The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 647-1792

Measured Radio Frequency Emissions From

Schrader Remote Tire Pressure Monitoring Transmitter Model: MRXTG224AM02

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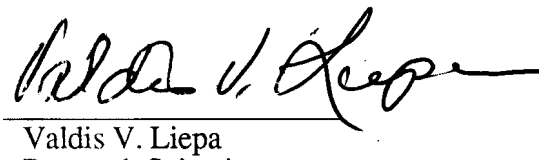
For:
Schrader Electronics Ltd.
11 Technology Park
Belfast Road
Antrim
N. Ireland, BT411 1QS
PO: R7459

Contact:
Brendan McDonnell
Tel: 011-44 2894-482078
Fax: 011-44 2894-468440

Measurements made by: Valdis V. Liepa

Tests supervised by:
Report approved by:



Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations, subject to Part 15, Subpart C, and with RSS-210 of Industry Canada were performed on Schrader Remote 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 between January 10 and February 18, 2001, the device tested in the worst case met the limits for radiated emissions by 5.3 dB (1735 MHz, 4th harmonic; 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 3 V internal lithium battery.

1. Introduction

Schrader Remote Tire Pressure Monitoring Transmitter, PN: 70503028, was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, and with Industry Canada RSS-210, Issue 2, dated February 14, 1998. 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 test equipment commonly used in our facility is listed in Table 2.1 below. The second column identifies the specific equipment used in these tests. The HP 8593E spectrum analyzer is used for primary amplitude and frequency reference.

Table 2.1. Test Equipment.

Test Instrument	Equipment Used	Manufacturer/Model	Cal. Date/By
Spectrum Analyzer (9kHz-22GHz)	X	Hewlett-Packard 8593A SN: 3107A01358	December 2000/UM
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	December 2000/HP
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard 182T/8558B SN: 1529A01114/543592	December 2000/UM
Preamplifier (5-1000MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	December 2000/UM
Preamplifier (5-4000 MHz)	X	Avantek	Oct. 1999/ U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	June 1999/U of M Rad Lab
Broadband Bicone (200-1000 MHz)	X	University of Michigan	June 1999/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)	X	University of Michigan	June 2000/UM
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	June 2000/UM
Active Loop Antenna (0.090-30MHz)		EMCO 6502 SN: 2855	December 1999/UM
Active Rod (30Hz-50 MHz)		EMCO 3301B SN: 3223	December 1999/UM
Ridge-horn Antenna (0.5-5 GHz)	X	University of Michigan	March 1999/U of M Rad Lab
LISN Box		University of Michigan	Dec. 2000/U of M Rad Lab
Signal Generator (0.1-2060 MHz)		Hewlett-Packard 8657B	January 2000/Uof M Rad Lab

3. Configuration and Identification of Device Under Test

The DUT is a 3.5 x 7.0 x 1.5 cm 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. The transmission consists of eight PWM words repeated typically every 30 seconds. The 434 MHz carrier is generated by a SAW stabilized oscillator. The coding is performed by an ASIC timed by a 32.768 kHz crystal oscillator.

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 Remote Tire Pressure Monitoring Transmitter
Model: MRXTG224AM02
SNs: (1) 04001266, (2) 04002244, (3) none
FCC ID: MRXTG224AM02
CANADA:

Three devices were provided. These were: (1) staddard, but with access to control pads; used for CW and pulsed measurements, (2) standard for outside photographs and (3) unpotted for photographs.

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	Fundamental Ave. E_{lim} (3m)		Spurious** Ave. E_{lim} (3m)	
(MHz)	(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 RBW up to 1 GHz, 1 MHz RBW 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 RBW)
Average readings apply above 1000 MHz (1 MHz RBW)

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 4.5 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 4.5 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 434 and 868 MHz using tuned dipoles and/or the high frequency bicone.

Appendix shows the DUT on the open-site table.

5.3 Computations and Results

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

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

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 8.7 dB at fundamental and by 5.3 dB at harmonics.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

The transmitter is activated by rotation of the wheel and transmits once every 33 seconds. The transmission consists of eight repeated words of (minimum) 105 ms period. In a word there are two 477.5μs timing pulses and 50 Manchester format encoded data pulses 110μs wide. Note, Manchester encoding uses low- high, high-low transition logic and when the highs are back-to-back, that appears as a wide pulse that actually are two pulses. See Figure 6.1. In this case, the averaging factor is

$$K_E = (2 \times .4775 + 50 \times 0.110) \text{ ms} / 100 \text{ ms} = 0.0644 \text{or } -23.8 \text{ dB} \quad (\text{Use } -20.0 \text{ dB})$$

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 434.0 MHz, or 1085 kHz, and from the plot we see that the -20 dB bandwidth is 53.0 kHz (actually this represents the RBW of the spectrum analyzer), and the center frequency is 433.935 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 paralelled by a laboratory variable power supply and relative power radiated was measured at the fundamental as the voltage was varied from 2.75 to 3.5 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current at Battery Terminals

$$V = 3.0 \text{ V}$$

$$I = 30.0 \text{ mA (CW)}$$

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Schrader/Brendan TX 434 MHz, 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	433.9	Dip	H	-23.6	Pk	21.8	21.1	64.1	72.8	8.7	flat
2	433.9	Dip	V	-25.7	Pk	21.8	21.1	62.0	72.8	10.8	end
3	867.8	Dip	H	-51.2	Pk	28.1	17.4	46.5	52.8	6.3	flat
4	867.8	Dip	V	-50.6	Pk	28.1	17.4	47.1	52.8	5.7	end
5	1301.7	Horn	H	-41.6	Pk	21.0	28.1	38.3	54.0	15.7	side
7	1735.6	Horn	H	-32.1	Pk	21.8	28.0	48.7	54.0	5.3	side *worst case
8	2169.5	Horn	H	-44.3	Pk	22.6	27.0	38.3	54.0	15.7	flat
9	2603.4	Horn	H	-48.1	Pk	24.1	26.1	36.9	54.0	17.1	flat
10	3037.3	Horn	H	-45.7	Pk	25.5	25.0	41.8	54.0	12.2	end
11	3471.2	Horn	H	-56.7	Pk	26.8	24.6	32.5	54.0	21.5	end
12	3905.1	Horn	H	-47.9	Pk	28.2	23.5	43.8	54.0	10.2	flat
13	4339.0	Horn	H	-60.2	Pk	29.5	19.0	37.3	54.0	16.7	side
14											
15											
16											
17											
18			*includes -20.0 dB duty factor								
19											
20											
21											

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											
2											
3			Digital emissions are more than 20 dB below FCC Class B limit								
4											

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

Meas. 01/10/01; U of Mich.

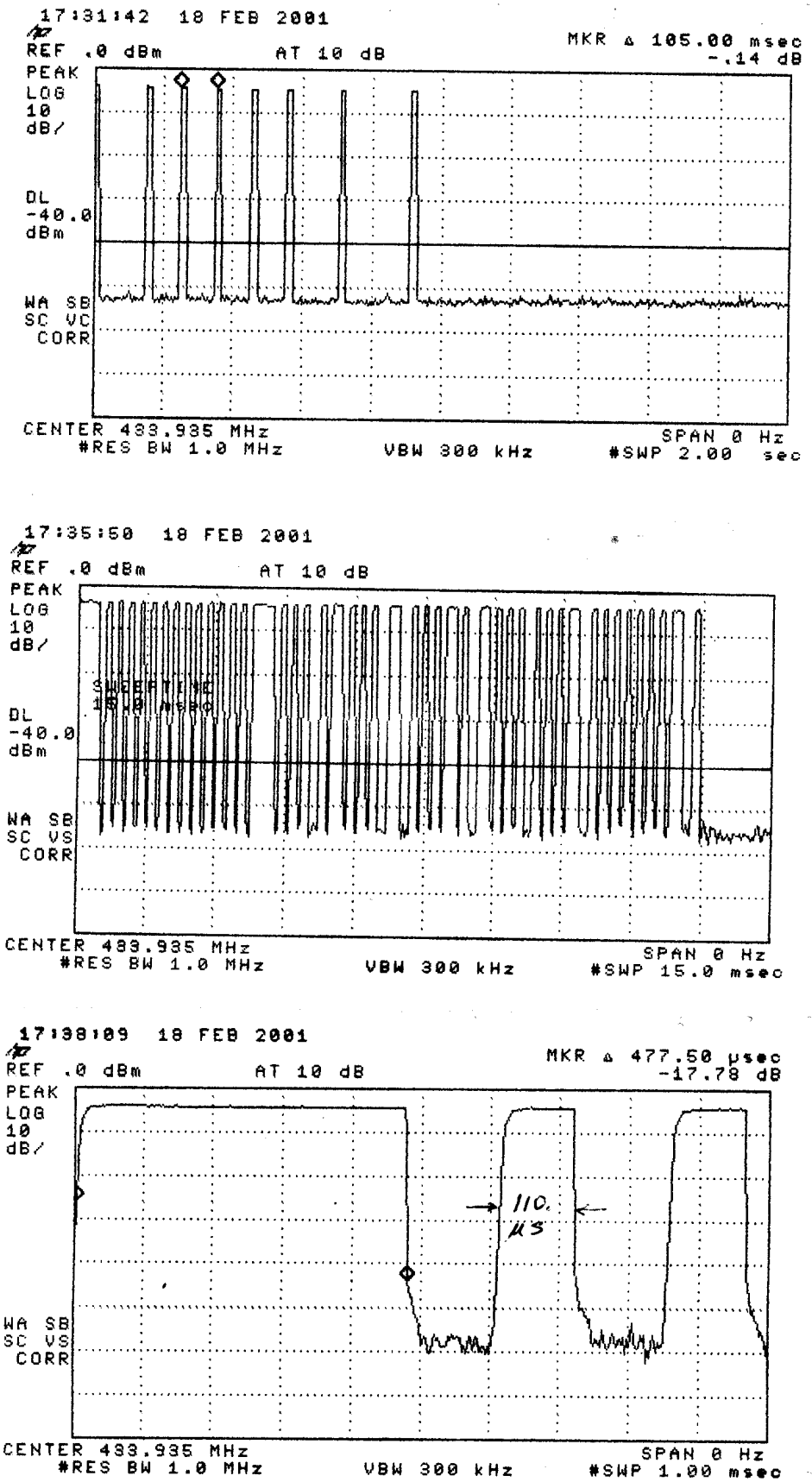

Figure 6.1. Transmissions modulation characteristics: (top) transmission repetition, (center) transmission pulses, (bottom) pulse width.

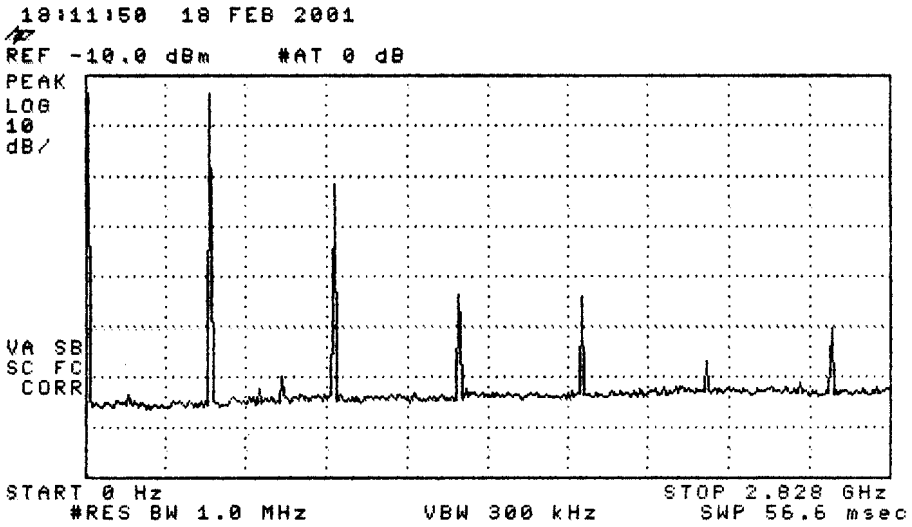

Figure 6.2. Emission spectrum of the DUT in free space (CW emission). The amplitudes are only indicative (not calibrated).

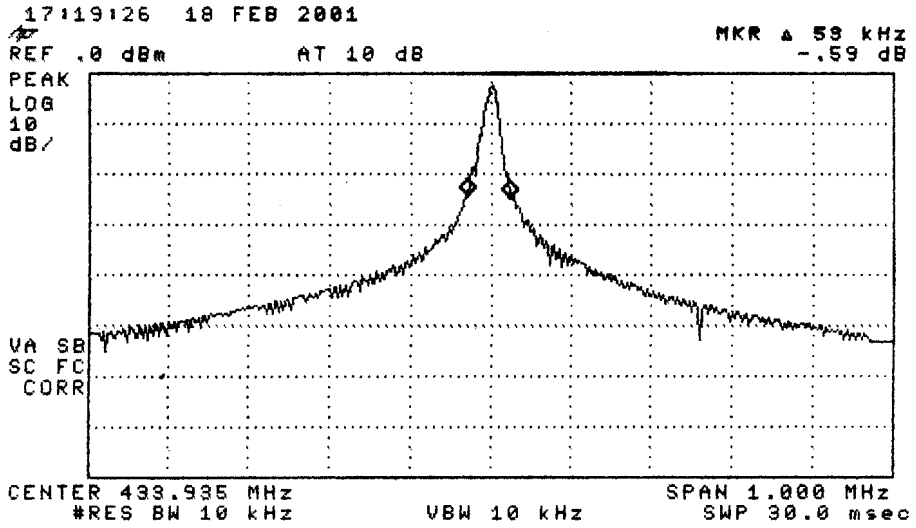

Figure 6.3. Measured bandwidth of the DUT (repated pulsed emission).

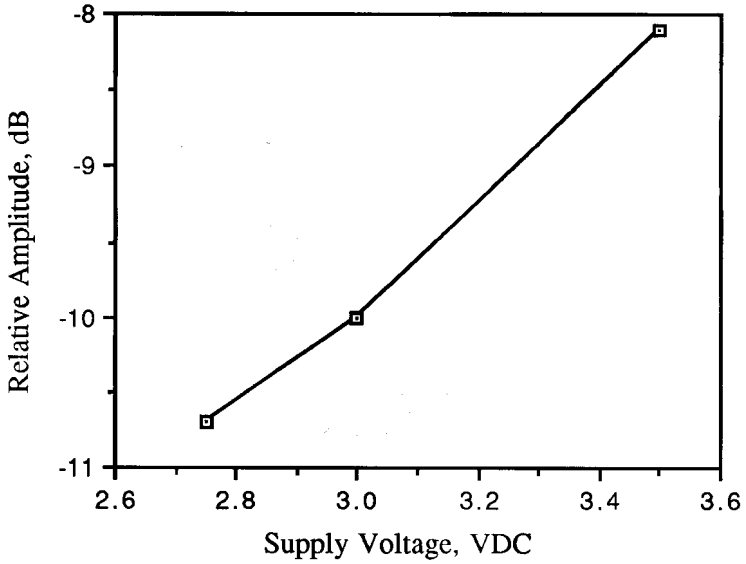

Figure 6.4. Relative emission at 434 MHz vs. supply voltage. (CW emission)