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Measured Radio Frequency Emissions
From

Schrader Remote Tire Pressure Monitoring Transmitter Part No: 70803006

Report No. 415031-031
March 10, 2000

For:
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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 on March 1-10, 2000, the device tested in the worst case met the limits for radiated emissions by 11.3 dB at fundamental and by 11.0 dB at harmonics (945 MHz, 3rd 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 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 file 31040/SIT) 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	October 1999/UM
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	September 1999/HP
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard 182T/8558B SN: 1529A01114/543592	October 1999/U of M Rad Lab
Preamplifier (5-1000MHz)	X	Watkins-Johnson A11 -1 plus A25-1S	October 1999/U of M Rad Lab
Preamplifier (5-4000 MHz)	X	Avantek	Oct. 1999/ U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Broadband Bicone (200-1000 MHz)		University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (25-1000 MHz)	X	University of Michigan	Dec. 1997/U of M Rad Lab
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	June 1996/U of M Rad Lab
Active Loop Antenna (0.090-30MHz)		EMCO 6502 SN: 2855	December 1993/ EMCO
Active Rod (30Hz-50 MHz)		EMCO 3301B SN: 3223	December 1993/EMCO
Ridge-horn Antenna (0.5-5 GHz)	X	University of Michigan	March 1999/U of M Rad Lab
LISN Box		University of Michigan	Dec. 1997/U of M Rad Lab
Signal Cables	X	Assorted	January 1993/U of M Rad Lab
X-Y Plotter		Hewlett-Packard 7046A	During Use/U of M Rad Lab
Signal Generator (0.1-990 MHz)	X	Hewlett-Packard 8656A	January 1990/U of M Rad Lab
Printer	X	Hewlett-Packard 2225A	August 1989/HP

3. Configuration and Identification of Device Under Test

The DUT is a 3.0 x 7.3 x 1.2 cm size potted tire pressure sensor/transmitter that mounts on a rim inside the tire using its own valve-stem for mounting. When the vehicle is in motion it transmits the tire pressure information to the receiver in the vehicle. The transmission consists of eight repeated words, 100 ms apart. The cylce repets every 60 seconds. The 315 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 brass valve stem is also the antenna for the device and, thus, protrudes outside the wheel. It is insulated from the wheel by a rubber bushing.

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
PN: 70803006
SN: FCCGen2A
FCC ID: MXRTTR1B0
CANADA: 2546 1021461

Three devices were provided. These were: (1) a modified one for CW emission measurements, (2) a standard one for bandwidth, etc., measurements, and (3) an unpotted one 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 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 315.0, 630.0, and 945.0 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

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

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 8.3dB at fundamental and by 1.5 dB at harmonics.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

In normal operation the transmitter is activated by rotation of the wheel and transmitts every 60 seconds and more often if there is a sudden change in pressure. The transmission consists of eight 6 ms long words about 100 ms apart. The data are ASK encoded. In the word the first pulse is 0.495 ms, followed by 39 wide (0.0975 ms) and narrow (0.0475 ms) pulses. See Figure 6.1. The worst case would be when all pulses are wide. In such case, the averaging factor would be

$$K_E = (0.495 + 39*0.0975) \text{ ms}/100.0 \text{ ms} = 0.0430 \text{ or } -27.3 \text{ dB} \quad \text{(Use -20.0 dB)}$$

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 315.0 MHz, or 786 kHz, and from the plot we see that the -20 dB bandwidth is 80.0 kHz , and the center frequency is 315.03 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 2.0 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 V

I = 1.1 mA (CW)

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF

Schrader 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	-28.2	Pk	18.9	21.3	56.4	67.7	11.3	side
2	315.0	Dip	V	-33.3	Pk	18.9	21.3	51.3	67.7	16.4	end
3	630.0	Dip	H	-64.0	Pk	25.2	17.7	30.6	47.7	17.1	flat
4	630.0	Dip	V	-66.4	Pk	25.2	17.7	28.2	47.7	19.5	end
5	945.0	Dip	H	-63.2	Pk	28.9	15.3	37.4	47.7	10.3	side
6	945.0	Dip	V	-63.9	Pk	28.9	15.3	36.7	47.7	11.0	end
7	1260.0	Horn	H	-50.0	Pk	20.4	28.1	29.3	47.7	18.4	flat
8	1575.0	Horn	H	-49.3	Pk	21.4	28.2	30.9	47.7	16.8	side
9	1890.0	Horn	H	-59.3	Pk	22.1	28.1	21.7	47.7	26.0	side
10	2205.0	Horn	H	-66.4	Pk	22.9	27.0	16.5	47.7	31.2	side
11	2520.0	Horn	H	-67.8	Pk	24.0	26.6	16.6	47.7	31.1	end
12	2835.0	Horn	H	-67.5	Pk	24.9	25.4	19.0	47.7	28.7	end
13	3150.0	Horn	H	-69.2	Pk	25.2	24.8	18.2	47.7	29.5	end, noise
14											
15											
16											
17											
18			*includes -20.0 dB duty factor								
19											
20			Digital emissions are more than 20 dB below FCC Class B limit								
21											
22											
23											
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. 3/1-10/00; U of Mich.

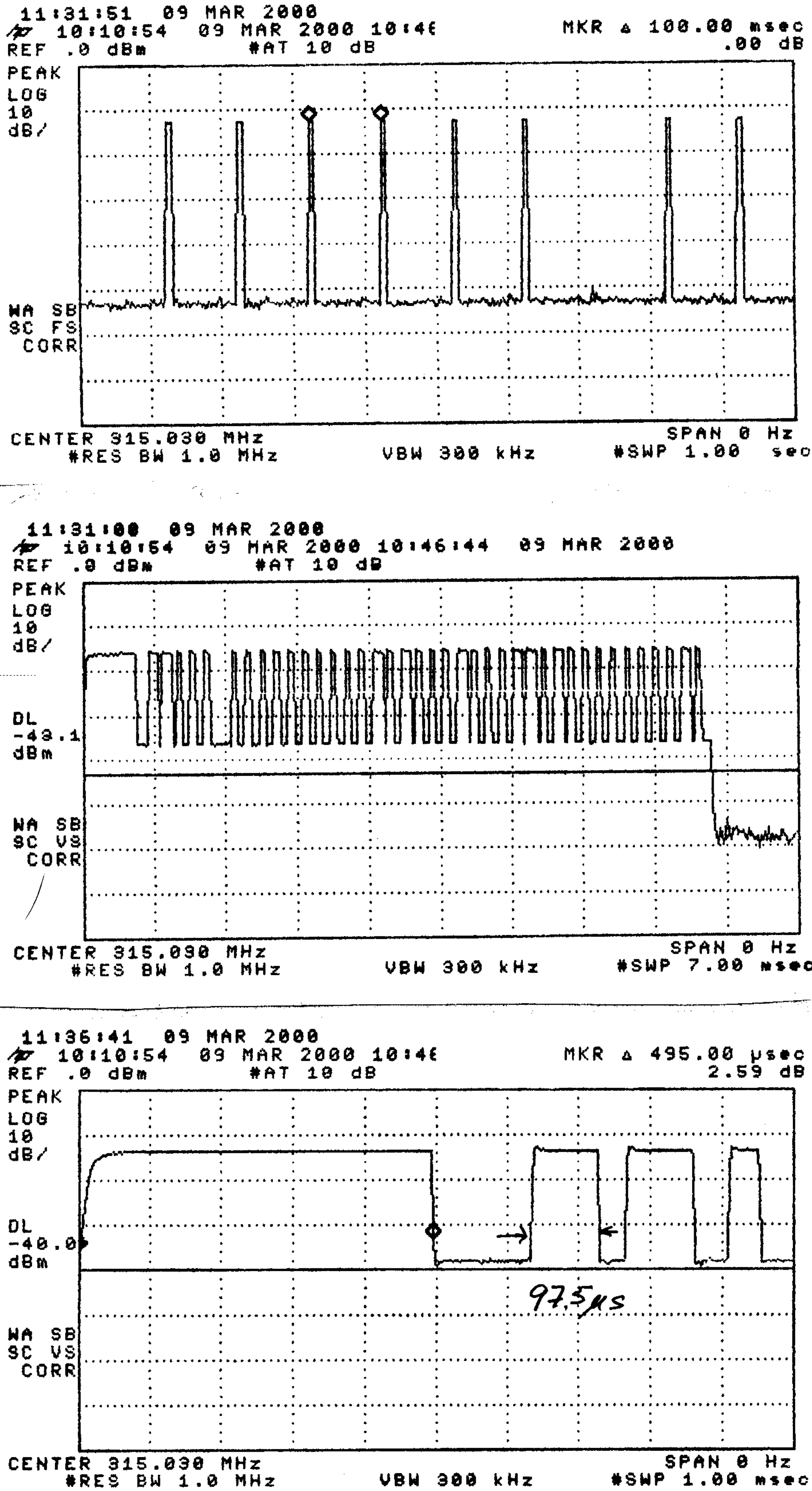

Figure 6.1. Transmissions modulation characteristics: (top) transmission repetition, (center) transmission pulses, (bottom) pulse width.

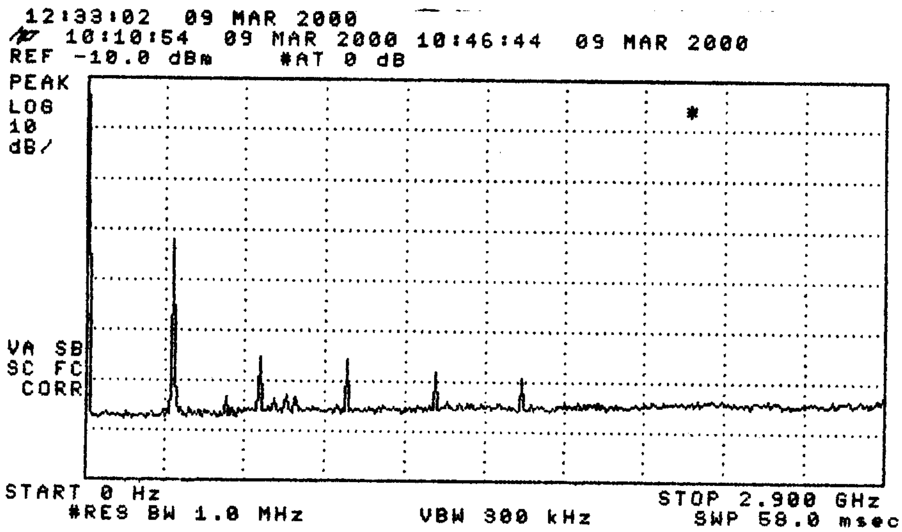

Figure 6.2. Emission spectrum of the DUT in free space (CW emission).
The amplitudes are only indicative (not calibrated).

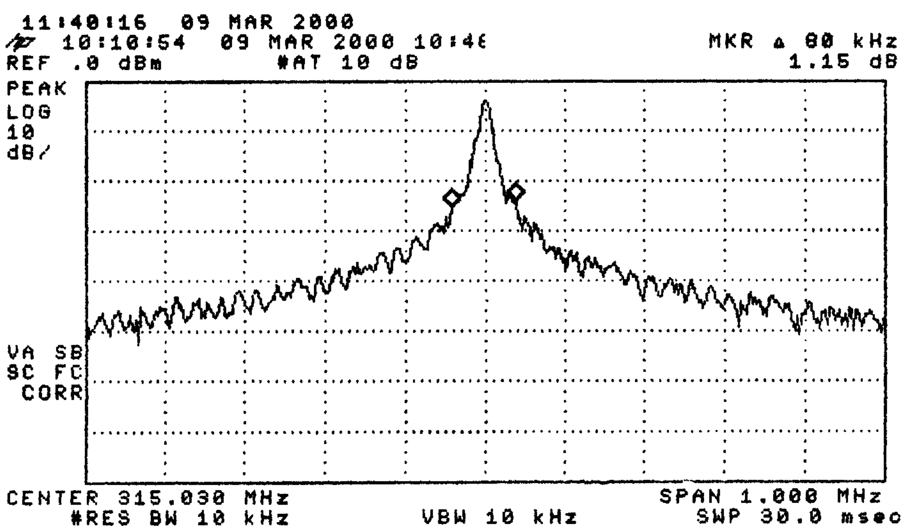

Figure 6.3. Measured bandwidth of the DUT (repated pulsed emission).

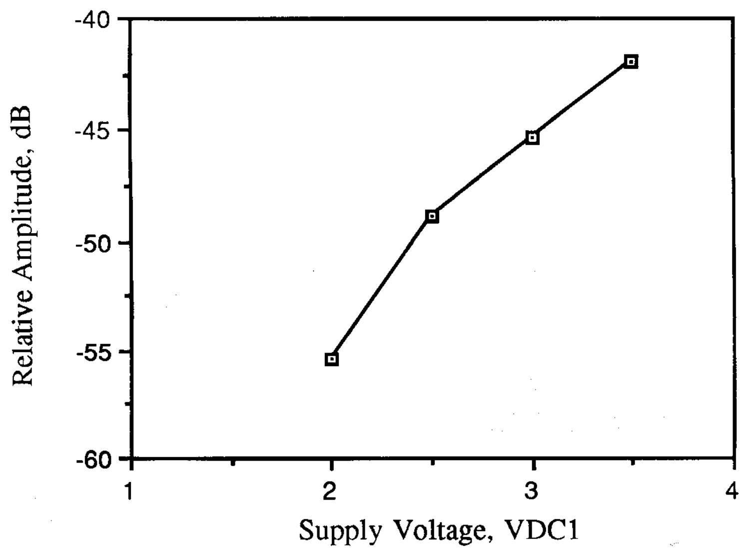

Figure 6.4. Relative emission at 315.0 MHz vs. supply voltage. (CW emission)