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Measured Radio Frequency Emissions
From

Schrader Remote Tire Pressure Monitoring Receiver System
(RX PNs: 24436873, 12798512, 13123864;
RFD PNs: 24447608,12791155, 24436875)

Report No. 415031-121
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Summary

Tests for compliance with FCC Regulations subject to Part 15, Subpart B, and with Industry Canada Regulations subject to RSS-210, were performed on Schrader TPM Receiver System. This device is subject to Rules and Regulations as a Receiver. As a Digital Device it is exempt, but such measurements were made to assess the receiver's overall emissions.

In testing performed on July 3 and 8, 2002, the device tested in the worst case met the allowed specifications for radiated emissions from the receiver section by greater than 9.1 dB (see p. 6). The line conducted emission tests do not apply, since the device is powered from an 12-volt DC supply, originating from automotive 12-volt electric system.

1. Introduction

Schrader TPM Receiver System, 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, 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. 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)		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)		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)	X	Hewlett-Packard, 8657B
Signal Generator (0.01-20 GHz)		Hewlett-Packard

3. Configuration and Identification of Device Under Test

The DUT is a five-module device, consisting of a 433.92 MHz main receiver and four remote RF Detectors (RFDs). Its application is for reception of tire pressure/status information sent by transmitters located in each wheel of a car. The receiver would be typically mounted inside the dash, and the RFDs typically would be located in a fender above each tire. They provide a signal strength information to the main receiver to identify the wheel from which the transmission originates. Whereas, the main receiver is of superheterodyne design with LO at 433.45 MHz, the RFDs are broadband energy detectors basically consisting of a detector diode and an RC circuit. The system is powered by 12 VDC.

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 Receiver System
PNs: 24436873, 12798512, 13123864
SNs: 00086, 00098, 00100 (Respectively)

FCC ID: MRXOPEL433RX1
IC: 2546A-OPELRX1

The three receivers have differences only in software and a bent in the antenna (some 20 degrees). Also there are three different RF Detectors, PNS: 24447608, 12791155, and 24436875. Electrically they are essentially identical, but have different mounting brackets to accommodate mounting them on different cars and fender locations. In the test setup four RFDs were used to simulate four wheel situation (two of 12791155 were used).

3.1 Modifications Made

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

4. Emission Limits

For FCC the DUT falls under Part 15, Subpart B, "Unintentional Radiators". For Industry Canada the DUT falls under Receiver category and is subject to technical requirement of sections 7.1 to 7.4 in RSS-210. The pertinent test frequencies, with corresponding emission limits, are given in Tables 4.1 and 4.2 below.

4.1 Radiated Emission Limits

Table 4.1. Radiated Emission Limits (FCC: 15.33, 15.35, 15.109; IC: RSS-210, 7.3).

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 Conducted Emission Limits

Table 4.2. Conducted Emission Limits (FCC: 15.107; IC: RSS-210, 6.6).

Freq. (MHz)	μV	dB(μV)
0.450 - 1.705	250	48.0
1.705 - 30.0	250	48.0

Note: Quasi-Peak readings apply here

5. Emission Tests and Results

5.1 Anechoic Chamber Radiated Emission Tests

To familiarize with the radiated emission behavior of the DUT, it was studied and measured in the shielded anechoic chamber. In the chamber there is a set-up similar to that of an outdoor 3-meter site, with turntable, antenna mast, and a ground plane. Instrumentation includes spectrum analyzers and other equipment as needed.

To study and test for radiated emissions, the DUT was powered by a laboratory power supply. A 433.92 MHz CW signal was injected (radiated) from a nearby signal generator using a short wire antenna. The DUT was placed on the test table on each of its three axis. For each placement, the table was rotated to obtain maximum signal for vertical and horizontal emission polarizations. This sequence was repeated throughout the required frequency range.

In the chamber we studied and recorded all the emissions using a ridge-horn antenna, which covers 200 MHz to 5000 MHz, up to 2 GHz. In scanning from 30 MHz to 2.0 GHz, there were no spurious emissions observed other than the LO, the injection signal, and the LO harmonics. Figures 5.1 and 5.2 show emissions measured 0-1000 MHz and 1000-2000 MHz, respectively. These measurements are made with a ridge-horn antenna at 3m, with spectrum analyzer in peak hold mode and the receiver rotated in all orientations. The measurements up to 1000 MHz (Fig. 5.1) are used for initial evaluation only, but those above 1000 MHz (Fig. 5.2) are used in final assessment for compliance.

5.2 Open Site Radiated Emission Tests

The DUT was then moved to the 3 meter Open Field Test Site where measurements were repeated up to 1000 MHz using a small bicone, or dipoles when the measurement is near the limit. The DUT was exercised as described in Sec. 5.1 above. The measurements were made with a spectrum analyzer using 120 kHz IF bandwidth and peak detection mode, and, when appropriate, using Quasi-Peak or average detection. When emissions are narrow band, as in a case of an LO, measurements in the 800 MHz range are made with lower RBW to help discriminate emissions from the ambient signals and the noise. The test set-up photographs are in the Appendix (i.e., end of this report).

The emissions from digital circuitry were measured using a standard bicone. These results are also presented in Table 5.1.

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 more than 9.1 dB.

5.4 Conducted Emission Tests

These tests do not apply, since the DUT is powered from a 12-volt automotive supply.

6. Other Measurements

6.1 Emission Spectrum Near Fundamental

Near operating frequency emission spectrum is measured typically over 50 MHz span with and without injection signal. These data are taken with the DUT close to antenna and, hence, amplitudes are relative. The plot is shown in Figure 6.1.

6.2 Effect of Supply Voltage Variation

The DUT has been designed to operate from 12 VDC power. Using a spectrum analyzer, relative radiated emissions were recorded at the "fundamental" (433.42 MHz) as voltage was varied from 4.0 to 18.0 VDC. Figure 6.2 shows the emission variation.

6.3 Operating Voltage and Current

V = 12.5 VDC
I = 40.1 mADC

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Table 5.1 Highest Emissions Measured

Radiated Emission - RF — Schrader TPM 433MHz RX; 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	433.5	SBic	H	-76.9	Pk	21.8	17.5	34.4	46.0	11.6	flat PN: 24436873
2	433.5	SBic	H	-74.4	Pk	21.8	17.5	36.9	46.0	9.1	side
3	433.5	SBic	H	-79.6	Pk	21.8	17.5	31.7	46.0	14.3	end
4	433.5	SBic	V	-78.3	Pk	21.8	17.5	33.0	46.0	13.0	flat
5	433.5	SBic	V	-81.1	Pk	21.8	17.5	30.2	46.0	15.8	side
6	433.5	SBic	V	-77.4	Pk	21.8	17.5	33.9	46.0	12.1	end
7	866.9	SBic	H	-90.4	Pk	28.1	13.8	30.9	46.0	15.1	flat, 3 kHz BW
8	866.9	SBic	H	-90.7	Pk	28.1	13.8	30.6	46.0	15.4	side, 3 kHz BW
9	866.9	SBic	H	-94.2	Pk	28.1	13.8	27.1	46.0	18.9	end, 3 kHz BW
0	866.9	SBic	V	-95.0	Pk	28.1	13.8	26.3	46.0	19.7	flat, 3 kHz BW
10	866.9	SBic	V	-93.9	Pk	28.1	13.8	27.4	46.0	18.6	side, 3 kHz BW
11	866.9	SBic	V	-94.9	Pk	28.1	13.8	26.4	46.0	19.6	end, 3 kHz BW
12	1300.0	Horn	H	-70.0	Pk	20.5	20.3	37.2	54.0	16.8	max of all
13	1733.8	Horn	H	-70.0	Pk	21.4	21.8	36.6	54.0	17.4	max of all
14											
15	PN: 12798512										
16	433.5	SBic	H	-74.9	Pk	21.8	17.5	36.4	46.0	9.6	side
17	PN: 13123864										
18	Not measured; same as above, except for the bent antenna										

Radiated Emission - Digital (Class B)

1											
2											
3	Digital Emissions more than 20 dB below FCC Class B limits										
4											
5											
6											
7											
8											
9											
10											
11											
12											

Conducted Emissions

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

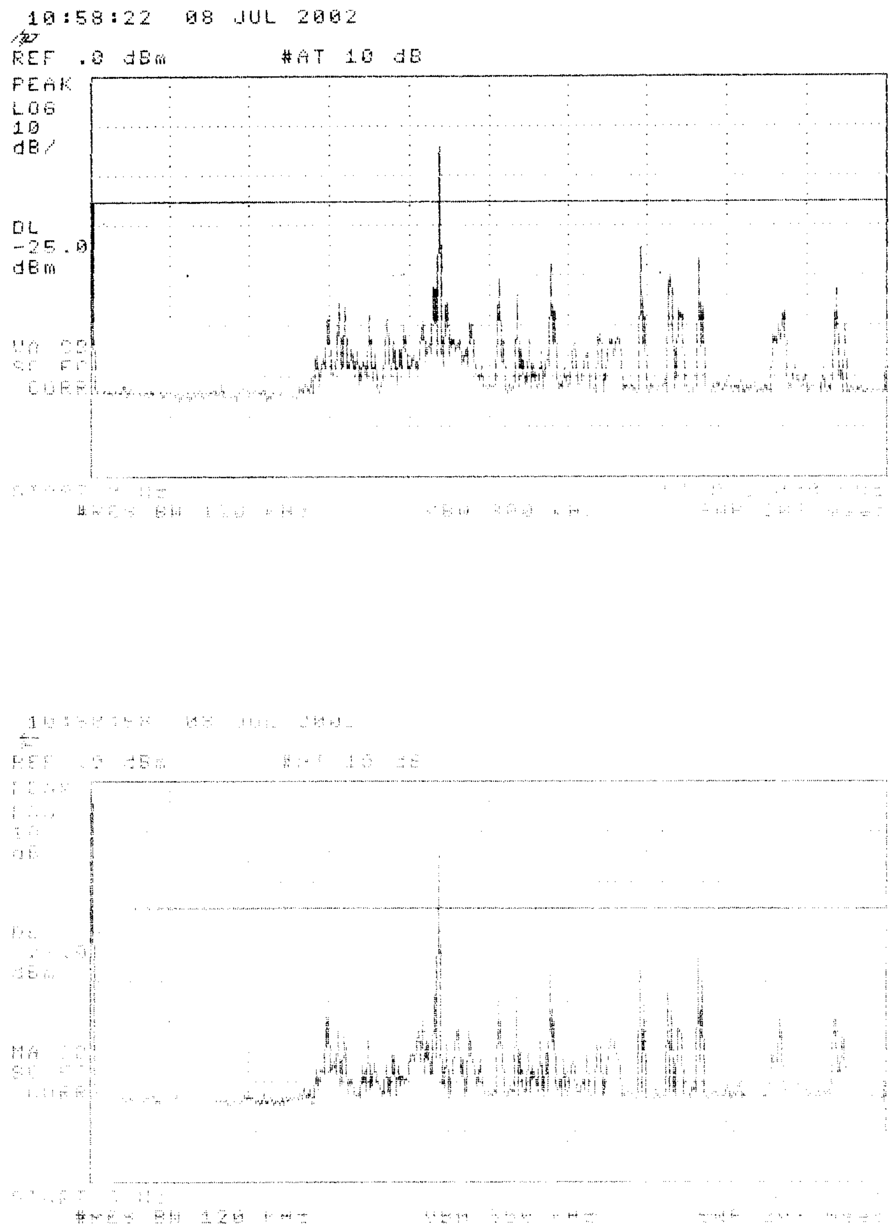
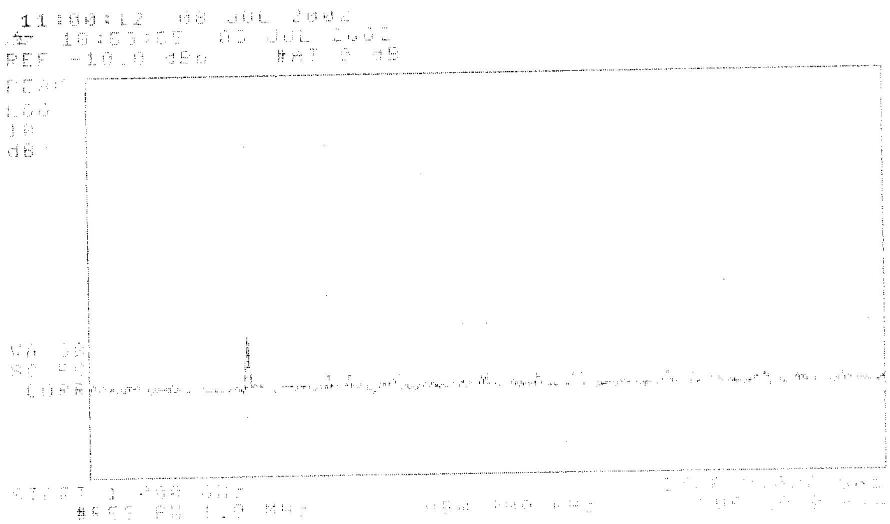


Figure 5.1. Emissions measured at 3 meters in anechoic chamber, 0-1000 MHz.
(top) Receiver plus ambient
(bottom) Ambient



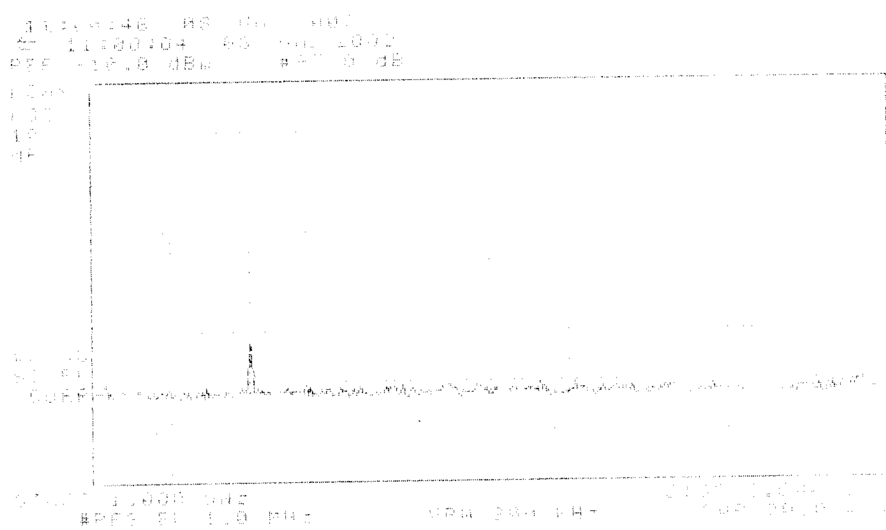


Figure 5.2. Emissions measured at 3 meters in anechoic chamber, 1000-2000 MHz.
(top) Receiver plus ambient
(bottom) Ambient

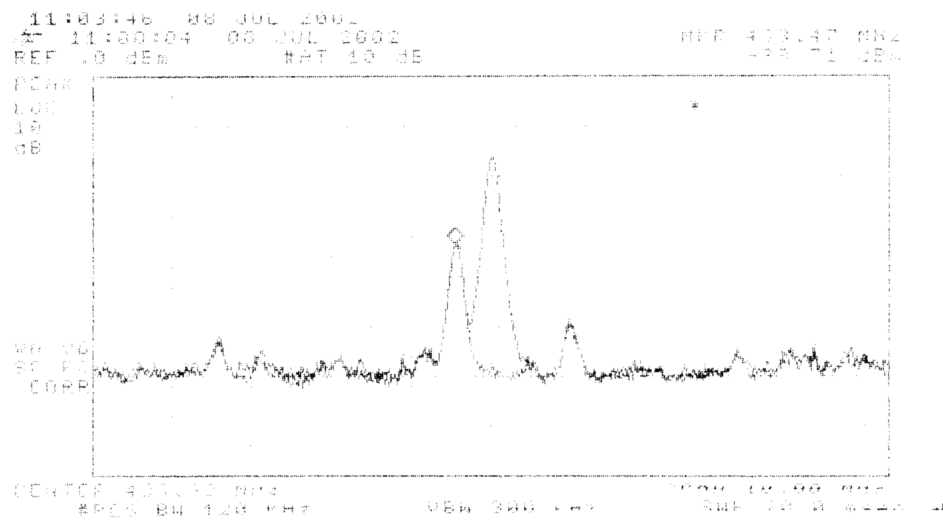


Figure 6.1. Relative receiver emissions in stand-by and "locked-in" modes. The final emission measurements were made with the receiver in "locked-in" mode.

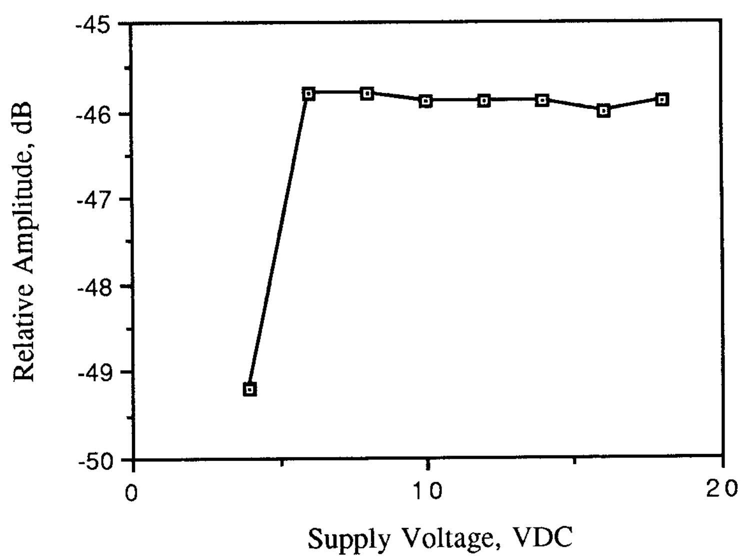


Figure 6.4. Relative emission vs. supply voltage at 433.5 MHz.