

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

Measured Radio Frequency Emissions
From

**Hafele America Transmitter
Model: WT2000T**

Report No. 415031-168
June 2, 2003

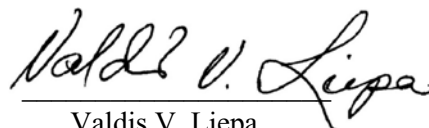
Copyright © 2003

For:
Hafele America Co.
3901 Cheyenne Drive
Archdale, NC 27263

Contact:
Rudor Teich
RMT Associates, Inc.
Tel: 973-669-8214
Fax: 973-669-5161

Measurements made by: Joseph D. Brunett
Edward A. Courtney

Tests supervised by:
Report approved by:


Valdis V. Liepa
Research Scientist

Summary

Tests for compliance with FCC Regulations, Part 15, Subpart C, and for compliance with Industry Canada RSS-210, were performed on Hafele America transmitter, model WT2000T. This device is subject to Rules and Regulations as a transmitter.

In testing completed 25-May-03, the device tested in the worst case met the allowed specifications for transmitter radiated emissions by 31.3 dB (see p. 7); digital emissions, Class B, were met by 3.9 dB (see p. 7); FCC/CISPR Class B conducted were met by 12.0 dB (see p. 7).

1. Introduction

Hafele America model WT2000T 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 a 135 kHz wall mounted RFID system. This system consists of a T/R module (including coupling coil antenna) and a "passive" transponder imbedded in a special key/card. The transponder in the key is considered passive because it uses the energy supplied by the transmitter coil to operate its micro and, hence, is not subject to the regulations. A multi-wire harness, a power supply, and a control box were used in testing. Power was supplied from switching power supply as provided by the manufacturer.

The DUT was designed and manufactured by Hafele America Co. It is identified as:

Hafele America Transmitter
Model: WT2000T
FCC ID: PW3110
CANADA: 4645A-110

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* (μ V/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) μ V/m	E _{lim} dB(μ V/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 (dB μ V)		Class B (dB μ V)	
	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: dB μ V = 50.25 - 19.12*log(f)

*Class B Average: dB μ V = 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(μ V/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 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)

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 31.3 dB. The digital emissions, Class B, were met by 3.9 dB.

6. Other Measurements and Computations

6.1 Correction For Pulse Operation

Under normal operation the transmitter is continuously polling. When the key/card is placed within reading distance of the DUT, the amplitude and duty cycle of the device decreases. See Figure 6.1. For 135 kHz operation under FCC Part 15.209 (IC RSS-210, 6.2.2(r)), averaging does not apply.

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 5.4 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 80-140 volts. The emission variation is shown in Figure 6.4.

6.5 Input Voltage and Current

$$V = 120 \text{ VAC}$$

$$I = 60 \text{ mA (pulsed)}$$

6.6 Field Behavior at 13 MHz

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 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:

Freq (kHz)	H-component	Extrapolated Position	Correction (dB)	Notes
135	Vertical – Radial	3m/300m	117.9 dB	Axial coupling
135	Vertical –Transverse	3m/300m	121.2 dB	Planar coupling
135	Horizontal –Transverse	3m/300m	121.2 dB	Planar coupling
270	Vertical – Radial	3m/300m	114.1 dB	Axial coupling
270	Vertical –Transverse	3m/300m	111.9 dB	Planar coupling
270	Horizontal –Transverse	3m/300m	111.9 dB	Planar coupling
405	Vertical – Radial	3m/300m	111.3 dB	Axial coupling
405	Vertical –Transverse	3m/300m	104.4 dB	Planar coupling
405	Horizontal –Transverse	3m/300m	104.4 dB	Planar coupling
540	Vertical – Radial	3m/30m	59.5 dB	Axial coupling
540	Vertical –Transverse	3m/30m	60.5 dB	Planar coupling
540	Horizontal –Transverse	3m/30m	60.5 dB	Planar coupling
675	Vertical – Radial	3m/30m	59.3 dB	Axial coupling
675	Vertical –Transverse	3m/30m	60.7 dB	Planar coupling
675	Horizontal –Transverse	3m/30m	60.7 dB	Planar coupling
810	Vertical – Radial	3m/30m	59.0 dB	Axial coupling
810	Vertical –Transverse	3m/30m	60.9 dB	Planar coupling
810	Horizontal –Transverse	3m/30m	60.9 dB	Planar coupling
945	Vertical – Radial	3m/30m	58.7 dB	Axial coupling
945	Vertical –Transverse	3m/30m	61.1 dB	Planar coupling
945	Horizontal –Transverse	3m/30m	61.1 dB	Planar coupling
1080	Vertical – Radial	3m/30m	58.4 dB	Axial coupling
1080	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1080	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1215	Vertical – Radial	3m/30m	58.0 dB	Axial coupling
1215	Vertical –Transverse	3m/30m	61.2 dB	Planar coupling
1215	Horizontal –Transverse	3m/30m	61.2 dB	Planar coupling
1350	Vertical – Radial	3m/30m	57.7 dB	Axial coupling
1350	Vertical –Transverse	3m/30m	61.0 dB	Planar coupling
1350	Horizontal –Transverse	3m/30m	61.0 dB	Planar coupling

In the data table, Table 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.

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

Table 5.1 Highest Emissions Measured

Transmitter Radiated Emissions											WT2000 TIRIS; FCC/IC	
#	Freq. kHz	Ant. Used	Ant.* Orien.	Pr, 3m dBm	Det. Used	Ka dB/m	Kg dB	Conv. 3/300 m	E300** dB μ V/m	E300lim dB μ V/m	Pass dB	Comments
1	136.3	Loop	V, CP	-37.1	Pk	9.9	0.0	121.0	-41.2	25.6	66.8	
2	136.3	Loop	V, CA	-36.9	Pk	9.9	0.0	117.7	-37.7	25.6	63.3	
3	136.3	Loop	H, CP	-51.3	Pk	9.9	0.0	121.0	-55.4	25.6	81.0	
4	272.6	Loop	V, CP	-68.3	Pk	9.8	0.0	111.9	-63.4	25.6	89.0	noise
5	272.6	Loop	V, CA	-63.7	Pk	9.8	0.0	114.1	-61.0	25.6	86.6	noise
6	272.6	Loop	H, CP	-73.8	Pk	9.8	0.0	111.9	-68.9	25.6	94.5	noise
7	408.9	Loop	V, CP	-62.1	Pk	9.8	0.0	104.4	-49.7	25.6	75.3	background
8	408.9	Loop	V, CA	-56.9	Pk	9.8	0.0	111.3	-51.4	25.6	77.0	background
9	408.9	Loop	H, CP	-74.8	Pk	9.8	0.0	104.4	-62.4	25.6	88.0	background
10	545.2	Loop	V, CP	-62.5	Pk	9.8	0.0	60.5	- 6.2	25.6	31.8	background
11	545.2	Loop	V, CA	-62.0	Pk	9.8	0.0	59.5	- 4.7	26.6	31.3	background
12	545.2	Loop	H, CP	-74.5	Pk	9.8	0.0	60.5	-18.2	27.6	45.8	background
13												
14												
15												
16												
17												
18	All other harmonics/orientations are in the noise (Pr < -70 dBm)											
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33	*CP - Coplanar; CA - Coaxial											
34	** The averaging factor is -5.7 dB; data is extrapolated to 300m distance.											
35	** RBW = 1kHz for all measurements											
36												
37												
38												
39												
40												

Meas. 07/3/02, 05/19/03; U of Mich.

Table 5.1 Highest Radiated Emissions Measured

WT2000 TIRIS; FCC B											
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr dBm	Det. Used	Ka dB/m	Kg dB	E3 dBμV/	E3lim dBμV/	Pass dB	Comments
1	81.0	Bic	H	-60.3	Pk	11.2	24.0	33.9	40.0	6.1	
2	81.0	Bic	V	-60.9	Pk	11.2	24.0	33.3	40.0	6.7	
3	121.7	Bic	H	-57.3	Pk	13.3	23.4	39.6	43.5	3.9	
4	121.9	Bic	V	-61.6	Pk	13.3	23.4	35.3	43.5	8.2	
5	163.5	Bic	V	-64.7	Pk	15.2	22.8	34.7	43.5	8.8	
6	169.6	Bic	H	-58.6	Pk	15.3	22.7	41.1	43.5	2.4	
7	228.6	Bic	H	-69.0	Pk	16.5	21.9	32.6	46.0	13.4	
8	230.4	Bic	H	-69.6	Pk	16.6	21.9	32.1	46.0	13.9	
9	234.1	Bic	H	-67.0	Pk	16.7	21.8	34.9	46.0	11.1	
10	235.9	Bic	V	-68.1	Pk	16.8	21.8	33.9	46.0	12.1	
11	243.2	Bic	H	-64.3	Pk	17.3	21.7	38.3	46.0	7.7	
12	289.5	SBic	H	-70.5	Pk	18.1	21.1	33.5	46.0	12.5	
13	317.2	SBic	H	-71.6	Pk	19.0	20.8	33.6	46.0	12.4	
14	350.3	SBic	H	-70.1	Pk	19.9	20.4	36.4	46.0	9.6	
15	355.9	SBic	V	-70.4	Pk	20.0	20.3	36.3	46.0	9.7	
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											

Meas. 12/17/02; U of Mich.

Table 5.2 Highest Conducted Emissions Measured

WT2000 TIRIS FCC/CISPR B												
#	Freq. MHz	Line Side	Peak Det.,		Pass dB*	QP Det.,		Pass dB	Ave. Det.,		Pass dB	Comments
			Vtest	Vlim*		Vtest	Vlim		Vtest	Vlim		
1	0.17	Lo		55.2		53.0	65.2	12.2		55.2		
2	0.20	Lo	36.0	53.6	17.6		63.6			53.6		
3	0.40	Lo	30.0	47.9	17.9		58.0			47.9		
4	1.09	Lo	31.0	46.0	15.0		56.0			46.0		
5	1.28	Lo	32.0	46.0	14.0		56.0			46.0		
6	1.51	Lo	32.0	46.0	14.0		56.0			46.0		
7	1.59	Lo	32.0	46.0	14.0		56.0			46.0		
8	1.75	Lo	29.0	46.0	17.0		56.0			46.0		
9	2.78	Lo	28.4	46.0	17.6		56.0			46.0		
10	19.90	Lo	32.0	50.0	18.0		60.0			50.0		
11	22.10	Lo	37.5	50.0	12.5		60.0			50.0		
12												
13	0.20	Hi		53.8	53.8	51.8	63.8	12.0		53.8		
14	0.39	Hi	36.0	48.1	12.1		58.2			48.1		
15	0.58	Hi	29.0	46.0	17.0		56.0			46.0		
16	0.80	Hi	26.0	46.0	20.0		56.0			46.0		
17	1.00	Hi	28.0	46.0	18.0		56.0			46.0		
18	1.20	Hi	29.0	46.0	17.0		56.0			46.0		
19	1.60	Hi	29.5	46.0	16.5		56.0			46.0		
20	2.80	Hi	29.0	46.0	17.0		56.0			46.0		
21	21.00	Hi	32.0	50.0	18.0		60.0			50.0		
22	22.10	Hi	37.5	50.0	12.5		60.0			50.0		
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
37												
38												
39												
40												
41												
42												
40												

*Average limit

Since $V_{peak} \geq V_{qp} \geq V_{ave}$ and if $V_{testpeak} < V_{avelim}$, the V_{qplim} and

Meas. 5/20/02; U of Mich.

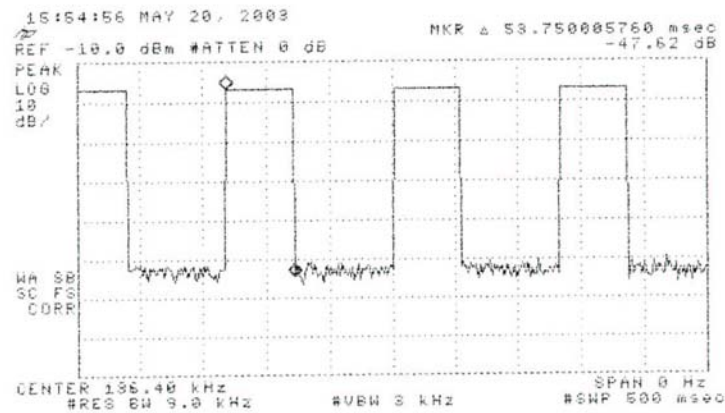
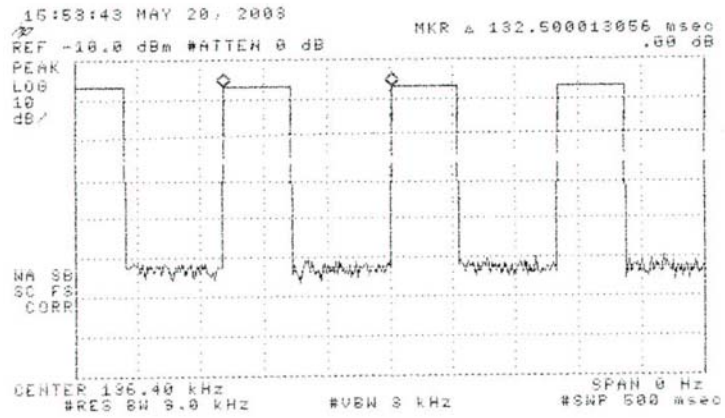


Figure 6.1. Transmission modulation characteristics.

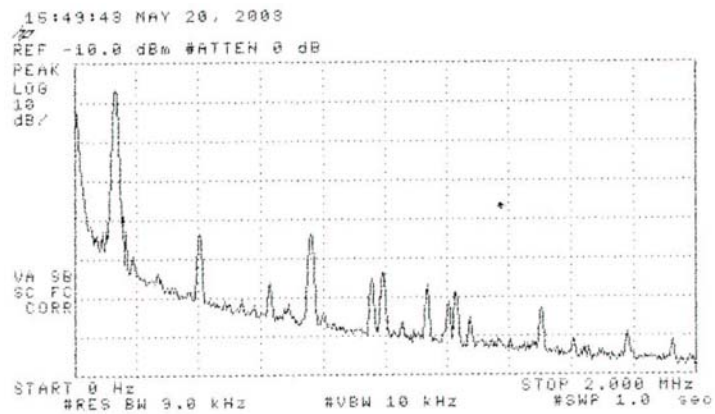


Figure 6.2. Emission spectrum of the DUT- amplitudes are only indicative (not calibrated).

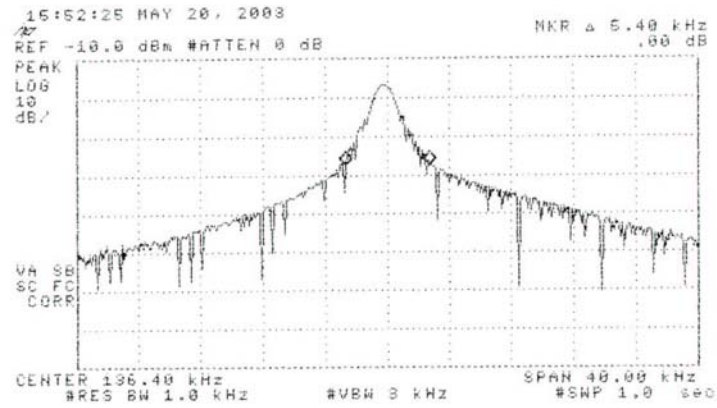


Figure 6.3. Measured bandwidth of the DUT. (pulsed)

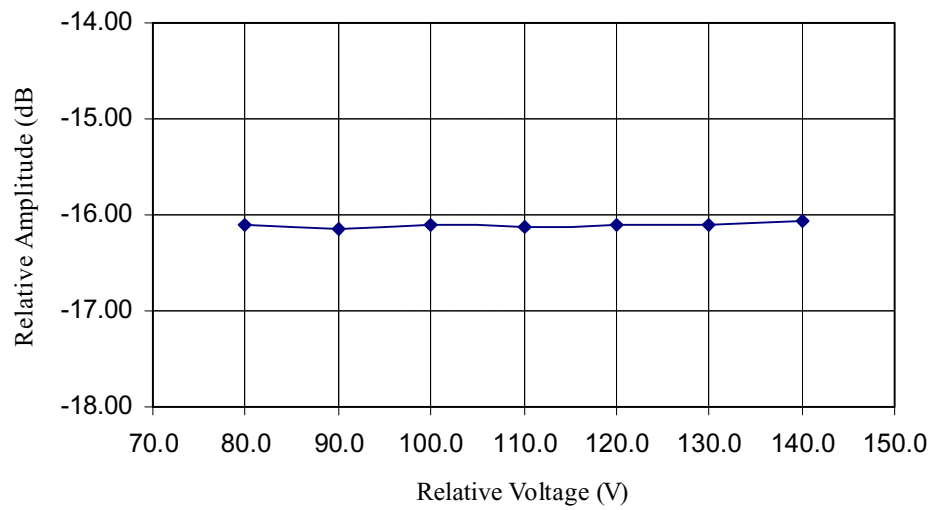
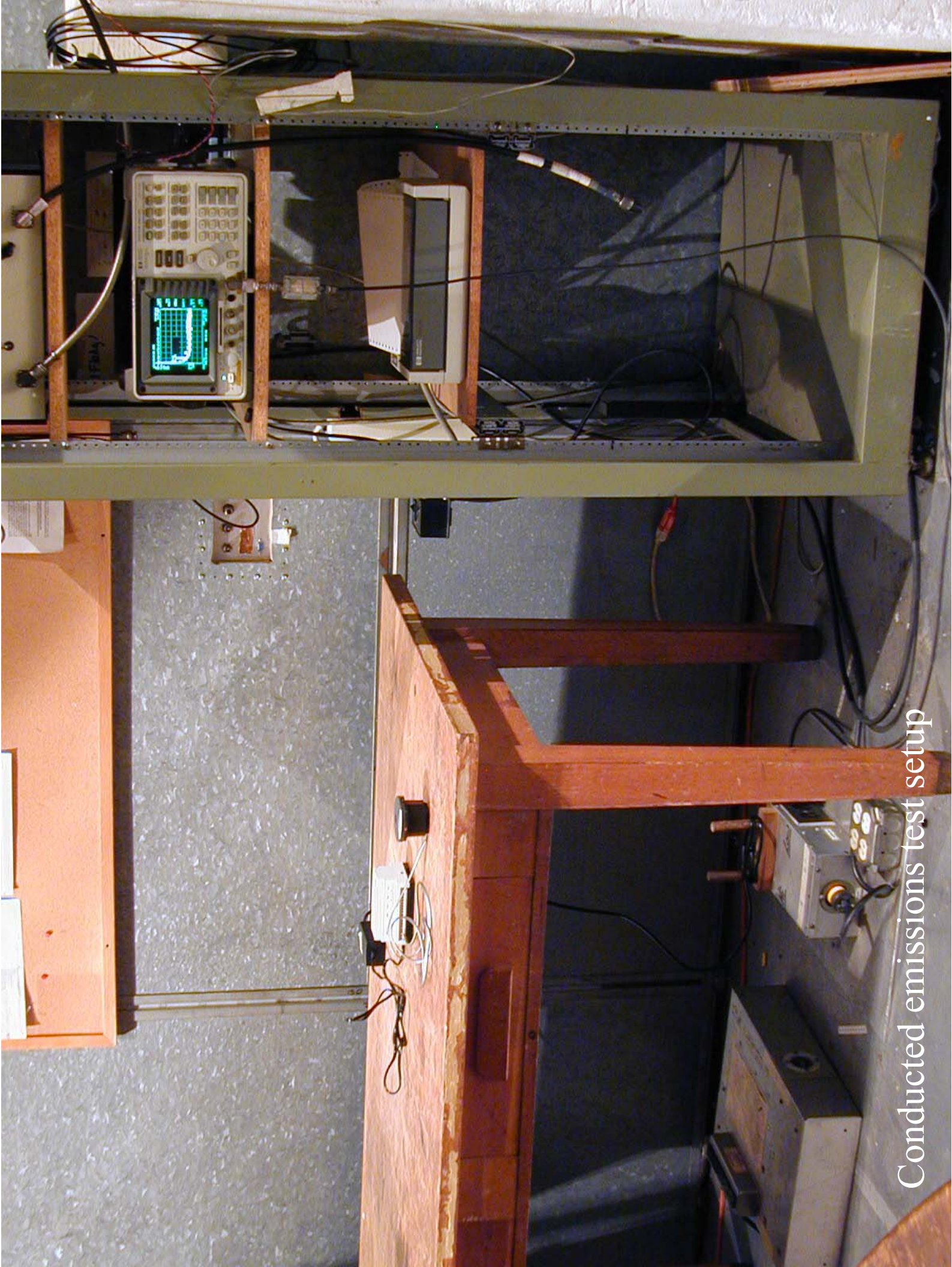


Figure 6.4. Relative emission at 135 kHz vs. supply voltage.







Conducted emissions test setup