The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 764-0500

Measured Radio Frequency Emissions
From

Michelin MEMS Truck Module
Transmitter Report
Model(s): RV2.01

Report No. 415031-311
June 28, 2006

For:
Michelin
515 Michelin Road
Greenville, SC 29615

Contact: Frank Gramling
Tel: (864) 422-4771
Fax: (864) 422-3578
PO: Verbal

Measurements made by: Joseph D. Brunett

Tests supervised by:
Report approved by:
Valdis V. Liepa
Research Scientist

Test Report Prepared by: Joseph D. Brunett

Summary

Tests for compliance with FCC Regulations Part 15, Subpart C, and Industry Canada RSS-210/GEN, were performed on Michelin model(s) RV2.01. 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 3.5 dB (see p. 6). Emissions from digital circuitry meet the Class A emissions limits by 3.0 dB and conducted emission tests do not apply since the device is powered from a 24 VDC vehicle battery source.

1. Introduction

Michelin model RV2.01 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 was designed and manufactured by Michelin, 515 Michelin Road, Greenville, SC 29615. It is identified as:

Michelin Truck Mounted Transceiver
Model(s): RV2.01
FCC ID: FI5-RV201
IC: 5056A-RV201

3.2 Models

There is only one model of the device. The DUT is composed of separate 433.92 MHz transmitter and superheterodyne receiver modules. This report details the emissions relating to the transmitter portion of the device. The DUT contains a 433.92 MHz FSK transmitter which can decode and encode Michelin tire pressure data it receives (retransmission is only performed after signal decoding and identification). It is designed for onboard automobile Tire Pressure data reception and re-transmission, and as such, it is powered from an automotive 24 VDC source. It is housed in a plastic case approximately 5 by 8 by 7 inches. Two exterior dipole antennas are provided by the manufacturer for use with the module, only one acts as a transmitter, while both are capable of diversity reception. Each exterior antenna attaches to the main unit via a TNC connector, and professional installation is required for this device (note statements included in the user's manual).

3.3 Modes of Operation

The device has the ability to re-transmit tire pressure monitor data that is receives and decodes, as well as direct data transmission. This device is subject to FCC 15.231(e), and compliance with 15.231(a) is demonstrated in Figure 6.1 of this report. The DUT ceases transmission within 5 seconds after interrogation by the associated hand held unit or TPM sensor.

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 22 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 3.5 dB.

5.4 Power Line Conducted Emission Testing

These tests do not apply, since the DUT is powered from a 24 VDC battery.

6. Test Results

6.1 Correction For Pulse Operation

When the transmitter is actived it can, in the worst case, transmit one FSK packet with an on time of 19.9 ms in any given 100 ms window. See Figure 6.1. Computing the duty factor results in:

$$K_E = 19.875 \text{ ms} / 100 \text{ ms} = 0.199 \text{ or } -14.0 \text{ dB.}$$

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, 99%) bandwidth is 0.25% of 433.92 MHz, or 1.085 MHz. From the plot we see that the -20 dB bandwidth is 100.0 kHz, and the center frequency is 433.92 MHz.

6.4 Effect of Supply Voltage Variation and Test Battery Voltages

The DUT has been designed to be powered by a 22 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 10 to 30 volts. The emission variation is shown in Figure 6.4.

Test Voltage	V	=	24.2 V
Ave. current from batteries	I	=	55 mA (pulsed)

Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Michelin, RV2; 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	-25.7	Pk	21.5	20.8	68.0	72.9	4.9	flat
2	433.9	Dip	V	-24.3	Pk	21.5	20.8	69.4	72.9	**3.5**	side
3	867.8	Dip	H	-65.2	Pk	27.8	17.5	38.1	52.9	14.8	end
4	867.8	Dip	V	-66.8	Pk	27.8	17.5	36.5	52.9	16.4	flat
5	1301.8	Horn	H	-51.4	Pk	20.7	28.0	34.3	54.0	19.7	flat
6	1735.7	Horn	H	-61.9	Pk	21.9	28.0	25.0	52.9	27.9	noise
7	2169.6	Horn	H	-50.7	Pk	22.9	28.0	37.2	52.9	15.7	flat
8	2603.5	Horn	H	-56.2	Pk	24.1	28.0	32.9	52.9	20.0	flat
9	3037.4	Horn	H	-64.6	Pk	25.5	28.1	25.8	52.9	27.1	noise
10	3471.4	Horn	H	-65.4	Pk	26.8	28.3	26.1	52.9	26.7	noise
11	3905.3	Horn	H	-65.2	Pk	28.1	28.2	27.7	54.0	26.3	noise
12	4339.2	Horn	H	-65.7	Pk	29.5	27.9	28.9	54.0	25.1	noise
13											
14											
15	* Includes 14.0 dB duty factor										
16											
Digital Radiated Emissions - Class A (Industrial)**											
#	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	65.0	Bic	V	-60.0	Pk	7.8	25.5	29.2	40.0	10.8	
2	74.7	Bic	V	-56.5	Pk	7.5	25.4	32.7	40.0	7.3	
3	75.5	Bic	V	-56.7	Pk	7.5	25.4	32.5	40.0	7.5	
4	115.8	Bic	H	-60.2	Pk	9.6	24.7	31.7	43.5	11.8	
5	116.8	Bic	H	-60.1	Pk	9.7	24.7	31.9	43.5	11.6	
6	117.7	Bic	H	-60.4	Pk	9.8	24.7	31.7	43.5	11.8	
7	169.8	Bic	H	-64.3	Pk	13.7	23.9	32.5	43.5	11.0	
8	171.9	Bic	H	-64.1	Pk	13.8	23.9	32.9	43.5	10.6	
9	206.4	Bic	H	-64.0	Pk	14.7	23.4	34.3	43.5	9.2	
10	227.5	Bic	H	-60.8	Pk	14.7	23.2	37.7	46.0	8.3	
11	265.4	SBic	H	-66.0	Pk	16.4	22.8	34.5	46.0	11.5	
12	265.4	SBic	V	-75.8	Pk	16.4	22.8	24.7	46.0	21.3	
13	309.3	SBic	H	-68.4	Pk	18.3	22.3	34.5	46.0	11.5	
14	309.3	SBic	V	-59.9	Pk	18.3	22.3	43.0	46.0	**3.0**	
15	442.4	SBic	H	-69.7	Pk	22.1	20.9	38.5	46.0	7.5	
16	442.4	SBic	V	-76.9	Pk	22.1	20.9	31.3	46.0	14.7	
17											
18											
19											
20	** For devices used in transportation vehicles, digital emissions are exempt from FCC regulations per FCC 1										
											Meas. 6/16/2006; U of Mich.

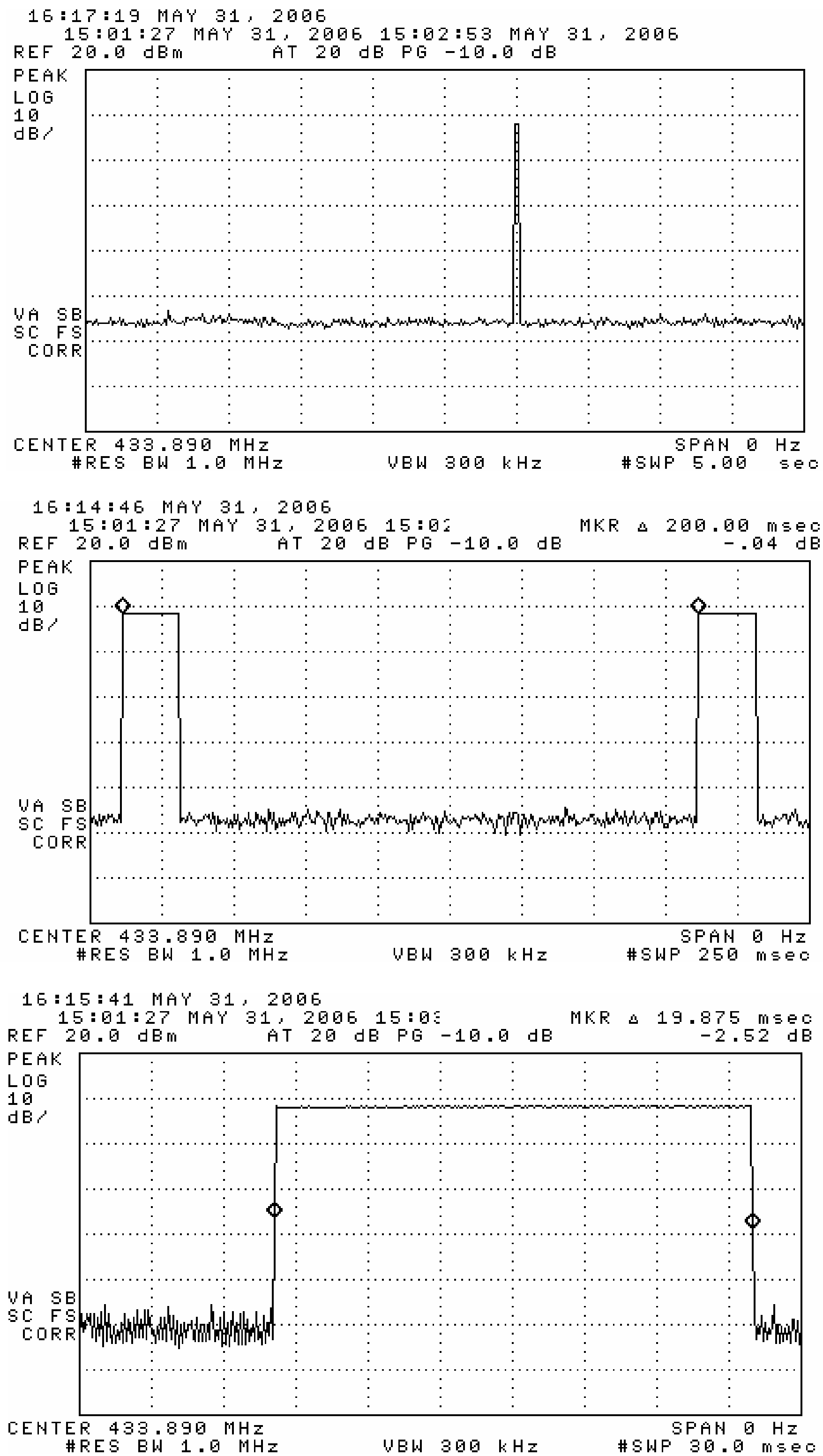


Figure 6.1. Transmissions modulation characteristics: (top) single activation, (center) max. repeated activation, (bottom) expanded word.

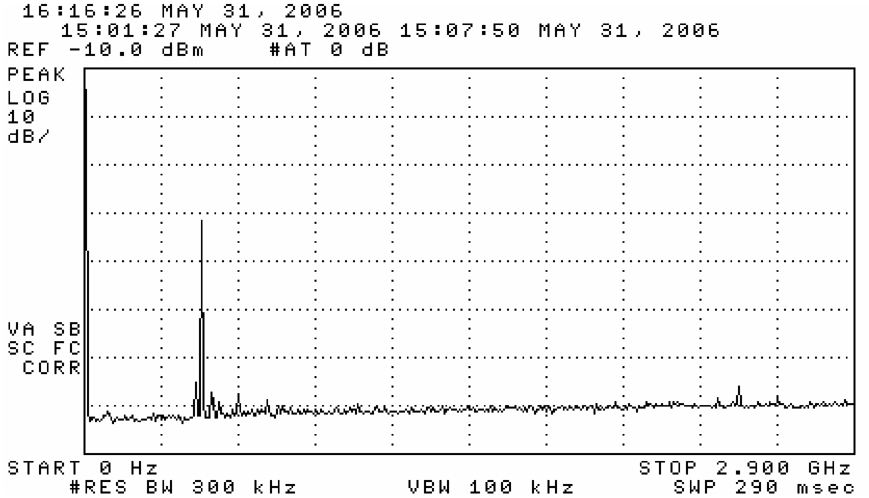


Figure 6.2. Emission spectrum of the DUT (pulsed emission). The amplitudes are only indicative (not calibrated).

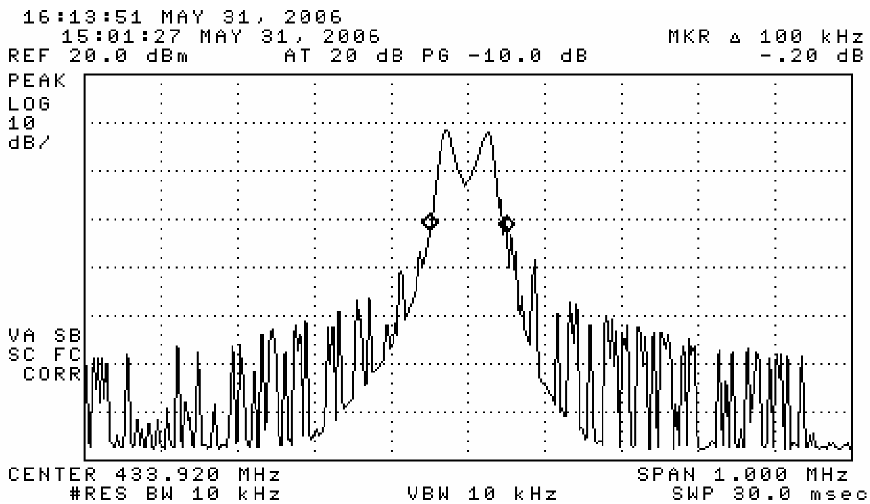


Figure 6.3. Measured bandwidth of the DUT (pulsed emission).

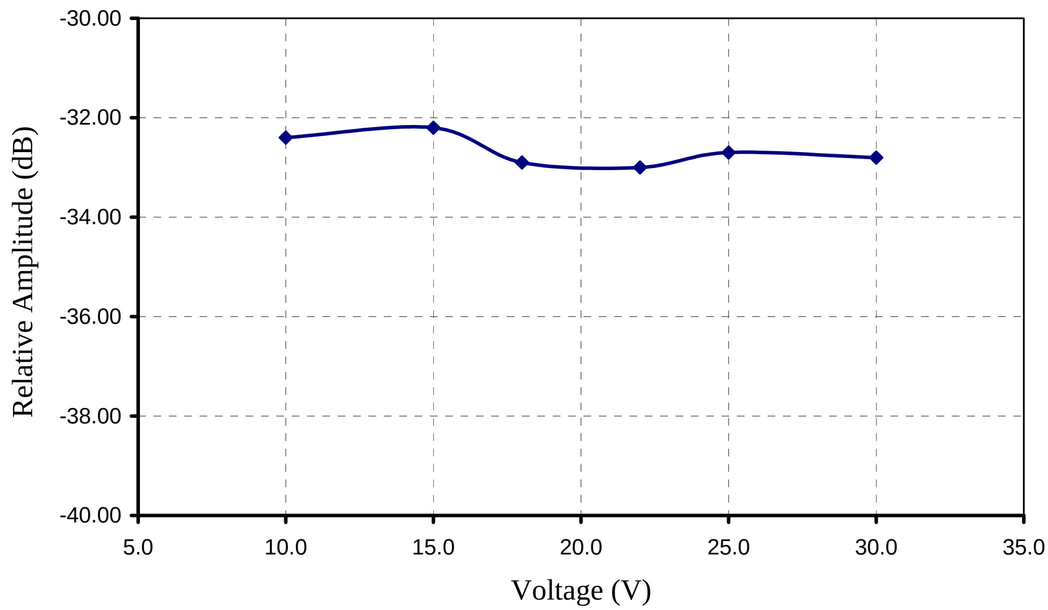
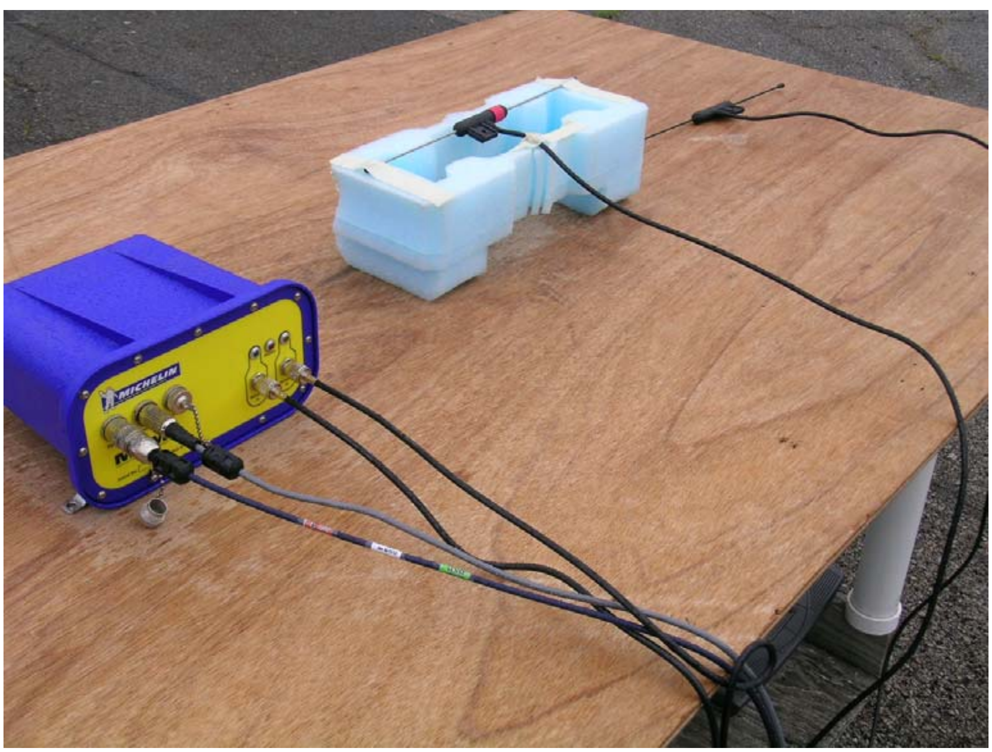


Figure 6.4. Relative emissions at 433.9 MHz vs. supply voltage. (pulsed emission)

DUT on OATS



DUT on OATS (close-up – TX antenna in center)

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 764-0500

Measured Radio Frequency Emissions
From

Michelin MEMS Truck Module
Receiver Report
Model(s): RV2.01

Report No. 415031-312
June 28, 2006

For:
Michelin
515 Michelin Road
Greenville, SC 29615

Contact:
Frank Gramling
Tel: (864) 422-4771
Fax: (864) 422-3578
PO: Verbal

Tests supervised by:
Report approved by: Valdis V. Liepa

Measurements made by: Valdis V. Liepa

Test Report Prepared by: Joseph D. Brunett

Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations Part 15, Subpart B, and Industry Canada RSS-GEN, were performed on Michelin model RV2.01. This device is subject to the Rules and Regulations as a Receiver.

In testing completed on June 21, 2006, the device tested in the worst case met the allowed Class B specifications for radiated emissions by 9.2 dB (see p. 6). The conducted emissions tests do not apply, since the device is powered from a 24 VDC system. Digital emissions are reported in the associated transmitter test report.

1. Introduction

Michelin model RV2.01 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, Issue 6 and RSS-Gen, Issue 1, 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	X	Hewlett-Packard 8657B

3. Configuration and Identification of Device Under Test

3.1 Design and Identification of the Device

The DUT was designed by Michelin, 515 Michelin Road, Greenville, SC 29615.
It is identified as:

Michelin MEMS Receiver
Model(s): RV2.01
FCC ID: FI5-RV201
IC: 5056A-RV201

3.2 Models

There is only one model of the device. The DUT is composed of separate 433.92 MHz transmitter and superheterodyne receiver modules. This report details the emissions relating to the receiver portion of the device. The DUT contains a 433.92 MHz receiver which can decode Michelin tire pressure data it receives. It is designed for onboard automobile Tire Pressure data reception and re-transmission, and as such, it is powered from an automotive 24 VDC source. It is housed in a plastic case approximately 5 by 8 by 7 inches. Two exterior dipole antennas are provided by the manufacturer for use with the module, the two are used to make the device capable of diversity reception. Each exterior antenna attaches to the main unit via a TNC connector, and professional installation is required for this device (note user's manual).

3.3 Modifications Made

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

4. Emission Limits

The DUT tested falls under Part 15, Subpart B, "Unintentional Radiators". 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 (Ref: FCC 15.33, 15.35, and 15.109; IC RSS-210, 2.6 Table 2).

Freq. (MHz)	E_{lim} (3m) μV/m	E_{lim} (3m) dB(μV/m)
30-88	100	40.0
88-216	150 μV/m	43.5
216-960	200 μV/m	46.0
960-2000	500 μV/m	54.0

Note: Quasi-Peak readings apply to 1000 MHz (120 kHz BW)
Average readings apply above 1000 MHz (1 MHz BW)

4.2 Power Line Conducted Emission Limits

Table 4.3 Conducted Emission Limits (FCC:15.107 (CISPR); IC: RSS-Gen, 7.2.2 Table 2).

Frequency MHz	Class A (dBμV)		Class B (dBμV)	
	Quasi-peak	Average	Quasi-peak	Average
.150 - 0.50	79	66	66 - 56*	56 - 46*
0.50 – 5.0	73	60	56	46
5.0 – 30.0	73	60	60	50

Notes:
1. The lower limit shall apply at the transition frequency
2. The limit decreases linearly with the logarithm of the frequency in the range 0.15-0.50 MHz:

*Class B Quasi-peak: dBμV = 50.25 - 19.12*log(f)
*Class B Average: dBμV = 40.25 - 19.12*log(f)

3. 9 kHz RBW

4.3 Antenna Power Conduction Limits
Ref: FCC 15.111(a). Pmax = 2 nW; for frequency range see Table 4.1.

5. Emission Tests and Results

Even though the FCC and Industry Canada specify radiated and conductive emissions be measured using the Quasi-Peak and/or average detection schemes, we normally use peak detection since Quasi-Peak is cumbersome to use with our instrumentation. In case the measurement fails to meet the limits or the measurement is near the limit, it is re-measured using the appropriate detection scheme. Note, a peak detected signal is always greater than or equal to the Quasi-Peak or average detected signal. In this report the margin of compliance may be better, but not worse than that indicated. The type of detection used is indicated in the data table, Table 5.1.

5.1 Semi-Anechoic Chamber Radiated Emission Tests
To become familiar with the emission behavior of the DUT, the device was first studied and measured in a shielded semi-anechoic chamber. In the chamber is a 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.

To study and test for radiated emissions, the DUT was powered by a laboratory power supply at 22 VDC. The receiver was activated, attached to a Styrofoam block, and placed on the test table on each of the three axis. At each orientation, 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. Detection of the LO required the addition of an LNA. 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 less than 3m distance, 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, while those above 1000 MHz (Fig. 5.2) are used in final assessment for compliance.

5.2 Open Area Test Site Radiated Emission Tests
After the chamber measurements are complete, emissions are re-measured on the outdoor 3-meter open area test site up to 1 GHz using tuned dipoles and/or a high frequency biconical antenna. 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 (see Section 5.0). Sometimes lower

IF bandwidth is used to help bring signals out of noise and this is noted in the data table. 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 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 9.2 dB.

5.4 Conducted Emission Tests

These tests do not apply, since the DUT is powered from a 22 VDC system.

6. Other Measurements

6.1 Emission Spectrum

The only detectable RF emission occurs at the LO or 2 x LO. The emission spectrum is measured typically over 1 MHz span. This data is 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 24 VDC power. Using a spectrum analyzer, relative radiated emissions were recorded at the LO or 2 x LO as voltage was varied from 10 to 30.0 VDC. Figure 6.2 shows the emission variation.

6.3 Operating Voltage and Current

V = 24.2 VDC
I = 55 mADC

The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, Michigan 48109-2122
(734) 764-0500

Table 5.1 Highest Emissions Measured

Radiated Emission - RF											Michelin, RV2; 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	423.2	Sbic	H	-78.8	Pk	21.6	21.1	28.7	46.0	17.3	noise
2	423.2	Sbic	V	-76.9	Pk	21.6	21.1	30.6	46.0	15.4	background
3	846.3	Sbic	H	-80.9	Pk	27.9	17.8	36.2	46.0	9.8	background
4	846.3	Sbic	V	-80.3	Pk	27.9	17.8	36.8	46.0	**9.2**	background
5	1000.0	Horn	H	-68.0	Pk	20.6	28.0	31.6	54.0	22.4	max. of all, noise
6	1100.0	Horn	H	-68.3	Pk	21.0	28.1	31.6	54.0	22.4	max. of all, noise
7	1200.0	Horn	H	-65.9	Pk	21.3	28.3	34.1	54.0	19.9	max. of all, noise
8	1300.0	Horn	H	-68.3	Pk	21.4	28.2	31.9	54.0	22.1	max. of all, noise
9	1400.0	Horn	H	-67.9	Pk	21.8	27.9	33.0	54.0	21.0	max. of all, noise
10	1500.0	Horn	H	-68.0	Pk	22.2	28.2	33.0	54.0	21.0	max. of all, noise
11	1600.0	Horn	H	-69.1	Pk	22.4	28.3	32.0	54.0	22.0	max. of all, noise
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
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	* See Transmitter Report										
5											
6											
7											
8											
9	* For devices used in transportation vehicles, digital emissions are exempt from FCC regulations per FCC 15										

Meas. 6/21/2006; U of Mich.

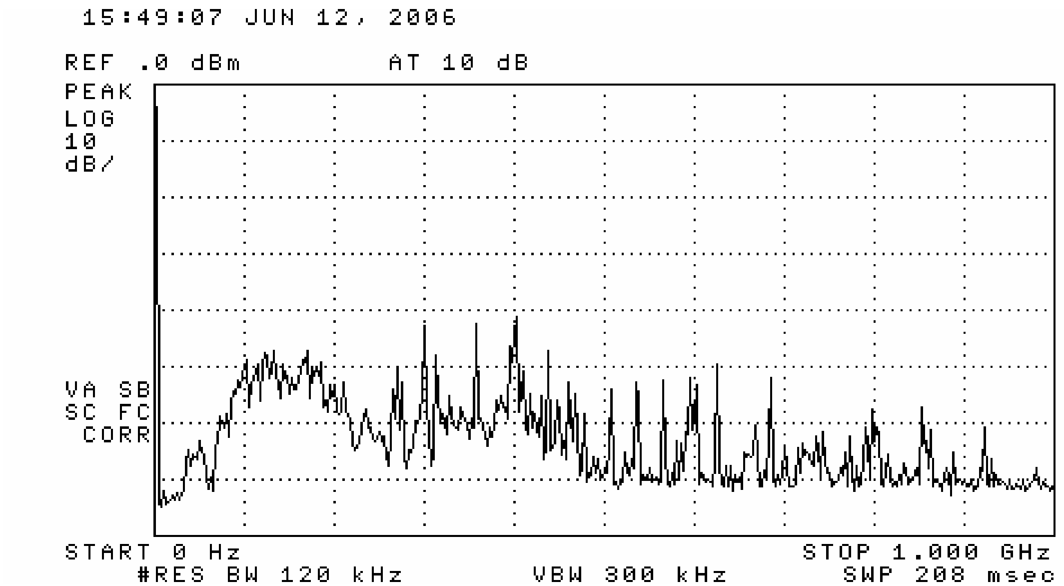


Figure 5.1. Emissions measured at 3 meters in chamber, 0-1000 MHz.

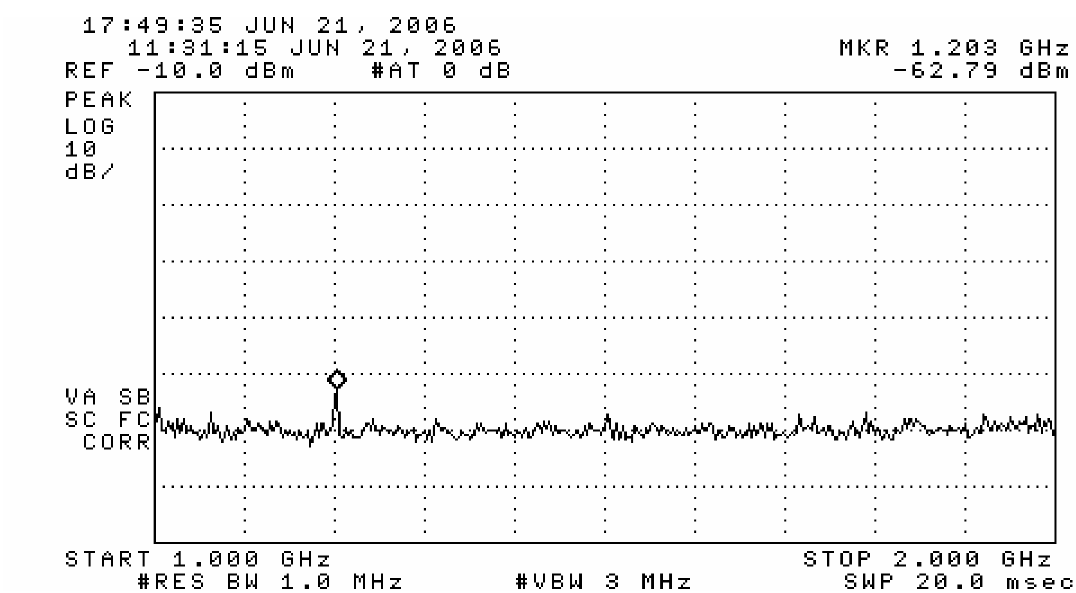


Figure 5.2. Emissions measured at 3 meters in chamber, 1000-2000 MHz.
(emission at marker is background)

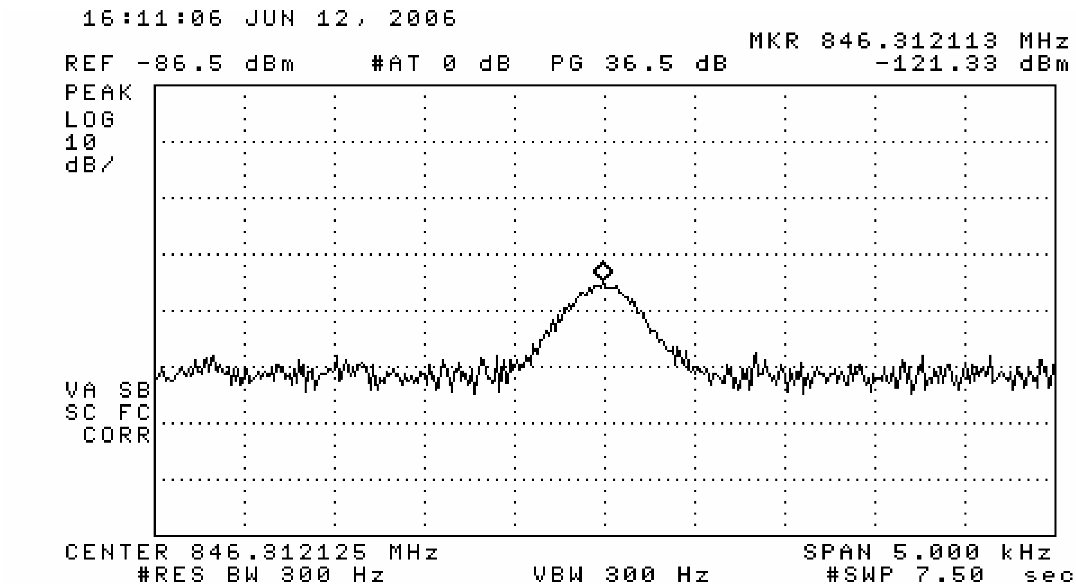


Figure 6.1. Relative receiver emissions.

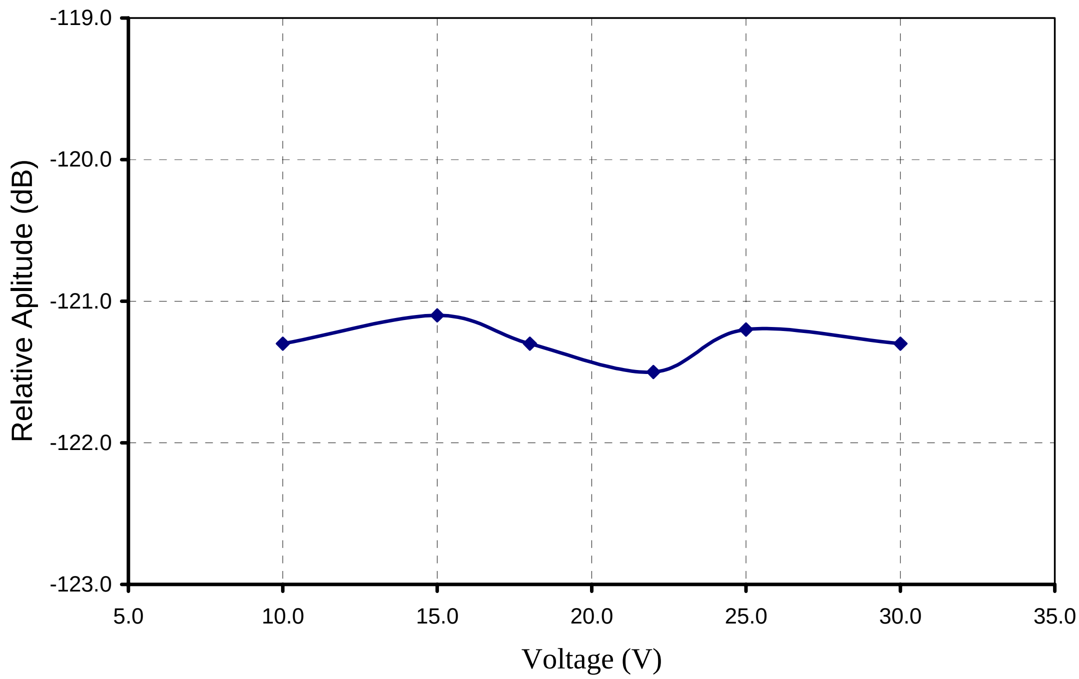
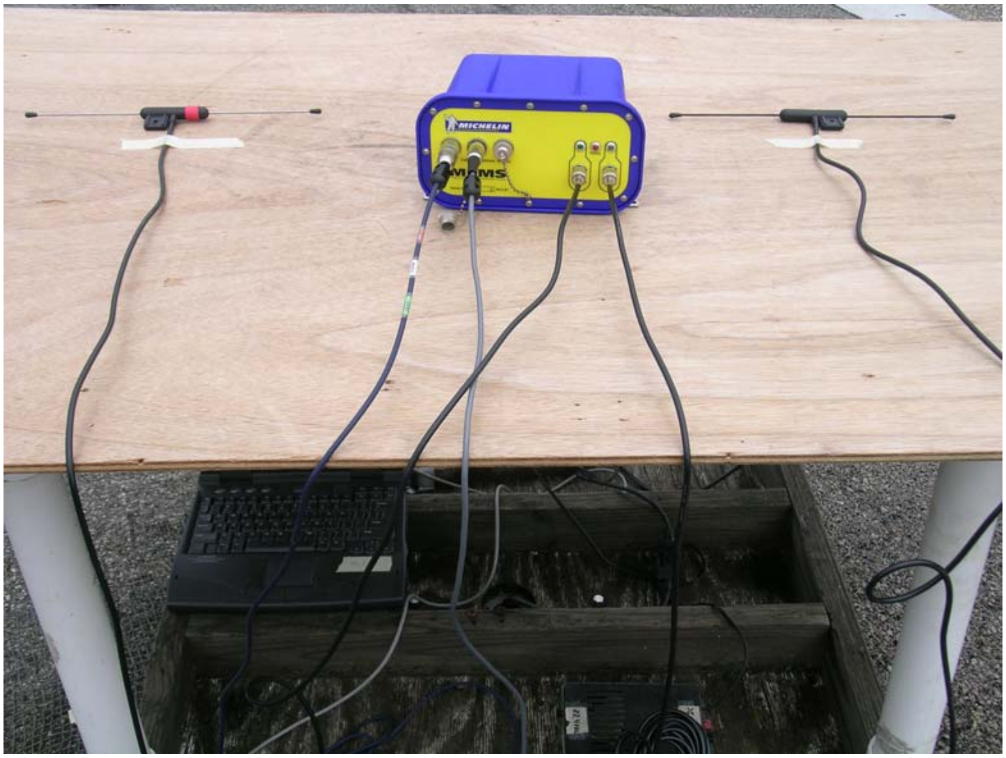


Figure 6.2. Relative emission at vs. supply voltage.

DUT on OATS



DUT on OATS (close-up)