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Measured Radio Frequency Emissions From

Microwave Sensors Pedestrian Monitor Model SmartWalk 1400

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For:
Microwave Sensors
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Summary
Tests for compliance with FCC Regulations, according to Part 15, Subpart C (Intentional Radiators) and B (Digital Devices), were performed on Microwave Sensors Pedestrian Monitor. In testing performed during May 25 through June 9, 1998, the device tested in the worst case met the allowed specifications for outdoor radiated emissions by 8.0 dB (see p. 6). The maximum RF Exposure Level was measured at 0.67 mW/cm2 (see Sec. 6.5).

The (digital) radiated emissions met Class A limits by 9.1 dB (see p. 6); the conducted Class B limits were met by 7.0 dB (see p. 6).

1. Introduction

Microwave Sensors Pedestrian Monitor was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989, plus the new guidelines to measure harmonics up to 200 GHz. 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" and new FCC Section 15.253, "Operation within the bands 46.7-46.9 GHz and 76.0-77.0 GHz". The attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland. (FCC file 31040/SIT)

2. Test Equipment Used

The pertinent test equipment commonly used in our facility for microwave measurements is listed in Table 2.1 below. The second column identifies the specific equipment used in these tests.

Table 2.1. Test Equipment.

Test Instrument	Equipment Used	Manufacturer/Model	Cal. Date/By
Spectrum Analyzer (9kHz-22GHz)		Hewlett-Packard 8593A SN: 3107A01358	July 1997/HP
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3412A01131	June 1997/HP
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8563E SN: 3310A01174	July 1997/HP
Harmonic Mixer (40-60 GHz)	X	Hewlett-Packard 11970U SN: 2332A00500	Febr 1996/HP
Harmonic Mixer (75-110 GHz)	X	Hewlett-Packard 11970W SN: 2521A00179	Febr 1996/HP
X-band horn (8.2- 12.4 GHz)		Narda 640	1970/Manufacturer
K-band horn (18-26.5 GHz)	X	FXR, Inc., K638KF	1970/Manufacturer
Ka-band horn (26.5-40 GHz)	X	FXR, Inc., U638A	1970/Manufacturer
U-band horn (40-60 GHz)	X	Custom Microwave, WR-19	1996/Manufacturer
W-band horn (75-110 GHz)	X	Custom Microwave, WR-10	1996/Manufacturer

3. Configuration and Identification of Device Under Test

The Device Under Test (DUT) is was a CW Doppler radar operating at 24.125 GHz (K-band) with approx. 5 mW rated output. Its application is for pedestrian detection. The unit is 2.5 x 3 x 6 inches and is intended to mount on a pole at pedestrian crossings. The antenna is 0.430 x 0.940 inches (I.D.) horn and is mounted inside the plastic case. A dual harmonic suppression filter is used between the source and the antenna. The unit uses a mirco timed by a 4 MHz clock, and a switching power supply operating at 50 kHz. It is powered by 12-24 VAC/VDC, usually obtained from door-bell transformer. For testing, the power was supplied by 120/24 VAC transformer. In all four 6-foot wires were attached to the DUT: two power, two relay out

The DUT was designed and manufactured by Microwave Sensors, 7885 Jackson Road, Ann Arbor, MI 48103. It is identified as:

Microwave Sensors Pedestrian Monitor
Model: SmartWalk 1400
S/N: PROTO4
FCC ID: BJD951400
CAN:

To supply the 24 VAC, an Ault Transformer, 120/24 VAC (0.41 A), PN 306-4024-000E, was supplied and used in the tests.

3.1 Changes made to the DUT
None.

4. Microwave Emission Limits

The DUT tested falls under Part 15, Subpart C (Intentional Radiators) and Subpart B (Digital Devices).

4.1 Radiated Emission Limits
For radiated emissions the applicable testing frequencies with corresponding emission limits are given in Table 4.1.

Table 4.1. Emission Limits (ref. 15.205, 15.209, 15.245).

Fundamental Frequency (MHz)	Fundamental Ave. E_{lim}(3m) (mV/m)	dB(μV/m)	Harmonics* Ave.E_{lim}(3m) (mV/m)	dB(μV/m)	Spurious** Ave.E_{lim}(3m) (mV/m)	dB(μV/m)	Application
24075-24175	2500	128	25.0	88.0	7.943	78	indoor
24075-24175	2500	128	7.5	77.5	0.7943	58	other

* Measure up to 100 GHz
** Other than fundamental and harmonics

4.2 Conductive Emission Limits
The conductive emission limits for intentional radiator are 250 mV, 450 kHZ to 30 MHz. This is same level as for a digital device, Class B.

4.3 (Digital) Radiated Emission Limits

Table 4.2. Radiated Emission Limits (Ref: 15.33, 15.35, 15.109) -- Digital.

Freq. (MHz)	Class A, E_{lim} dB(μV/m)	Class B, E_{lim} dB(μV/m)
30-88	49.5	40.0
88-216	54.0	43.5
216-960	56.9	46.0
960-2000	60.0	54.0

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

Because the device tested would be used outdoors, it must meet, at least, Class A limits.

5. Radiated Emission Tests and Results

5.1 Test Procedure

Prior to any measurements, all active components of the test setup were allowed a warm-up for a period of approximately one hour as recommended by their manufacturers.

To familiarize with emissions, the unit is held within a meter or less of the receiving antenna and the spectrum scanned from the fundamental through the harmonics.

For the tests, the unit is placed on the pedestal at a 3 or 1 (or even 0.25m) meter distance, depending on the available signal strength, and rotated through 360 degrees to determine the most intense radiation lobe. Due to the rigid connection of the receive antenna to the spectrum analyzer, the DUT is also rotated around its antenna axes to match the polarizations of the emission for maximum reading. Once the maximum lobe and polarization is found, both its maximum intensity and frequency are recorded. Figure 5.1 is a photograph of the measurement set-up.

5.2 Measurements

Starting scans at the fundamental, there were no detectable emissions other than the fundamental and the three harmonics. Table 5.1 shows the received power levels measured at these frequencies. Measurements were made with the normal CW emission. The spectrum analyzer was set to 1 MHz resolution bandwidth and 100 Hz video resolution bandwidth to produce the average readings.

After the in chamber (microwave) measurements, the digital emissions were measured on our outdoor 3-meter site. The measurements were made using standard digital equipment measurement procedures using 100 kHz resolution bandwidth.

5.3 Computations and Results

When the measurement is made at a distance other than 3m, the reading is extrapolated to the 3m. This is done using the 20 dB/decade field behavior relation when translating in the far field ,and 40 dB/decade relation when translating in the near field. The near-field/far-field criterion, N/F, is determined from

$$N/F = 2*D*D/wavelength$$

where D is the max. of the transmitter or receiver antenna dimension, and wavelength is that of the frequency measured. Suppose N/F = 2 m and the measurement is made at 1 m. Here the 40 dB/ decade relation is applied from 1 to 2 m, and 20 dB/decade relation is applied from 2 to 3 m. In dBs, this gives a 15.6 dB adjustment.

To convert the dBms measured or extrapolated to 3 m, the E_3(dBmV/m) is computed from

$$E_3(\text{dBmV/m}) = 107 + P_R + K_A + K_E$$

where P_R = power recorded on spectrum analyzer, dBm (or extrapolated to 3 m distance)
K_A = antenna factor, dB/m
K_E = pulse operation correction factor, dB (see 6.1)

For microwave measurements, either the receive antenna is connected directly to the spectrum analyzer (up to 26 GHz), or it is connected to the mixer followed by an insignificant length cables. Hence, no cable loss term is used. The mixer conversion losses are programmed in the spectrum analyzer and are included in the dB values.

The results are given in Table 5.1. There we see that the DUT meets radiated microwave emission level by 8.0 dB at 48.25 GHz. The radiated digital emissions are met by 9.1 dB, Class A.

6. Other Measurements and Computations

6.1 Spectrum of the fundamental (15.209, 15.245(b)(3)).

Figure 6.1 is a plot of spectrum at fundamental emission. The -50 dB bandwidth is 1.38 MHz, and falls well within the +/-50 MHz limits. The center frequency is 24.127GHz.

6.2 Correction for Pulse Operation (Ref. 15.35)

None (K_E = 0 dB).

6.3 Effect of Supply Voltage Variation

The DUT has been designed to operate from 115 VAC mains via 24 volt transformer. Using a spectrum analyzer, the relative radiated emissions and frequency were recorded at the "fundamental" (24.125 GHz) as the supply voltage was varied from 30 to 143 VAC. Figure 6.2 shows the emission power variation and figure 6.3 shows the emission frequency variation. The current at 24 VAC is 96.2 mA.

6.4 Conducted Emission Measurements

These measurements were made on the DUT, plus the 24 V transformer. Standard FCC/IC measurement procedures were used and the dominant emissions are presented in Table 5.1. From there we see that the DUT meets the Class B limits by 7.0 dB.

6.5 Potential Health Hazard EM Radiation Level

The maximum radiation level from the unit was determined by using an open-end waveguide probe feeding directly into a spectrum analyzer. In case the 1 mW/cm2 limit is exceeded, the maximum distance from the DUT is determined by measurement where the field density is 1 mW/cm2.

An open-end waveguide probe is as basic as a standard gain horn. Their characteristics have been extensively studied and experimentally verified. (Yaghjian, IEEE/APS pp. 378-384, April, 1984.) For the K-band (WR-42) waveguide at 24.125 GHz, for open-end waveguide Gain is 7.07 dBi and this equates to Aeq = 0.626 cm2 giving p(mW/cm2) = 1.60 P(mW) where P(mW) is power received.

For the subject DUT , the max. power measured was -1.75 dBm or power density of 0.67 mW/cm2. This was at the surface of the plastic case, i.e., the radome.

Table 5.1 Highest Emissions Measured

Microwave Radiated Emissions

Microwave Sensors,1400

#	Freq. GHz	Ant. Used	Ant. D,cm	Meas. dist., m	Pr dBm	N/F m	Pr(3m) dBm	Ka dB/m	Kg dB	E3 dBμV/m	E3lim dBμV/m	Pass dB	Comments
1	24.13	K-horn	10.2	3.00	-30.5	1.68	-30.5	32.2	0.0	108.7	128.0	19.3	
2	48.25	U-horn	4.6	1.00	-68.8	0.68	-78.3	40.8	0.0	69.5	77.5	**8.0**	
3	72.38	W-horn	2.5	0.25	-64.5	0.30	-88.2	45.1	0.0	63.9	77.5	13.6	Noise floor
4	96.50	W-horn	2.5	0.25	-61.4	0.40	-87.1	46.5	0.0	66.4	77.5	11.1	Noise floor

NOTES:

- Mixer conversion loss is programmed in the spectrum analyzer and automatically adjusts the readings
- When extrapolating to 3 m, use Near (40 dB/dec) and Far Fld (20 dB/dec) behavior
- To obtain Ave. measurement, a 100 Hz VBW was used; RBW was 1 MHz
- DUT max. antenna size, D= 2.39 cm

Digital Radiated Emissions, Class A

#	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	33.5	Bic	V	-67.0	Pk	13.4	26.2	27.2	49.5	22.3	Noise like signal
2	48.0	Bic	H	-70.0	Pk	11.7	25.9	22.8	49.5	26.7	Noise like signal
3	52.0	Bic	V	-58.0	Pk	11.4	25.9	34.5	49.5	15.0	Noise like signal
4	70.0	Bic	V	-52.0	Pk	11.0	25.6	40.4	49.5	**9.1**	Noise like signal
5	81.0	Bic	H	-58.0	Pk	11.2	25.4	34.8	49.5	14.7	Noise like signal
6	109.5	Bic	H	-67.0	Pk	12.6	25.0	27.6	54.0	26.4	
7	109.5	Bic	V	-64.0	Pk	12.6	25.0	30.6	54.0	23.4	Noise like signal
8	144.0	Bic	V	-73.0	Pk	14.5	24.5	24.0	54.0	30.0	
9	147.0	Bic	V	-72.0	Pk	14.6	24.4	25.2	54.0	28.8	
10	150.0	Bic	H	-74.0	Pk	14.7	24.4	23.3	54.0	30.7	
11											
12											
13											
14											
15											
16											
17											
18											
19											

Conducted Emissions, Class B

#	Freq. MHz	Line Side	Det. Used	Vtest dBμV	Vlim dBμV	Pass dB	Comments
1	16.80	Hi	Pk	35	48.0	13.0	
2	18.30	Hi	Pk	38	48.0	10.0	
3	17.80	Lo	Pk	40	48.0	8.0	
4	19.30	Lo	Pk	41	48.0	**7.0**	

Mea

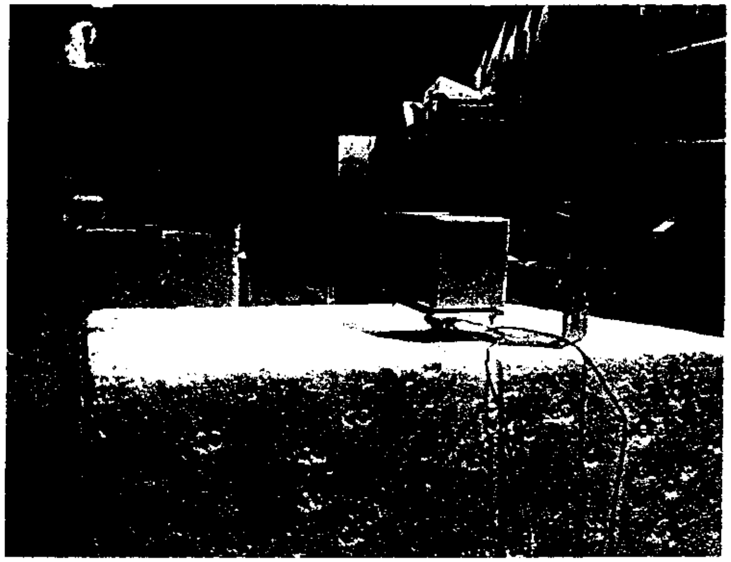

Figure 5.1. DUT tested at fundamental.

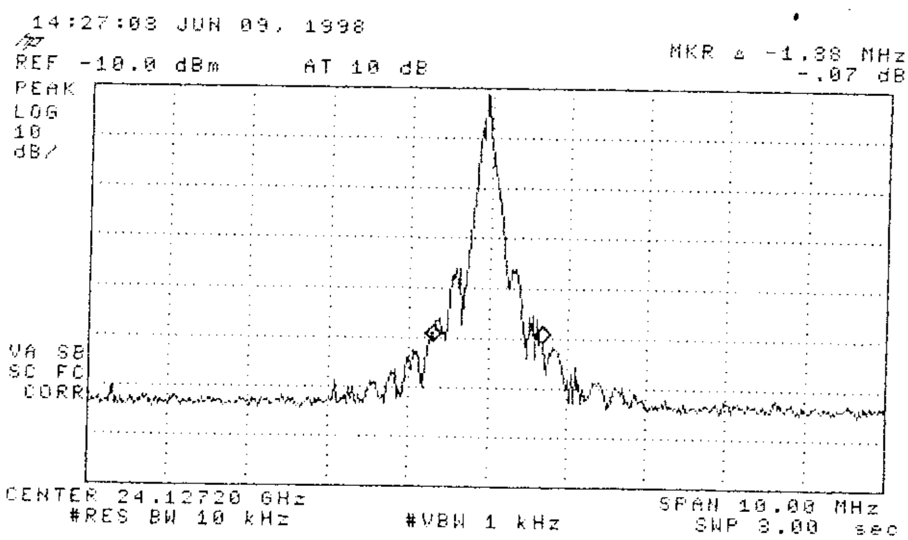

Figure 6.1. Fundamental emission spectrum.

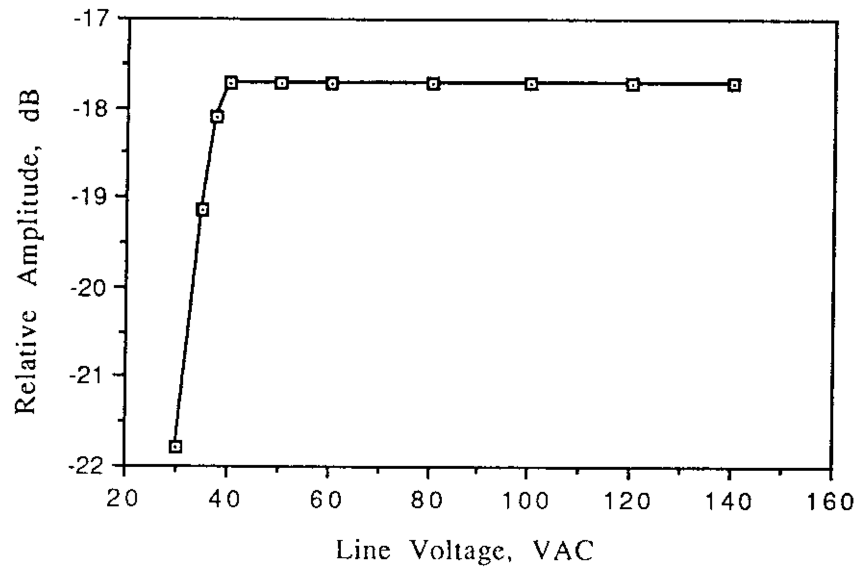

Figure 6.2. Relative emission at fundamental vs. supply voltage.

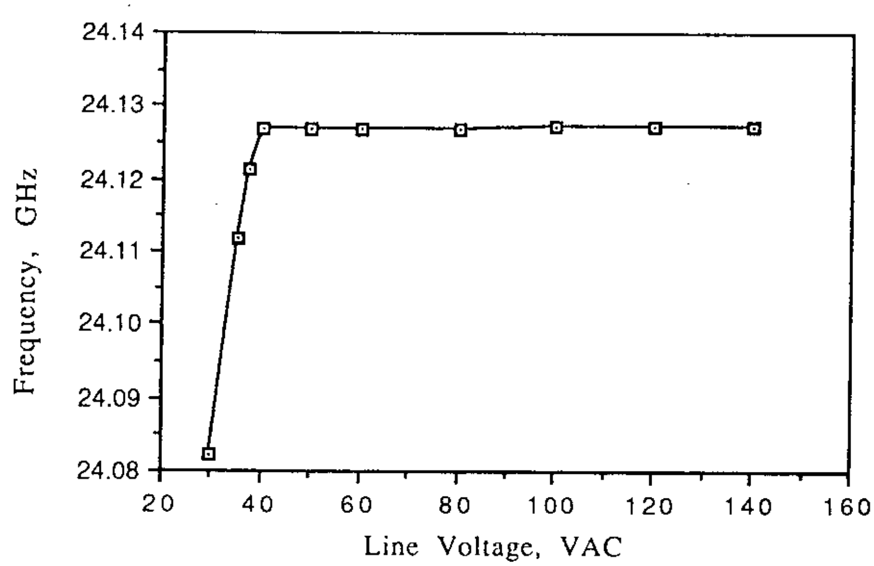

Figure 6.3. Fundamental frequency vs. supply voltage.