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Measured Radio Frequency Emissions
From

USM Systems Transmitter
Model: CR2A-USMS

Report No. 415031-196
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For:
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Summary

Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-210, were performed on USM Systems, Ltd transmitter, model CR2A-USMS. This device is subject to Rules and Regulations as a transmitter.

In testing completed January 28, 2004, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 19.8 dB (see p. 7); digital emissions, Class A, were met by 2.2 dB (see p. 7); FCC/CISPR Class A conducted were met by 2.8 dB (see p. 7).

1. Introduction

USM Systems model CR2A-USMS 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, 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 Procedures 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)	X	EMCO 6502, SN:2855
Ridge-horn Antenna (300-5000 MHz)	X	University of Michigan
Amplifier (5-1000 MHz)	X	Avantek, A11-1, A25-1S
Amplifier (5-4500 MHz)	X	Avantek
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. Configurations and Identification of Device Under Test

The DUT is an industrial use RFID system. This system consists of a 154 kHz Tx / 115 kHz Rx module with varying LF loop antenna sizes. (An assortment of antenna sizes have been tested, limited to a maximum loop size of 24 sq. ft. with 3 turns.) A active transponder (FCC ID: JHD-CEN1,2,3,4) is used to communicate with the system. The loop antenna is connected to a series capacitor jumper box for resonating the antenna at the Tx operating frequency (154 kHz). From the capacitor box, 25 ft of twisted pair multi-conductor wire runs to the control box. Within the control box is the AC power supply, LF driver circuitry, and RS-232 interface. Another 25 ft. of RS-232 cable is used to connect the control box to a Laptop computer that receives id numbers from a transponder, as detected by the DUT.

The DUT was designed and manufactured by USM Systems, Ltd, Suite 200, 2998 Eleven Mile Road, Berkley, MI 48072. It is identified as:

USM Systems, Ltd Transmitter
Model: CR2A-USMS
FCC ID: RMM-USMS2A-A

This test report demonstrates that this device is compliant with the FCC rules and regulations as a LF transmitter for all loop antennas with a minimum effective area of 2 ft^2 (2 ft^2 x 1 turn) and a maximum effective area of 72 ft^2 (24 ft^2. x 3 turns).

3.1 EMI Relevant Modifications

No EMI Relevant Modifications were performed by this test laboratory.

4. Emission Limits

4.1 Radiated Emission Limits

The DUT tested falls under the category of an Intentional Radiators and the Digital Devices, subject to Subpart C, Section 15.209; and Subpart B, Section 15.109 (transmitter generated signals excluded); and Subpart A, Section 15.33. The applicable testing frequencies with corresponding emission limits are given in Tables 4.1 and 4.2 below. As a digital device, it is exempt.

Table 4.1. Radiated Emission Limits (FCC: 15.205, 15.35; IC: RSS-210 (6.2.2(r), 6.3)). (Transmitter)

Frequency (MHz)	Fundamental and Spurious* (μV/m)
0.009-0.490 0.490-1.705	2400/F(kHz), 300m 24,000/F(kHz), 30m
0.090-0.110 0.49-0.51	Restricted Bands

* Harmonics must be below the fundamental.

For extrapolation to other distances, see Section 6.6.

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

4.2 Conductive Emission Limits

Table 4.3 Conducted Emission Limits (FCC:15.107 (CISPR); IC: RSS-210, 6.6).

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	73	60	56	46
5 - 30	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

5. Radiated Emission Tests and Results

5.1 Anechoic Chamber Measurements

To become familiar with the radiated emission behavior of the DUT, the DUT was first studied and measured in a 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 this case, the receiving antenna was an active loop, placed on a tripod, approximately 1.5 meters above ground.

The DUT was laid on the test table as seen in the Attachment-Test Setup Photos. Using the loop antenna we studied emissions up to 2 MHz. The spectrum analyzer resolution and video bandwidths were usually set to 1 kHz, and sometimes to 300 Hz. Emissions were studied with the plane of the loop perpendicular and parallel to the direction of propagation from the DUT. In the chamber we also recorded the spectrum and modulation characteristics of the carrier. These data are presented in subsequent sections

5.2 Outdoor Measurements
After the chamber measurements, the emissions on our outdoor 3-meter site were measured. For transmitter emissions a loop antenna was used; the resolution bandwidth was usually 1 kHz. See Appendix for measurement set-up. For digital emissions bicone and dipole antennas were used. See Section 6.6 for field extrapolation of transmitter data from 3 m to 300 m.

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

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

where P_R = power recorded on spectrum analyzer, dB, measured at 3 m
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)
C_F = 3/300 m or 3/30 m conversion factor, 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 as a transmitter, the DUT meets the limit by 19.8 dB.

Pre-testing demonstrated that the worst case digital emissions, for all the antenna configurations tested, occurred with the 6 ft^2 x 3 turn antenna attached. The test data for this configuration is given in Table 5.1-B, where it is demonstrated that digital emissions, FCC Class A, were met by 2.2 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation
The DUT modulation consists of 4.50 ms wide pulses with a period of 9.67 ms. See Figure 6.1.
Thus,

$$K_E = 4.50/9.67 = 0.465 \text{ or } -6.64 \text{ dB}.$$

This correction factor is only applicable below 490 kHz.

6.2 Emission Spectrum
Using the loop antenna, the 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. From the plot we see that the -20 dB bandwidth is 40.1 kHz, and the emission are -36.3 dB down from the peak at 110 kHz.

6.4 Effect of Supply Voltage Variation
For this test, the relative power radiated was measured at the fundamental as the voltage was varied from 40 to 140 VAC. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

V = 120 VAC

I = 28.5 mAAC (pulsed emission)

6.6 Field Behavior at 154 kHz

Because at the specified 300/30 m measurement distance the signal is too small to measure, measurements were made at 3 m. To translate the measurement from 3 m or 10 m to the 300/30 m distance, we computed the field behavior for a Hertzian (small loop) dipole using equations found in most antenna books, such as, Balanis Antenna Theory Analysis and Design, 1997 John Wiley & Sons, 2nd Edition, pg. 207-208. The applicable results that we need are:

For measurements at 3 m distance:

Freq (kHz)	H-component	Extrapolated Position	Correction (dB)	Notes
154	Vertical – Radial	3m/300m	117.1 dB	Axial coupling
154	Vertical –Transverse	3m/300m	120.3 dB	Planar coupling
154	Horizontal –Transverse	3m/300m	120.3 dB	Planar coupling
308	Vertical – Radial	3m/300m	113.2 dB	Axial coupling
308	Vertical –Transverse	3m/300m	109.5 dB	Planar coupling
308	Horizontal –Transverse	3m/300m	109.5 dB	Planar coupling
462	Vertical – Radial	3m/300m	110.3 dB	Axial coupling
462	Vertical –Transverse	3m/300m	102.0 dB	Planar coupling
462	Horizontal –Transverse	3m/300m	102.0 dB	Planar coupling
616	Vertical – Radial	3m/30m	59.4 dB	Axial coupling
616	Vertical –Transverse	3m/30m	60.6 dB	Planar coupling
616	Horizontal –Transverse	3m/30m	60.6 dB	Planar coupling
770	Vertical – Radial	3m/30m	59.1 dB	Axial coupling
770	Vertical –Transverse	3m/30m	60.8 dB	Planar coupling
770	Horizontal –Transverse	3m/30m	60.8 dB	Planar coupling
924	Vertical – Radial	3m/30m	58.8 dB	Axial coupling
924	Vertical –Transverse	3m/30m	61.1 dB	Planar coupling
924	Horizontal –Transverse	3m/30m	61.1 dB	Planar coupling
1078	Vertical – Radial	3m/30m	58.4 dB	Axial coupling
1078	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1078	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1232	Vertical – Radial	3m/30m	58.0 dB	Axial coupling
1232	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1232	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1386	Vertical – Radial	3m/30m	57.6 dB	Axial coupling
1386	Vertical –Transverse	3m/30m	60.8 dB	Planar coupling
1386	Horizontal –Transverse	3m/30m	60.8 dB	Planar coupling
1540	Vertical – Radial	3m/30m	57.2 dB	Axial coupling
1540	Vertical –Transverse	3m/30m	60.2 dB	Planar coupling
1540	Horizontal –Transverse	3m/30m	60.2 dB	Planar coupling

For measurements at 10 m distance:

Freq (kHz)	H-component	Extrapolated Position	Correction (dB)	Notes
154	Vertical – Radial	10m/300m	85.8 dB	Axial coupling
154	Vertical –Transverse	10m/300m	88.9 dB	Planar coupling
154	Horizontal –Transverse	10m/300m	88.9 dB	Planar coupling
308	Vertical – Radial	10m/300m	81.9 dB	Axial coupling
308	Vertical –Transverse	10m/300m	78.1 dB	Planar coupling
308	Horizontal –Transverse	10m/300m	78.1 dB	Planar coupling
462	Vertical – Radial	10m/300m	78.9 dB	Axial coupling
462	Vertical –Transverse	10m/300m	70.6 dB	Planar coupling
462	Horizontal –Transverse	10m/300m	70.6 dB	Planar coupling
616	Vertical – Radial	10m/30m	28.1 dB	Axial coupling
616	Vertical –Transverse	10m/30m	29.2 dB	Planar coupling
616	Horizontal –Transverse	10m/30m	29.2 dB	Planar coupling
770	Vertical – Radial	10m/30m	27.8 dB	Axial coupling
770	Vertical –Transverse	10m/30m	29.4 dB	Planar coupling
770	Horizontal –Transverse	10m/30m	29.4 dB	Planar coupling
924	Vertical – Radial	10m/30m	27.5 dB	Axial coupling
924	Vertical –Transverse	10m/30m	29.6 dB	Planar coupling
924	Horizontal –Transverse	10m/30m	29.6 dB	Planar coupling
1078	Vertical – Radial	10m/30m	27.2 dB	Axial coupling
1078	Vertical –Transverse	10m/30m	29.7 dB	Planar coupling
1078	Horizontal –Transverse	10m/30m	29.7 dB	Planar coupling
1232	Vertical – Radial	10m/30m	26.9 dB	Axial coupling
1232	Vertical –Transverse	10m/30m	29.5 dB	Planar coupling
1232	Horizontal –Transverse	10m/30m	29.5 dB	Planar coupling
1386	Vertical – Radial	10m/30m	26.5 dB	Axial coupling
1386	Vertical –Transverse	10m/30m	29.2 dB	Planar coupling
1386	Horizontal –Transverse	10m/30m	29.2 dB	Planar coupling
1540	Vertical – Radial	10m/30m	26.2 dB	Axial coupling
1540	Vertical –Transverse	10m/30m	28.5 dB	Planar coupling
1540	Horizontal –Transverse	10m/30m	28.5 dB	Planar coupling

In the data table, Tables 5.1, the measured field is decreased by the dB values given above to represent the field at 300m or 30m, which ever is applicable.

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Table 5.1(a) Highest Emissions Measured

Transmitter Radiated Emissions												USMS 1T 2 sq. ft.; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 3/30/300 m	E300* dBµV/m	E300lim dBµV/m	Pass dB	Comments
1	154.0	Loop	V/perp	-30.9	Pk	9.9	0.0	117.1	-37.8	23.9	**61.6**	loop perp. (axia in dir. of prop.)
2	154.0	Loop	V/par	-36.2	Pk	9.9	0.0	120.3	-46.2	23.9	70.1	loop paral. (loop in dir. of prop.)
3	154.0	Loop	H, CP	-39.2	Pk	9.9	0.0	120.3	-49.2	23.9	73.1	loop horiz. (loop in horiz. plane)
4	308.0	Loop	V/perp	-55.4	Pk	9.8	0.0	113.2	-58.5	17.8	76.3	noise
5	308.0	Loop	V/par	-54.7	Pk	9.8	0.0	109.5	-54.0	17.8	71.8	noise
6	308.0	Loop	H, CP	-69.2	Pk	9.8	0.0	109.5	-68.5	17.8	86.3	noise
7	462.0	Loop	V/perp	-48.5	Pk	9.8	0.0	110.3	-48.6	14.3	62.9	background rf
8	462.0	Loop	V/par	-53.5	Pk	9.8	0.0	102.0	-45.3	14.3	59.6	background rf
9	462.0	Loop	H, CP	-54.8	Pk	9.8	0.0	102.0	-46.6	14.3	60.9	background rf
10	616.0	Loop	V/perp	-47.4	Pk	9.8	0.0	59.4	10.0	31.8	21.8	background rf
11	616.0	Loop	V/par	-50.2	Pk	9.8	0.0	60.6	6.0	31.8	25.8	background rf
12	616.0	Loop	H, CP	-60.0	Pk	9.8	0.0	60.6	- 3.8	31.8	35.6	noise
13	770.0	Loop	V/perp	-37.2	Pk	9.8	0.0	59.1	20.5	29.9	9.4	background rf
14	770.0	Loop	V/par	-38.2	Pk	9.8	0.0	60.8	17.8	29.9	12.1	background rf
15	770.0	Loop	H, CP	-39.9	Pk	9.8	0.0	60.8	16.1	29.9	13.8	background rf
16	924.0	Loop	All	-46.1	Pk	9.8	0.0	58.8	11.9	28.3	16.4	background rf
17	1078.0	Loop	All	-42.8	Pk	9.8	0.0	58.4	15.6	27.0	11.4	background rf
18	1232.0	Loop	All	-46.3	Pk	9.8	0.0	58.0	12.5	25.8	13.3	background rf
19	1386.0	Loop	All	-56.4	Pk	9.8	0.0	57.6	2.8	24.8	22.0	noise
20	1540.0	Loop	All	-63.0	Pk	9.8	0.0	57.2	- 3.4	23.9	27.3	noise
21												
22												
23												
24	Measured at 3 m distance											
25	6.64 dB Duty Factor Applied below 490 kHz											
26												
27												
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Meas.09/30/2003; U of Mich.

Table 5.1(b) Highest Emissions Measured

Transmitter Radiated Emissions												USMS 2T 6 sq. ft.; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 3/30/300 m	E300* dBµV/m	E300lim dBµV/m	Pass dB	Comments
1	154.0	Loop	V/perp	-26.8	Pk	9.9	0.0	117.1	-33.7	23.9	**57.5**	loop perp. (axia in dir. of prop.)
2	154.0	Loop	V/par	-32.0	Pk	9.9	0.0	120.3	-42.0	23.9	65.9	loop paral. (loop in dir. of prop.)
3	154.0	Loop	H, CP	-33.1	Pk	9.9	0.0	120.3	-43.1	23.9	67.0	loop horiz. (loop in horizontal plar
4	308.0	Loop	V/perp	-47.8	Pk	9.8	0.0	113.2	-50.9	17.8	68.7	loop perp.
5	308.0	Loop	V/par	-47.5	Pk	9.8	0.0	109.5	-46.8	17.8	64.6	background rf
6	308.0	Loop	H, CP	-68.6	Pk	9.8	0.0	109.5	-67.9	17.8	85.7	noise
7	462.0	Loop	V/perp	-44.2	Pk	9.8	0.0	110.3	-44.3	14.3	58.6	loop perp.
8	462.0	Loop	V/par	-53.5	Pk	9.8	0.0	102.0	-45.3	14.3	59.6	background rf
9	462.0	Loop	H, CP	-58.4	Pk	9.8	0.0	102.0	-50.2	14.3	64.5	loop horiz.
10	616.0	Loop	V/perp	-30.8	Pk	9.8	0.0	59.4	26.6	31.8	5.2	background rf
11	616.0	Loop	V/par	-35.6	Pk	9.8	0.0	60.6	20.6	31.8	11.2	background rf
12	616.0	Loop	H, CP	-58.0	Pk	9.8	0.0	60.6	- 1.8	31.8	33.6	noise
13	770.0	Loop	V/perp	-36.4	Pk	9.8	0.0	59.1	21.3	29.9	8.6	background rf
14	770.0	Loop	V/par	-33.5	Pk	9.8	0.0	60.8	22.5	29.9	7.4	background rf
15	770.0	Loop	H, CP	-46.8	Pk	9.8	0.0	60.8	9.2	29.9	20.7	background rf
16	924.0	Loop	All	-48.4	Pk	9.8	0.0	58.8	9.6	28.3	18.7	background rf
17	1078.0	Loop	All	-45.0	Pk	9.8	0.0	58.4	13.4	27.0	13.6	background rf
18	1232.0	Loop	All	-48.9	Pk	9.8	0.0	58.0	9.9	25.8	15.9	background rf
19	1386.0	Loop	All	-53.3	Pk	9.8	0.0	57.6	5.9	24.8	18.9	background rf
20	1540.0	Loop	All	-62.4	Pk	9.8	0.0	57.2	- 2.8	23.9	26.7	noise
21												
22												
23												
24	Measured at 3 m distance											
25	6.64 dB Duty Factor Applied below 490 kHz											
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Meas.09/30/2003; U of Mich.

Table 5.1(c) Highest Emissions Measured

Transmitter Radiated Emissions												USMS 3T 6 sq. ft.; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 3/30/300 m	E300* dBµV/m	E300lim dBµV/m	Pass dB	Comments
1	154.0	Loop	V/perp	0.6	Pk	9.9	0.0	117.1	- 6.3	23.9	**30.1**	loop perp. (axia in dir. of prop.)
2	154.0	Loop	V/par	- 3.9	Pk	9.9	0.0	120.3	-13.9	23.9	37.8	loop paral. (loop in dir. of prop.)
3	154.0	Loop	H, CP	-12.9	Pk	9.9	0.0	120.3	-22.9	23.9	46.8	loop horiz. (loop in horiz. plane)
4	308.0	Loop	V/perp	-55.3	Pk	9.8	0.0	113.2	-58.4	17.8	76.2	noise
5	308.0	Loop	V/par	-54.1	Pk	9.8	0.0	109.5	-53.4	17.8	71.2	loop paral.
6	308.0	Loop	H, CP	-61.0	Pk	9.8	0.0	109.5	-60.3	17.8	78.1	noise
7	462.0	Loop	V/perp	-42.0	Pk	9.8	0.0	110.3	-42.1	14.3	56.4	loop perp.
8	462.0	Loop	V/par	-53.3	Pk	9.8	0.0	102.0	-45.1	14.3	59.4	loop paral.
9	462.0	Loop	H, CP	-65.3	Pk	9.8	0.0	102.0	-57.1	14.3	71.4	loop horiz.
10	616.0	Loop	V/perp	-72.5	Pk	9.8	0.0	59.4	-15.1	31.8	46.9	noise
11	616.0	Loop	V/par	-70.0	Pk	9.8	0.0	60.6	-13.8	31.8	45.6	noise
12	616.0	Loop	H, CP	-74.1	Pk	9.8	0.0	60.6	-17.9	31.8	49.7	noise
13	770.0	Loop	V/perp	-41.7	Pk	9.8	0.0	59.1	16.0	29.9	13.9	background rf
14	770.0	Loop	V/par	-44.7	Pk	9.8	0.0	60.8	11.3	29.9	18.6	background rf
15	770.0	Loop	H, CP	-64.8	Pk	9.8	0.0	60.8	- 8.8	29.9	38.7	noise
16	924.0	Loop	All	-67.9	Pk	9.8	0.0	58.8	- 9.9	28.3	38.2	noise
17	1078.0	Loop	All	-61.6	Pk	9.8	0.0	58.4	- 3.2	27.0	30.2	background rf
18	1232.0	Loop	All	-74.7	Pk	9.8	0.0	58.0	-15.9	25.8	41.7	noise
19	1386.0	Loop	All	-65.5	Pk	9.8	0.0	57.6	- 6.3	24.8	31.1	background rf
20	1540.0	Loop	All	-73.9	Pk	9.8	0.0	57.2	-14.3	23.9	38.2	noise
21												
22												
23												
24	Measured at 3 m distance											
25	6.64 dB Duty Factor Applied below 490 kHz											
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27												
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Meas.09/30/2003; U of Mich.

Table 5.1(d) Highest Emissions Measured

Transmitter Radiated Emissions												USMS 2T 24 sq. ft.; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 0/30/300 m	E300* dBµV/m	E300lim dBµV/m	Pass dB	Comments
1	154.0	Loop	V/perp	-20.4	Pk	9.9	0.0	85.8	4.1	23.9	**19.8**	loop perp. (axia in dir. of prop.)
2	154.0	Loop	V/par	-24.5	Pk	9.9	0.0	88.9	- 3.1	23.9	27.0	loop paral. (loop in dir. of prop.)
3	154.0	Loop	H, CP	-36.5	Pk	9.9	0.0	88.9	-15.1	23.9	39.0	loop horiz. (loop in horizontal pla
4	308.0	Loop	V/perp	-67.1	Pk	9.8	0.0	81.9	-38.8	17.8	56.7	noise
5	308.0	Loop	V/par	-67.0	Pk	9.8	0.0	78.1	-34.9	17.8	52.8	noise
6	308.0	Loop	H, CP	-69.0	Pk	9.8	0.0	78.1	-36.9	17.8	54.8	noise
7	462.0	Loop	V/perp	-66.5	Pk	9.8	0.0	78.9	-35.2	14.3	49.6	loop perp.
8	462.0	Loop	V/par	-67.9	Pk	9.8	0.0	70.6	-28.3	14.3	42.7	loop paral.
9	462.0	Loop	H, CP	-70.3	Pk	9.8	0.0	70.6	-30.7	14.3	45.1	noise
10	616.0	Loop	V/perp	-60.0	Pk	9.8	0.0	28.1	28.7	31.8	3.1	background rf
11	616.0	Loop	V/par	-68.9	Pk	9.8	0.0	29.2	18.7	31.8	13.1	noise
12	616.0	Loop	H, CP	-71.7	Pk	9.8	0.0	29.2	15.9	31.8	15.9	noise
13	770.0	Loop	V/perp	-59.5	Pk	9.8	0.0	27.8	29.5	29.9	0.4	background rf
14	770.0	Loop	V/par	-60.1	Pk	9.8	0.0	29.4	27.3	29.9	2.6	background rf
15	770.0	Loop	H, CP	-63.8	Pk	9.8	0.0	29.4	23.6	29.9	6.3	noise
16	924.0	Loop	All	-68.7	Pk	9.8	0.0	27.5	20.6	28.3	7.7	noise
17	1078.0	Loop	All	-68.4	Pk	9.8	0.0	27.2	21.2	27.0	5.8	noise
18	1232.0	Loop	All	-77.6	Pk	9.8	0.0	26.9	12.3	25.8	13.5	noise
19	1386.0	Loop	All	-65.6	Pk	9.8	0.0	26.5	24.7	24.8	0.1	background rf
20	1540.0	Loop	All	-71.0	Pk	9.8	0.0	26.2	19.6	23.9	4.3	noise
21												
22												
23												
24	Measured at 10 m distance											
25	6.64 dB Duty Factor Applied below 490 kHz											
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Meas.09/30/2003; U of Mich.

Table 5.1(e) Highest Emissions Measured

Transmitter Radiated Emissions												USMS 3T 24 sq. ft.; FCC/IC
#	Freq. kHz	Ant. Used	Ant. Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 0/30/300 m	E300* dBµV/m	E300lim dBµV/m	Pass dB	Comments
1	154.0	Loop	V/perp	-22.5	Pk	9.9	0.0	85.8	2.0	23.9	**21.9**	loop perp. (axia in dir. of prop.)
2	154.0	Loop	V/par	-26.2	Pk	9.9	0.0	88.9	- 4.8	23.9	28.7	loop paral. (loop in dir. of prop.)
3	154.0	Loop	H, CP	-39.6	Pk	9.9	0.0	88.9	-18.2	23.9	42.1	loop horiz. (loop in horiz. plane)
4	308.0	Loop	V/perp	-65.5	Pk	9.8	0.0	81.9	-37.2	17.8	55.1	noise
5	308.0	Loop	V/par	-64.1	Pk	9.8	0.0	78.1	-32.0	17.8	49.9	noise
6	308.0	Loop	H, CP	-64.9	Pk	9.8	0.0	78.1	-32.8	17.8	50.7	noise
7	462.0	Loop	V/perp	-63.1	Pk	9.8	0.0	78.9	-31.8	14.3	46.2	loop perp.
8	462.0	Loop	V/par	-70.0	Pk	9.8	0.0	70.6	-30.4	14.3	44.8	noise
9	462.0	Loop	H, CP	-70.0	Pk	9.8	0.0	70.6	-30.4	14.3	44.8	noise
10	616.0	Loop	V/perp	-58.2	Pk	9.8	0.0	28.1	30.5	31.8	1.3	background rf
11	616.0	Loop	V/par	-68.5	Pk	9.8	0.0	29.2	19.1	31.8	12.7	loop paral.
12	616.0	Loop	H, CP	-74.8	Pk	9.8	0.0	29.2	12.8	31.8	19.0	noise
13	770.0	Loop	V/perp	-60.3	Pk	9.8	0.0	27.8	28.7	29.9	1.2	background rf
14	770.0	Loop	V/par	-61.1	Pk	9.8	0.0	29.4	26.3	29.9	3.6	background rf
15	770.0	Loop	H, CP	-73.6	Pk	9.8	0.0	29.4	13.8	29.9	16.1	noise
16	924.0	Loop	All	-66.5	Pk	9.8	0.0	27.5	22.8	28.3	5.5	noise
17	1078.0	Loop	All	-65.7	Pk	9.8	0.0	27.2	23.9	27.0	3.1	background rf
18	1232.0	Loop	All	-75.4	Pk	9.8	0.0	26.9	14.5	25.8	11.3	noise
19	1386.0	Loop	All	-68.0	Pk	9.8	0.0	26.5	22.3	24.8	2.5	background rf
20	1540.0	Loop	All	-73.4	Pk	9.8	0.0	26.2	17.2	23.9	6.7	noise
21												
22												
23												
24	Measured at 10 m distance											
25	6.64 dB Duty Factor Applied below 490 kHz											
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Meas.09/30/2003; U of Mich.

Table 5.1-B Highest Digital Radiated Emissions Measured

USMS CR2A-USMS; FCC 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	28.9	Bic	H	-62.3	Pk	14.2	25.4	33.5	49.5	16.0	
2	28.9	Bic	V	-48.5	Pk	14.2	25.4	47.3	49.5	**2.2**	
3	31.8	Bic	H	-65.9	Pk	13.7	25.4	29.4	49.5	20.1	
4	31.8	Bic	V	-50.8	Pk	13.7	25.4	44.5	49.5	5.0	
5	57.8	Bic	H	-72.0	Pk	11.1	24.9	21.2	49.5	28.3	
6	61.4	Bic	H	-71.8	Pk	11.0	24.9	21.4	49.5	28.1	
7	61.4	Bic	V	-65.1	Pk	11.0	24.9	28.1	49.5	21.4	
8	63.9	Bic	V	-65.4	Pk	11.0	24.8	27.7	49.5	21.8	
9	78.9	Bic	H	-71.4	Pk	11.1	24.7	22.1	49.5	27.4	
10	82.1	Bic	H	-68.3	Pk	11.2	24.6	25.3	49.5	24.2	
11	83.4	Bic	V	-67.5	Pk	11.2	24.6	26.1	49.5	23.4	
12	122.4	Bic	H	-78.1	Pk	13.3	24.1	18.1	54.0	35.9	
13	122.4	Bic	V	-78.7	Pk	13.3	24.1	17.5	54.0	36.5	
14	222.4	Bic	H	-78.2	Pk	16.3	22.8	22.3	56.9	34.6	
15	222.4	Bic	V	-79.5	Pk	16.3	22.8	21.0	56.9	35.9	
16	249.4	Bic	V	-75.7	Pk	17.8	22.5	26.7	56.9	30.2	
17	292.2	SBic	V	-77.5	Pk	18.2	22.0	25.7	56.9	31.2	
18	325.1	SBic	H	-80.6	Pk	19.2	21.6	24.0	56.9	32.9	
19	325.1	SBic	V	-81.2	Pk	19.2	21.6	23.4	56.9	33.5	
20	361.2	SBic	H	-77.5	Pk	20.2	21.2	28.4	56.9	28.5	
21	373.7	SBic	V	-77.9	Pk	20.5	21.1	28.5	56.9	28.4	
22	493.7	SBic	H	-80.1	Pk	23.0	19.8	30.1	56.9	26.8	
23	493.7	SBic	V	-81.7	Pk	23.0	19.8	28.5	56.9	28.4	
24	612.3	SBic	H	-80.3	Pk	24.9	20.1	31.6	56.9	25.3	
25	612.3	SBic	V	-82.0	Pk	24.9	20.1	29.9	56.9	27.0	
26	804.1	SBic	H	-78.0	Pk	27.4	18.6	37.8	56.9	19.1	
27	804.1	SBic	V	-78.5	Pk	27.4	18.6	37.3	56.9	19.6	
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Meas. 1/26/04; U of Mich.

Table 5.2(a) Highest Conducted Emissions Measured

												USMS CR2A-USMS; FCC/CISPR A
	Freq.	Line	Peak Det., dBµV		Pass	QP Det., dBµV		Pass	Ave. Det., dBµV		Pass	
#	MHz	Side	Vtest	Vlim*	dB*	Vtest	Vlim	dB	Vtest	Vlim	dB	Comments
1	0.22	Lo	69.4	66.0	- 3.4	60.5	79.0	18.5	48.4	66.0	17.6	
2	0.23	Lo	66.7	66.0	- 0.7	62.6	79.0	16.4	52.6	66.0	13.4	
3	0.40	Lo	54.3	66.0	11.7		79.0			66.0		
4	0.42	Lo	52.2	66.0	13.8		79.0			66.0		
5	0.77	Lo	43.5	60.0	16.5		73.0			60.0		
6	0.77	Lo	43.2	60.0	16.8		73.0			60.0		
7	1.38	Lo	44.5	60.0	15.5		73.0			60.0		
8	1.38	Lo	44.7	60.0	15.3		73.0			60.0		
9	1.69	Lo	44.1	60.0	15.9		73.0			60.0		
10	2.00	Lo	44.5	60.0	15.5		73.0			60.0		
11	15.98	Lo	48.1	60.0	11.9		73.0			60.0		
12	16.28	Lo	51.3	60.0	8.7		73.0			60.0		
13	16.28	Lo	51.6	60.0	8.4		73.0			60.0		
14	16.28	Lo	51.4	60.0	8.6		73.0			60.0		
15	16.28	Lo	51.3	60.0	8.7		73.0			60.0		
16	19.97	Lo	47.4	60.0	12.6		73.0			60.0		
17	20.28	Lo	48.3	60.0	11.7		73.0			60.0		
18	23.96	Lo	43.5	60.0	16.5		73.0			60.0		
19	24.42	Lo	44.0	60.0	16.0		73.0			60.0		
20	25.13	Lo	54.1	60.0	5.9		73.0			60.0		
21	25.50	Lo	53.6	60.0	6.4		73.0			60.0		
22	25.65	Lo	54.6	60.0	5.4		73.0			60.0		
23	25.96	Lo	54.6	60.0	5.4		73.0			60.0		
24	25.96	Lo	54.7	60.0	5.3		73.0			60.0		
25	26.11	Lo	57.2	60.0	**2.8**		73.0			60.0		
26	26.73	Lo	56.2	60.0	3.8		73.0			60.0		
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**Average limit* Meas. 12/12/2003; U of Mich.

Since Vpeak >= Vqp >= Vave and if Vtestpeak < Vavelim, then Vqplim and Vavelim are met.

Table 5.2(b) Highest Conducted Emissions Measured

												USMS CR2A-USMS; FCC/CISPR A
	Freq.	Line	Peak Det., dBµV		Pass	QP Det., dBµV		Pass	Ave. Det., dBµV		Pass	
#	MHz	Side	Vtest	Vlim*	dB*	Vtest	Vlim	dB	Vtest	Vlim	dB	Comments
1	0.20	Hi	71.5	66.0	- 5.5	69.5	79.0	9.5	58.2	66.0	7.8	
2	0.23	Hi	68.8	66.0	- 2.8	64.4	79.0	14.6	54.8	66.0	11.2	
3	0.40	Hi	55.7	66.0	10.3		79.0			66.0		
4	0.76	Hi	46.4	60.0	13.6		73.0			60.0		
5	0.77	Hi	46.4	60.0	13.6		73.0			60.0		
6	0.77	Hi	46.1	60.0	13.9		73.0			60.0		
7	1.08	Hi	43.7	60.0	16.3		73.0			60.0		
8	1.08	Hi	43.2	60.0	16.8		73.0			60.0		
9	1.08	Hi	44.6	60.0	15.4		73.0			60.0		
10	1.38	Hi	48.6	60.0	11.4		73.0			60.0		
11	1.69	Hi	51.4	60.0	8.6		73.0			60.0		
12	1.81	Hi	48.0	60.0	12.0		73.0			60.0		
13	16.28	Hi	52.5	60.0	7.5		73.0			60.0		
14	16.44	Hi	46.3	60.0	13.7		73.0			60.0		
15	16.59	Hi	48.6	60.0	11.4		73.0			60.0		
16	20.28	Hi	52.1	60.0	7.9		73.0			60.0		
17	20.28	Hi	52.2	60.0	7.8		73.0			60.0		
18	20.28	Hi	52.2	60.0	7.8		73.0			60.0		
19	20.58	Hi	51.6	60.0	8.4		73.0			60.0		
20	20.89	Hi	51.3	60.0	8.7		73.0			60.0		
21	21.20	Hi	53.8	60.0	**6.2**		73.0			60.0		
22	21.50	Hi	53.2	60.0	6.8		73.0			60.0		
23	21.51	Hi	53.4	60.0	6.6		73.0			60.0		
24	21.51	Hi	53.5	60.0	6.5		73.0			60.0		
25	21.81	Hi	48.8	60.0	11.2		73.0			60.0		
26	21.81	Hi	49.0	60.0	11.0		73.0			60.0		
27	22.12	Hi	46.2	60.0	13.8		73.0			60.0		
28	22.43	Hi	49.8	60.0	10.2		73.0			60.0		
29	22.73	Hi	49.2	60.0	10.8		73.0			60.0		
30	23.66	Hi	45.9	60.0	14.1		73.0			60.0		
31	23.96	Hi	47.5	60.0	12.5		73.0			60.0		
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**Average limit* Meas. 12/12/2003; U of Mich.

Since Vpeak >= Vqp >= Vave and if Vtestpeak < Vavelim, then Vqplim and Vavelim are met.

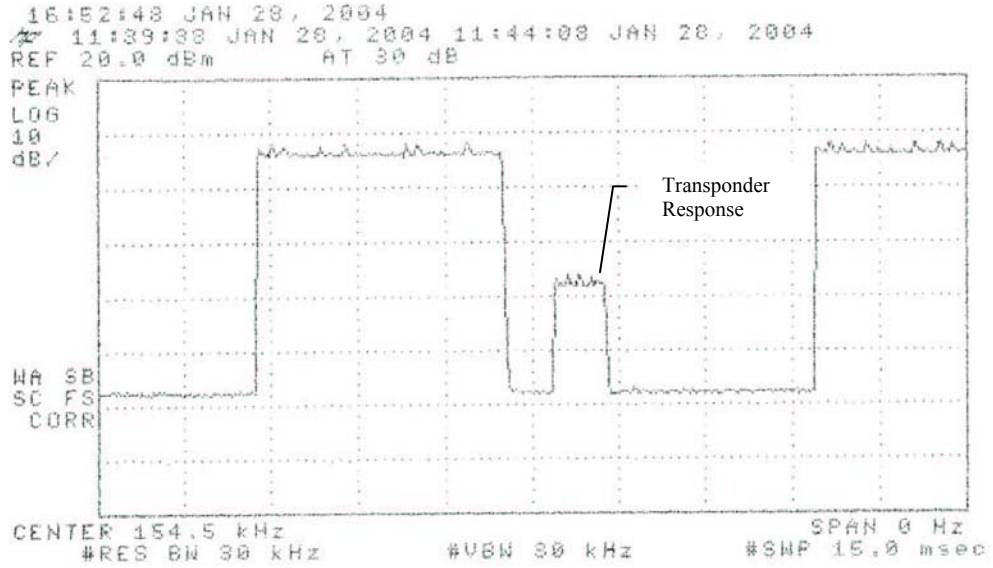

Figure 6.1. Transmission modulation characteristics.

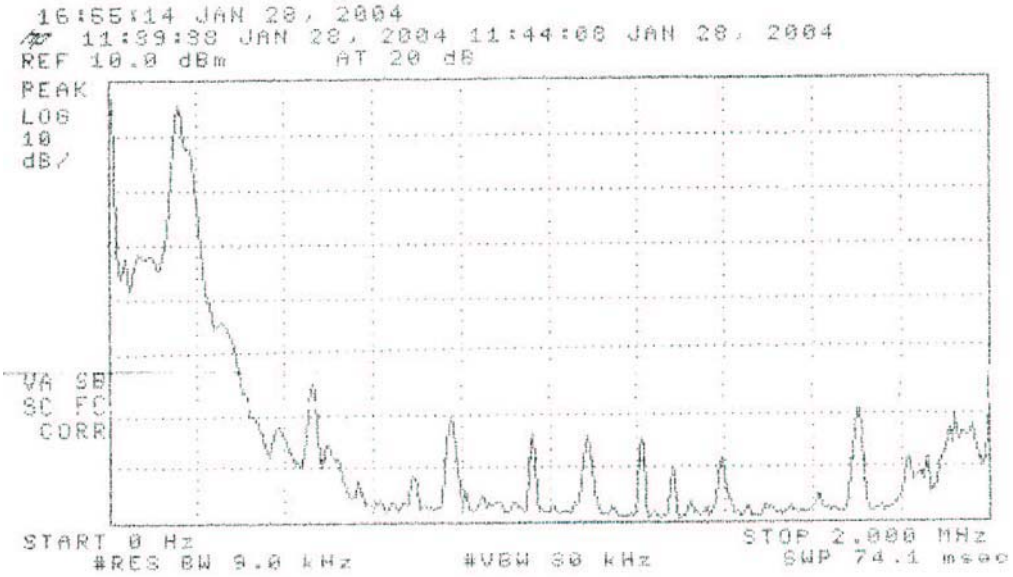

Figure 6.2. Emission spectrum of the DUT. The amplitudes are only indicative (not calibrated).

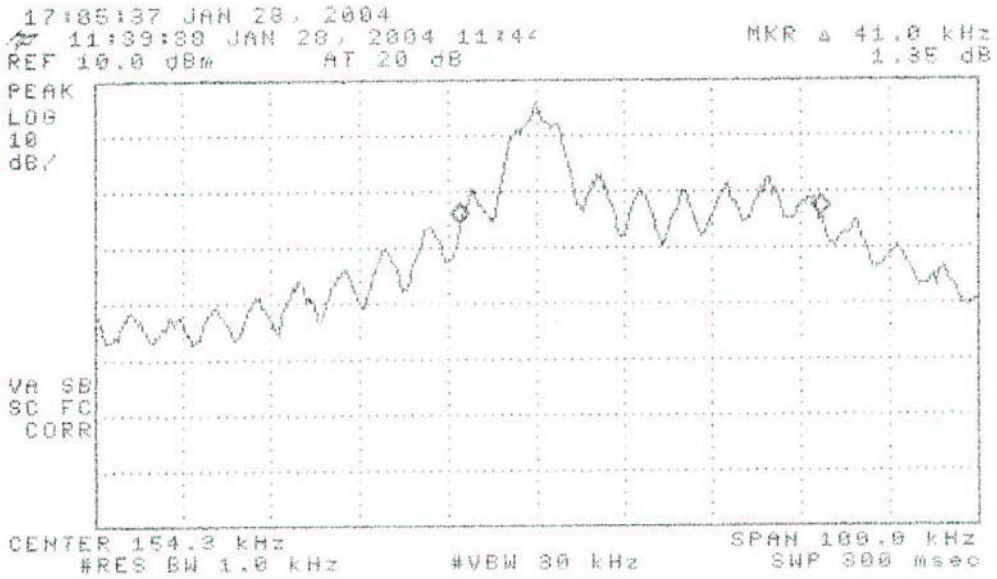

Figure 6.3.Measured bandwidth of the DUT. (pulsed)

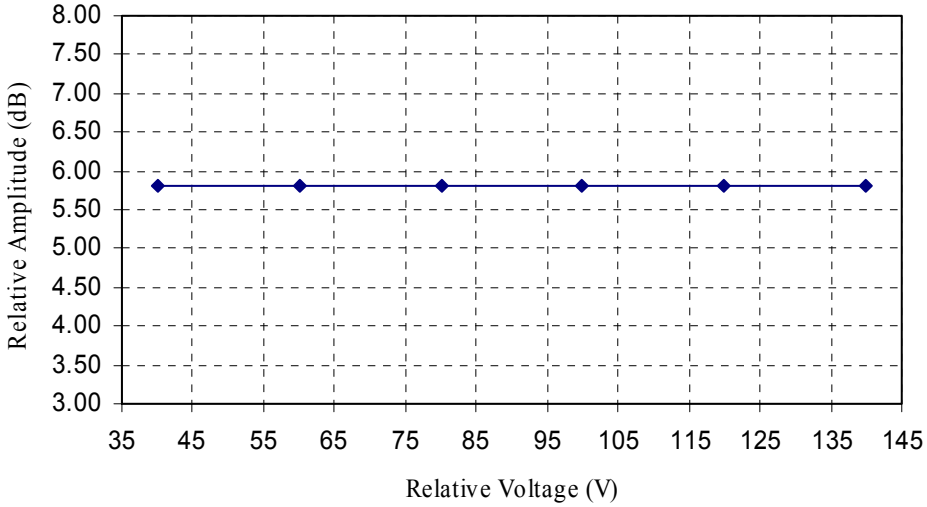

Figure 6.4. Relative emission at 135 kHz vs. supply voltage.