing	V_{oc} =	3.0 V
Ave. current from batteries		I =	12.0 mA (pulsed)

Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Schrader GM07; 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	-24.3	Pk	18.6	21.7	60.4	67.7	7.3	flat
2	315.0	Dip	V	-28.1	Pk	18.6	21.7	56.6	67.7	11.1	side
3	630.0	Dip	H	-54.2	Pk	24.4	18.7	39.3	47.7	8.4	flat
4	630.0	Dip	V	-55.6	Pk	24.4	18.7	37.9	47.7	9.8	side
5	945.0	Horn	H	-68.6	Pk	28.8	16.8	31.2	47.7	16.4	flat
6	945.0	Horn	V	-72.4	Pk	28.8	16.8	27.4	47.7	20.2	end
7	1260.0	Horn	H	-37.3	Pk	20.6	28.0	43.1	54.0	10.9	flat
8	1575.0	Horn	H	-46.4	Pk	21.5	28.0	34.9	54.0	19.1	flat
9	1890.0	Horn	H	-34.0	Pk	22.2	28.0	48.0	54.0	**6.0**	end
10	2205.0	Horn	H	-50.6	Pk	23.0	28.1	32.1	54.0	21.9	end
11	2520.0	Horn	H	-50.1	Pk	23.9	28.3	33.3	54.0	20.7	flat
12	2835.0	Horn	H	-50.0	Pk	24.8	28.2	34.4	54.0	19.6	flat
13	3150.0	Horn	H	-49.5	Pk	25.8	27.9	36.2	54.0	17.8	flat
14											
15											
16											
17											
18	* Includes 19.2 dB duty factor										
19											
20											
21											
22	Digital emissions more than 20 dB below FCC/IC Class B Limit.										
23											
24											
25											
26											
27											

Digital Radiated Emissions*											
#	Freq. kHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
1											
2											
3											
4	Digital emissions more than 20 dB below FCC/IC Class B Limit.										
5											
6											
7											
8											
9	* For devices used in transportation vehicles, digital emissions are exempt from FCC regulations per FCC 15.103(a)										

Meas. 07/10/2006; U of Mich.

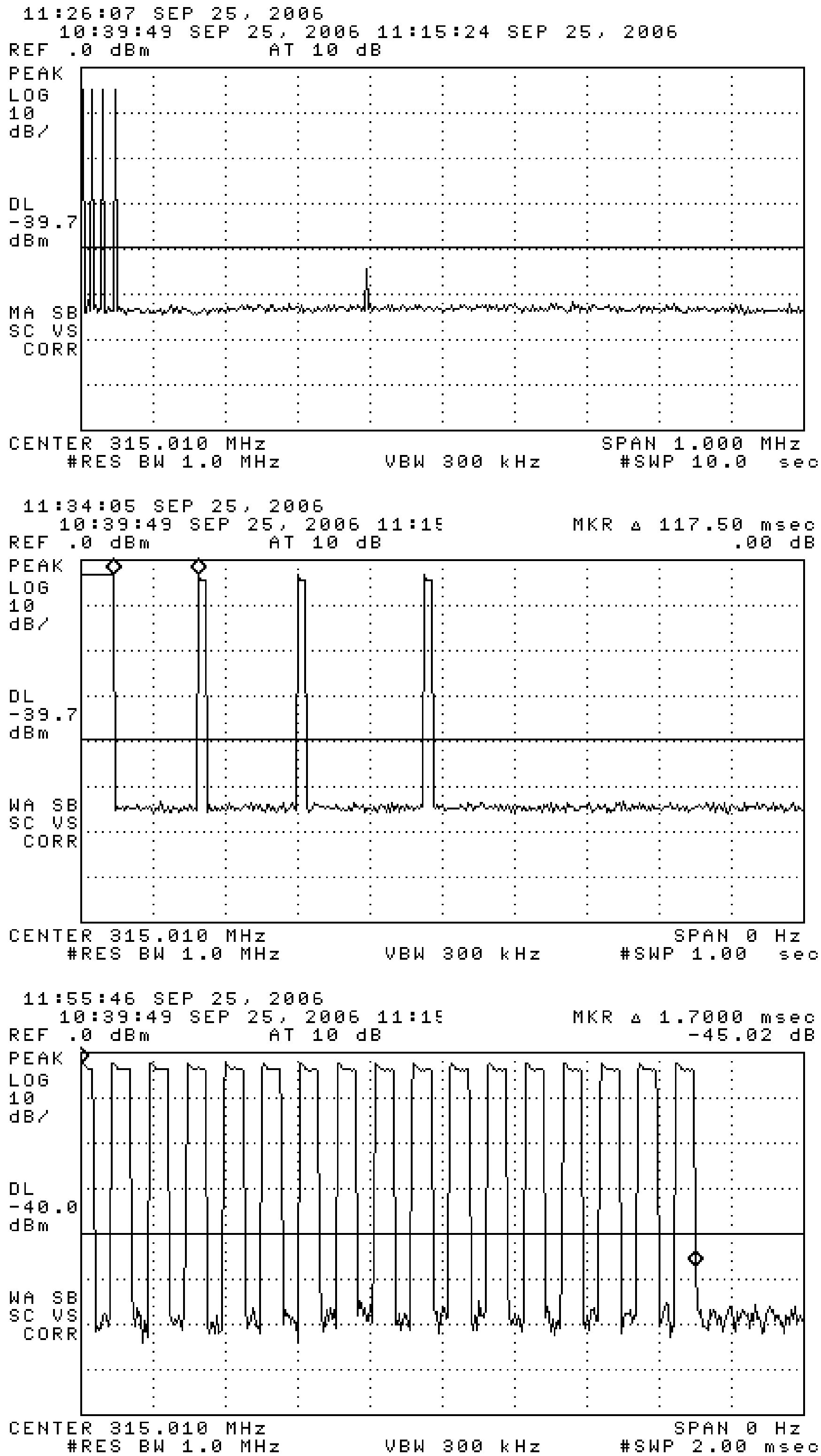


Figure 6.1(a). Transmissions modulation characteristics: (top) single actuation, (center) sync and data pulses, (bottom) expanded sync pulse.

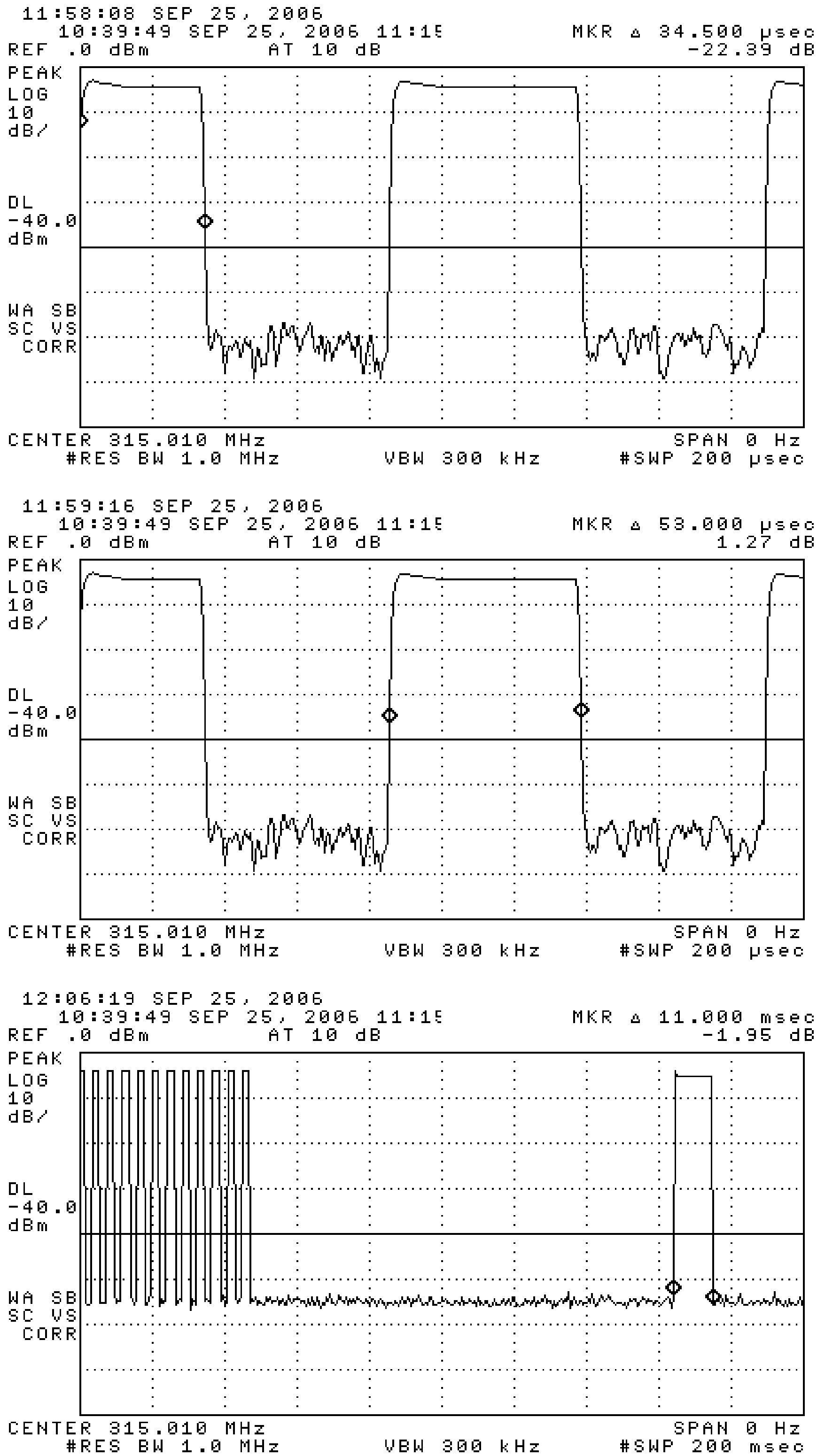


Figure 6.1(b). Transmissions modulation characteristics: (top) narrow sync, (center) wide sync, (bottom) data pulse.

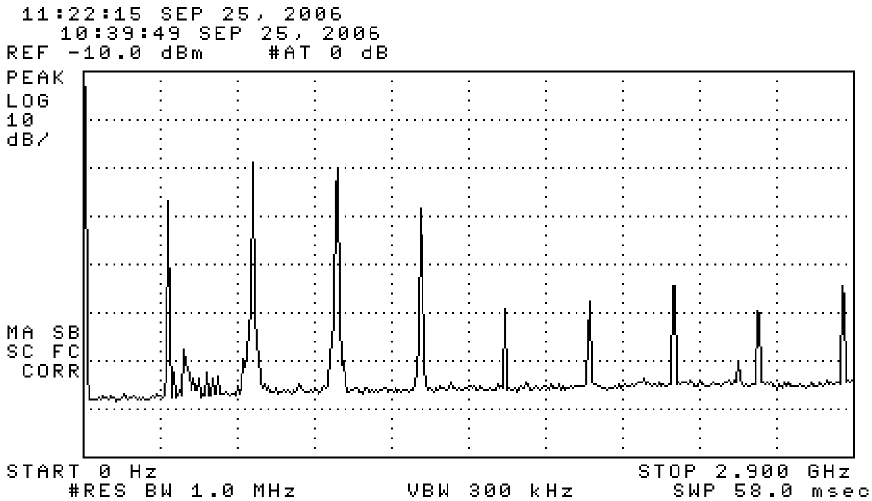


Figure 6.2. Emission spectrum of the DUT (pulsed emission). The amplitudes are only indicative (not calibrated), note that the ridge-horn cutoff occurs below 500 MHz, causing the fundamental amplitude to appear lower than harmonics. This is not the case.

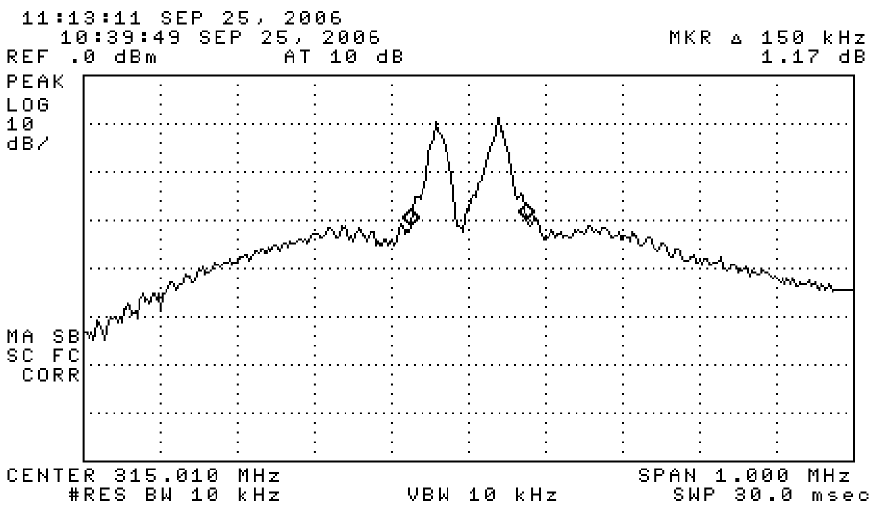


Figure 6.3. Measured FSK bandwidth of the DUT (pulsed emission).

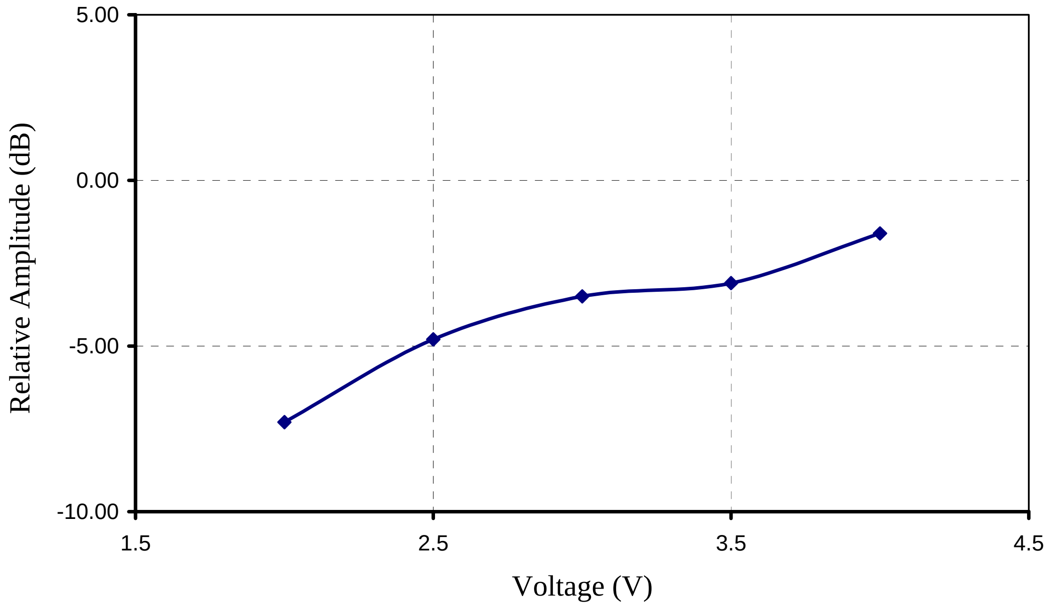
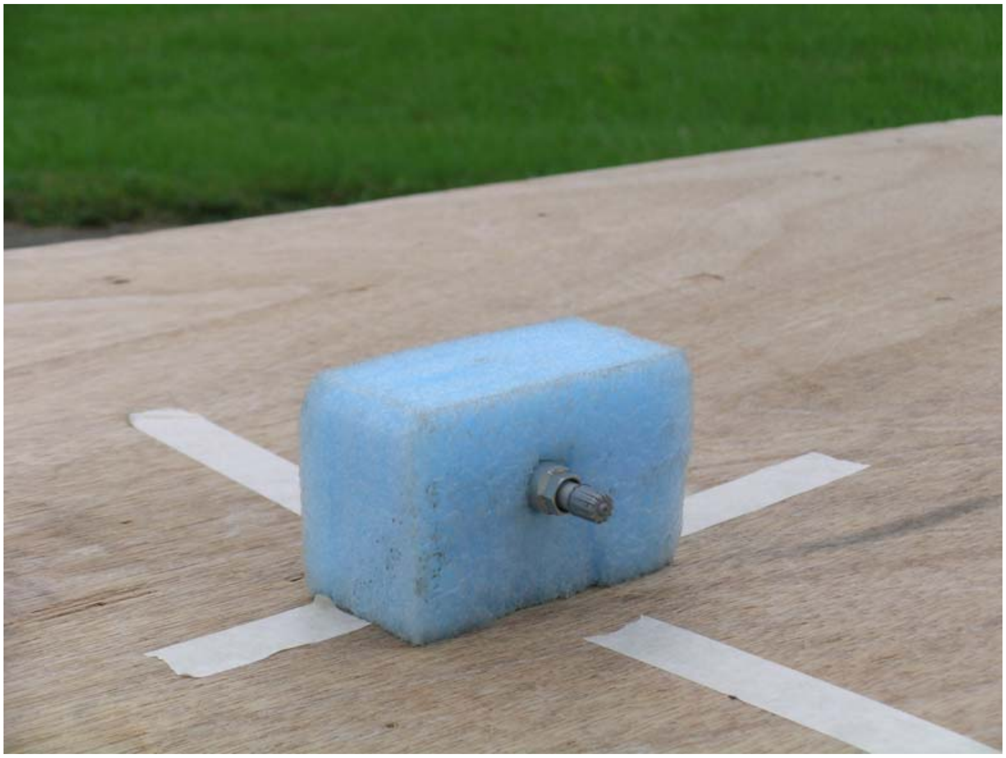


Figure 6.4. Relative emissions vs. supply voltage. (CW emission)

DUT on OATS



DUT on OATS (close-up)