The University of Michigan
Radiation Laboratory
3228 EECS Building
Ann Arbor, MI 48109-2122
Tel: (734) 647-1792

Measured Radio Frequency Emissions
From

Hyperlink/Lucent Extended Range Radio with HyperAmp (Transmitter)

Report No. 415031-046
May 13, 2000

For:
Hyperlink Technologies Inc.
1201 Clint Moore Road
Boca Raton, FL 33487

Contact:
Peter Roth
Tel: (561) 995-2256
Fax: (561) 995-2432
PO: verbal

Measurements made by:
Joseph Brunett
Elliot Smith

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

Summary

Tests for compliance with FCC Regulations subject to Part 15 were performed on HyperLink spread spectrum RF link with amplifier and 8 antennas. The DUT is subject to FCC Rules and Regulations as a transmitter, a receiver, and as a digital device. This link uses an already certified spread spectrum Lucent WaveLAN radio, power feed, cable, amplifier with internal attenuator, and antennas. Here we report on measurements of radiated emissions in restricted bands and on signal spectral characteristics. Health hazard measurements were also made and are reported.

In testing performed on May 10 and 11, 1998, the device tested in the worst case met the allowed FCC specifications for radiated emissions in restricted bands by 0.5 dB (see pp. 14 &15). The amplifier power supply conducted emissions, Class B DVE supply, were met by 0.9 dB (see p. 16) and Class A Sunfone supply, were met by 1.6 dB (see p. 17).

1. Introduction

HyperLink/Lucent Extended Range Radio with amp was tested for compliance with FCC Regulations, Part 15, adopted under Docket 87-389, April 18, 1989. 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 attenuation characteristics of the Open Site facility are on file with FCC Laboratory, Columbia, Maryland. (FCC file 31040/SIT)

2. Test Procedure and Equipment Used

The test equipment commonly used in our facility is listed in Table 2.1 below. The second column identifies the specific equipment used in these tests. The HP 8593E spectrum analyzer is used for primary amplitude and frequency reference.

Table 2.1. Test Equipment.

Test Instrument	Equipment Used	Manufacturer/Model	Cal. Date/By
Spectrum Analyzer (9kHz-22GHz)		Hewlett-Packard 8593A SN: 3107A01358	October 1999/HP
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	September 1999/HP
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard 182T/8558B SN: 1529A01114/543592	October 1997/U of M Rad Lab
Preamplifier (5-1000MHz)		Watkins-Johnson A11 -1 plus A25-1S	October 1999/U of M Rad Lab
Preamplifier (5-4000 MHz)		Avantek	Nov. 1996/ U of M Rad Lab
Power Meter w/ Thermistor	X	Hewlett-Packard 432A Hewlett-Packard 478A	August 1998/U of M Rad Lab
Broadband Bicone (20-200 MHz)	X	University of Michigan	June 1996/U of M Rad Lab
Broadband Bicone (200-1000 MHz)		University of Michigan	June 1996/U of M Rad Lab
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	February 1996/EMCO
S-Band Std. Gain Horn	X	S/A, Model SGH-2.6	Manufacturer, NRL design
C-Band Std. Gain Horn	X	University of Michigan	Manufacturer, NRL design
XN-Band Std. Gain Horn	X	University of Michigan	Manufacturer, NRL design
X-Band Std. Gain Horn	X	S/A, Model 12-8.2	Manufacturer, NRL design
Ku-Band Std. Gain Horn	X	University of Michigan	Manufacturer, NRL design
K-Band Std. Gain Horn	X	University of Michigan	Manufacturer, NRL design
Ridge-horn Antenna (0.5-5 GHz)		University of Michigan	March 1999/U of M Rad Lab
LISN Box	X	University of Michigan	December 1997/U f M Rad Lab
Signal Cables	X	Assorted	October 1999/U of M Rad Lab
Signal Generator (0.1-990 MHz)		Hewlett-Packard 8656A	January 1996/U of M Rad Lab
Printer	X	Hewlett-Packard 2225A	August 1989/HP

3. Configuration and Identification of Device Under Test

The DUT is a spread spectrum RF wireless link operating in 2400 - 2483.5 MHz band. The system tested consists of a laptop computer, Lucent WaveLAN PCMCIA card, lightning protector, 50-foot coax cable, and choice of six antennas.

The DUT has 7 channels, covering 2422 - 2452 MHz. Since the laptop computer and the WaveLAN card have already been previously certified, here we only need to test for emissions in restricted bands for signal characteristics and test for the maximum RF exposure level. Measurements were made with the DUT operated at lowest (3), mid (6), and highest channels (9). Except at 2483.5 MHz, all the other emissions were unmeasurable, even at a 1 meter distance.

The subsystems added to the Lucent card in the DUT were designed and manufactured by Hyperlink Technologies Inc., 1201 Clint Moore Rd., Boca Raton, FL 33687. The system is identified as:

HyperLink/Lucent Extended Range Radio
Model: WL2401
SN: Proto6
FCC ID: MYF-WL2401

Components evaluated:

Lucent RF Card Model WaveLAN 802.11 PCMCIA	SN: 994T12466095 FCC ID: 1MRWLPCE24H
IBM Laptop, Model: IBM ThinkPad	SN: 23-RYY74 FCC ID: ANO263OCS
Amplifier, HyperAmp	SN: 005233 FCCID: MYF-WL2401
DC Injector, Hyperlink Model: 2404	SN: N/A
Power Supply for HyperLink amplifier DVE, Model: SDSA-0301-12	SN: 4497
Power Supply for HyperLink amplifier Sunfone, Model: ACSM-26	SN: 1288
Attenuator, Hyperlink Variable (selected attenuation values will be incorporated in the amplifier housing).	SN: N/A

Cables
Antenna cable, 50 feet
Amphenol, TWB4001, with N-connectors

Pigtail cable, between PCMCIA card and
DC Injector, 1/2 meter, Model WL2-cable 4

Pigtail cable, between HyperAmp and
Antenna, part of antenna

Antennas
Antenna, Omni, V-pol
Model: HG 2408U, 8.0 dBi

Antenna, Omni, V-pol
Model: HG 2415U, 15 dBi

Antenna, Yagi, V/H-pol
Model: HG 2415Y, 14.5 dBi

Antenna, Parabolic, V/H-pol
Model: HG 2415G, 15.0 dBi

Antenna, Parabolic, V/H-pol
Model: HG 2419G, 19.0 dBi

Antenna, Reflector, V/H-pol
Model: HG 2424G, 23.5 dBi

Antenna, Patch, V/H-pol
Model: HG 2408P, 7.5 dBi

Antenna, Array, V/H-pol
Model: HG 2412P, 12.0 dBi

3.1 EMI Relevant Modifications

Channels 1,2 and 10,11 where deleted from testing, since their spectrum exceeded the adjacent restricted bands. During testing, attenuation values for specific antenna were selected to meet the maximum power requirements.

4. Emission Limits

4.1 Radiated Emission Limits

Since the DUT is a spread spectrum device (15.247, 2.4 GHz), the radiated emissions are subject to emissions in restricted bands only (15.205). The applicable frequencies, through ten harmonics, are given below in Table 4.1. Emission limits from digital circuitry are specified in Table 4.2.

Table 4.1. Radiated Emission Limits (Ref: 15.205) — Transmitter.

Frequency (MHz)	Fundamental Ave. E_{lim} (3m)		Spurious* Ave. E_{lim} (3m)	
	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
2400-2483.5	---		---	
2383.5-2500 4500-5250 7250-7750	Restricted Bands		500	54.0
14470-14500 17700-21400 22010-23120 23600-24000	Restricted Bands		500	54.0

* Measure up to tenth harmonic; 1 MHz res. BW, 100 Hz video BW (for average detection)

Table 4.2 Radiated Emission Limits (15.109) — Digital device.

Frequency	Class A ds = 10 m		Class B ds = 3 m	
(MHz)	(μV/m)	dB (μV/m)	(μV/m)	dB (μV/m)
30-88	90	39.0	100	40.0
88-216	150	43.5	150	43.5
219-960	210	46.4	200	46.0
960-	300	49.5	500	54.0

120 kHz BW up to 1 GHz, 1 MHz BW above 1 GHz

4.2 Conductive Emission Limits

Table 4.3. Conducted Emission Limits (15.107).

Frequency	Class A ds = 10 m		Class B ds = 3 m	
(MHz)	μV	dBμV	μV	dBμV
0.45-1.705	1000	60.0	250	48.0
1.705-30.0	3000	69.6	250	48.0

Note: Quasi-Peak readings apply here (9 kHz BW)

Class A limits apply to the DUT.

5. Radiated Emission Tests and Results

5.1 Anechonic Chamber Measurements

In our 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. For these tests the receiver (horn) antennas were placed on a Styrofoam block, at about 1.2 m height, and the DUT on a turntable, at 3 meter distance, then moved to 1 m distance.

Standard gain horn antennas were used for measurements. Up to 7 GHz the horns were connected to a spectrum analyzer via RG-214 coaxial cable, and above 7 GHz a pre-amp was added. The cables and the pre-amplifier used were specially calibrated for these tests using a network analyzer.

For each DUT antenna used, the DUT antenna was rotated in all possible ways and the maximum emission recorded. Except at 2483.5 MHz, in all other cases only noise was observed. A photograph in Figure 5.1 shows the measurement set-up.

5.2 Outdoor Measurements

None made

5.3 Computations and Results

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

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

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
K_E = pulse operation correction factor, dB

When presenting the data, at each frequency the dominant measured emissions under all of the possible situations are given. Computations and results are given in Tables 5.1 through 5.8. There we see that in the worst case the DUT meets the limit by 0.5 dB at 2483.5 MHz.

6. Other Measurements and Computations

6.1 Peak-to-Average Ratio (15.35(b))

For the measurements presented here for emissions in restricted bands, the DUT was programmed to transmit continuous, and such was verified with spectrum analyzer set to zero-span mode. See Figure 6.1. The average measurements were made using 1 MHz RBW and 100 Hz VBW (sometimes to 300 Hz -- it goes faster). The peak measurements, were made using 1 MHz RBW and 1 MHz VBW.

When a real signal was measured from the DUT, the worst case ratio was 9.8 dB (Table 5.2), and when no signal was detected (a noise floor), the worst case ratio was 13.9 dB (Table 5.4).

6.2 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 S-band (WR-284) waveguide at 2445 MHz, for open-end waveguide Gain is 5.7 dBi and this equates to Aeq = 44.25 cm2, giving

$$p(mW/cm2) = 0.026\ P(mW)$$ where P(mW) is power received.

For the subject DUT, we probed, in the near field, each of the eight antennas connected in the system transmitting CW emission. In the worst case, with the 2408U antenna, we measured 14.2 dBm which corresponds to 0.68 mW/cm2. This was measured right at the feed element.

6.3 Maximum Peak Output Power (15.247(b))

For this, the DUT was put in a test mode for continuous data transmission and minimum attenuation (2 dB). A bolometer type microwave power meter was connected to the connector that would connect to the antenna. Since the DUT transmits a continuous, there is no adjustment needed to the reading. See figure 6.1.

Frequency	Meter Reading	
Ch. 3: 2422MHz	23.6 dBm	(Limit 30 dBm)
Ch. 6: 2437MHz	24.0 dBm	
Ch. 9: 2452MHz	24.4 dBm	

We also measured the max. peak power with the spectrum analyzer with RBW=3 MHz (max. available), and there read 20.9 dBm (Channel 6). Obviously, the value is lower due to a reduced receiving bandwidth. See also Figure 6.1.

6.4 Power Line Conducted Emissions (15.270)

The RF amplifier that goes at the antenna is powered through the RF cable, which in turn, is powered from a switching power supply via a bias Tee. Conducted emissions were measured using LISN. The

worst case conducted emissions met FCC Class B limit by 0.9 dB using the DVE supply (see Table 6.1) and met FCC Class A limits by 1.6 dB using the Sunfone supply (see Table 6.2).

The radio and the laptop conducted emissions were not measured, since they are compliant.

6.5 Bandwidth (15.247(a)(2))

For this, the DUT was put in a test mode for continuous data transmission. With spectrum analyzer connected at the connector that would connect to the antenna and the analyzer set for RBW=100 kHz and SPAN= 100 MHz, the 6 dB bandwidth value obtained was:

Frequency	6 dB Bandwidth
2.4370 GHz	10.1 MHz

See Figure 6.3.

6.6 RF Antenna Conducted Spurious Emissions (15.247(c))

For this, the DUT was put in a test mode for continuous data transmission. The spectrum analyzer was connected to the connector that would connect to the antenna. The analyzer was set for RBW=VBW=100 kHz, the frequency was swept from 0 to 25 GHz. Only the fundamental and the second harmonic were seen. The worst case was a noise measurement at 21.0 GHz of –32.0 dB below the carrier. (Limit -20.0 dB below carrier). See Figure 6.4.

6.7 Power Spectral Density (15.247(d))

For this, the DUT was put in a test mode for continuous data transmission. The spectrum analyzer was connected to the connector that would connect to the antenna. Spectrum was first scanned for the maximum spectrum peaks and then at these peaks the sweep was repeated with RBW=3 kHz, VBW=100 kHz, SPAN=300 kHz, and SWEEP TIME=100s. The maximum readings obtained were:

Frequency	Meter Reading	
2.452 GHz	0.93 dBm	(Limit 8.0 dBm)

The spectrum line spacing was 5.3 kHz. See Figure 6.5.

NOTE:

The plots (figures) 6.1 through 6.5 are for Ch. 6. Data was taken for Ch. 3 and 9 and is similar, also complying with the FCC requirement.

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Table 5.1 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2408U; 50 ft coax, 2dB attenuator										
1	2390.0	HornS	H/V	-78.5	-71.5	21.5	- 0.6	50.6	54.0	3.4	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-80.7	-71.6	21.5	- 0.6	48.4	54.0	5.6	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-80.3	-71.1	21.5	- 0.6	48.8	54.0	5.2	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-79.9	-70.6	21.5	- 0.6	49.2	54.0	4.8	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-79.9	-70.8	21.5	- 0.6	49.2	54.0	4.8	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-78.5	-70.0	21.5	- 0.6	50.6	54.0	3.4	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-76.0	-70.5	25.5	- 0.7	47.7	54.0	6.3	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-76.4	-70.5	25.5	- 0.7	47.3	54.0	6.7	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-76.9	-70.5	25.5	- 0.7	46.8	54.0	7.2	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-77.4	-66.2	25.0	- 0.8	45.9	54.0	8.1	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-77.2	-66.2	25.0	- 0.8	46.1	54.0	7.9	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-77.4	-66.2	25.0	- 0.8	45.9	54.0	8.1	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-74.5	-60.7	30.9	17.3	36.6	54.0	17.4	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-68.9	-57.2	32.3	32.0	28.9	54.0	25.1	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-68.9	-57.2	32.3	32.0	28.9	54.0	25.1	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-67.1	-69.5	32.3	32.0	30.7	54.0	23.3	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-67.3	-69.5	32.3	32.0	30.5	54.0	23.5	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-67.4	-69.5	32.3	32.0	30.4	54.0	23.6	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Bellow	
1	Channel 3:		14.2	26.3			0.68	1.0		1.7	
2	Channel 6:		12.0	15.8			0.41	1.0		3.9	
3	Channel 9:		12.5	17.8			0.46	1.0		3.4	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.2 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2408P; 50 ft coax, 12dB attenuator										
1	2390.0	HornS	H/V	-78.7	-71.5	21.5	- 0.6	50.4	54.0	3.6	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-79.8	-71.6	21.5	- 0.6	49.3	54.0	4.7	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-79.5	-71.1	21.5	- 0.6	49.6	54.0	4.4	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-79.8	-70.6	21.5	- 0.6	49.3	54.0	4.7	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-80.5	-70.8	21.5	- 0.6	48.6	54.0	5.4	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-77.4	-69.4	21.5	- 0.6	51.7	54.0	2.3	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-71.0	-70.5	25.5	- 0.7	52.7	54.0	1.3	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-75.6	-70.5	25.5	- 0.7	48.1	54.0	5.9	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-78.6	-70.5	25.5	- 0.7	45.1	54.0	8.9	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-79.5	-66.2	25.0	- 0.8	43.8	54.0	10.2	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-79.5	-66.2	25.0	- 0.8	43.8	54.0	10.2	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-79.5	-66.2	25.0	- 0.8	43.8	54.0	10.2	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-74.2	-61.1	30.9	17.3	36.9	54.0	17.1	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-66.4	-69.5	32.3	32.0	31.4	54.0	22.6	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		9.6	9.1			0.24	1.0		6.3	
2	Channel 6:		8.5	7.1			0.18	1.0		7.4	
3	Channel 9:		8.8	7.6			0.20	1.0		7.1	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.3 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2412P; 50 ft coax, 6dB attenuator										
1	2390.0	HornS	H/V	-78.4	-71.5	21.5	- 0.6	50.7	54.0	3.3	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-78.1	-71.6	21.5	- 0.6	51.0	54.0	3.0	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-78.8	-71.1	21.5	- 0.6	50.3	54.0	3.7	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-78.8	-70.6	21.5	- 0.6	50.3	54.0	3.7	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-78.4	-70.8	21.5	- 0.6	50.7	54.0	3.3	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-77.4	-69.4	21.5	- 0.6	51.7	54.0	2.3	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-79.1	-70.5	25.5	- 0.7	44.6	54.0	9.4	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-84.0	-70.5	25.5	- 0.7	39.7	54.0	14.3	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-83.3	-70.5	25.5	- 0.7	40.4	54.0	13.6	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-79.6	-66.2	25.0	- 0.8	43.7	54.0	10.3	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-79.7	-66.2	25.0	- 0.8	43.6	54.0	10.4	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-79.9	-66.2	25.0	- 0.8	43.4	54.0	10.6	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-74.1	-60.3	30.9	17.3	37.0	54.0	17.0	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-68.9	-57.2	32.3	32.0	28.9	54.0	25.1	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-68.9	-57.2	32.3	32.0	28.9	54.0	25.1	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-66.4	-69.5	32.3	32.0	31.4	54.0	22.6	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-66.6	-69.5	32.3	32.0	31.2	54.0	22.8	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-67.9	-69.5	32.3	32.0	29.9	54.0	24.1	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		3.7	2.3			0.06	1.0		12.2	
2	Channel 6:		4.0	2.5			0.07	1.0		11.9	
3	Channel 9:		3.3	2.1			0.06	1.0		12.6	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.4 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2415G; 50 ft coax, 6dB attenuator										
1	2390.0	HornS	H/V	-77.9	-71.6	21.5	- 0.6	51.2	54.0	2.8	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-77.6	-71.5	21.5	- 0.6	51.5	54.0	2.5	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-78.8	-71.1	21.5	- 0.6	50.3	54.0	3.7	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-77.7	-70.6	21.5	- 0.6	51.4	54.0	2.6	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-76.6	-70.7	21.5	- 0.6	52.5	54.0	1.5	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-76.1	-70.0	21.5	- 0.6	53.0	54.0	1.0	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-77.6	-70.5	25.5	- 0.7	46.1	54.0	7.9	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-80.3	-70.5	25.5	- 0.7	43.4	54.0	10.6	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-82.7	-70.5	25.5	- 0.7	41.0	54.0	13.0	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-77.3	-66.2	25.0	- 0.8	46.0	54.0	8.0	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-77.3	-66.2	25.0	- 0.8	46.0	54.0	8.0	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-77.3	-66.2	25.0	- 0.8	46.0	54.0	8.0	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-74.3	-60.4	30.9	17.3	36.8	54.0	17.2	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-69.1	-57.2	32.3	32.0	28.7	54.0	25.3	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		5.7	3.7			0.10	1.0		10.2	
2	Channel 6:		6.0	4.0			0.10	1.0		9.9	
3	Channel 9:		4.8	3.0			0.08	1.0		11.1	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.5 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2415U; 50 ft coax, 6dB attenuator										
1	2390.0	HornS	H/V	-78.7	-71.6	21.5	- 0.6	50.4	54.0	3.6	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-79.6	-71.5	21.5	- 0.6	49.5	54.0	4.5	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-79.5	-71.1	21.5	- 0.6	49.6	54.0	4.4	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-78.7	-70.6	21.5	- 0.6	50.4	54.0	3.6	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-78.8	-70.7	21.5	- 0.6	50.3	54.0	3.7	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-78.5	-70.0	21.5	- 0.6	50.6	54.0	3.4	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-80.3	-70.5	25.5	- 0.7	43.4	54.0	10.6	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-81.0	-70.5	25.5	- 0.7	42.7	54.0	11.3	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-81.6	-70.5	25.5	- 0.7	42.1	54.0	11.9	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-77.8	-66.2	25.0	- 0.8	45.5	54.0	8.5	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-77.7	-66.2	25.0	- 0.8	45.6	54.0	8.4	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-77.8	-66.2	25.0	- 0.8	45.5	54.0	8.5	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-72.1	-60.9	30.9	17.3	39.0	54.0	15.0	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-67.1	-57.2	32.3	32.0	30.7	54.0	23.3	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-67.1	-57.2	32.3	32.0	30.7	54.0	23.3	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-67.1	-57.2	32.3	32.0	30.7	54.0	23.3	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-64.4	-69.5	32.3	32.0	33.4	54.0	20.6	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-64.5	-69.5	32.3	32.0	33.3	54.0	20.7	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-64.4	-69.5	32.3	32.0	33.4	54.0	20.6	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		4.9	3.1			0.08	1.0		11.0	
2	Channel 6:		4.0	2.5			0.07	1.0		11.9	
3	Channel 9:		4.1	2.6			0.07	1.0		11.8	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.6 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2415Y; 50 ft coax, 6dB attenuator										
1	2390.0	HornS	H/V	-77.8	-71.5	21.5	- 0.6	51.3	54.0	2.7	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-78.1	-71.6	21.5	- 0.6	51.0	54.0	3.0	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-78.6	-71.1	21.5	- 0.6	50.5	54.0	3.5	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-78.6	-70.6	21.5	- 0.6	50.5	54.0	3.5	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-78.0	-70.8	21.5	- 0.6	51.1	54.0	2.9	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-77.1	-69.4	21.5	- 0.6	52.0	54.0	2.0	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-83.3	-70.5	25.5	- 0.7	40.4	54.0	13.6	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-83.5	-70.5	25.5	- 0.7	40.2	54.0	13.8	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-84.0	-70.5	25.5	- 0.7	39.7	54.0	14.3	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-79.8	-66.2	25.0	- 0.8	43.5	54.0	10.5	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-79.6	-66.2	25.0	- 0.8	43.7	54.0	10.3	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-79.6	-66.2	25.0	- 0.8	43.7	54.0	10.3	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-74.2	-61.0	30.9	17.3	36.9	54.0	17.1	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-66.4	-69.5	32.3	32.0	31.4	54.0	22.6	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		8.3	6.8			0.18	1.0		7.6	
2	Channel 6:		8.0	6.3			0.16	1.0		7.9	
3	Channel 9:		7.5	5.6			0.15	1.0		8.4	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.7 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2419G; 50 ft coax, 5dB attenuator										
1	2390.0	HornS	H/V	-77.3	-71.6	21.5	- 0.6	51.8	54.0	2.2	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-77.3	-71.5	21.5	- 0.6	51.8	54.0	2.2	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-78.1	-71.1	21.5	- 0.6	51.0	54.0	3.0	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-75.6	-70.6	21.5	- 0.6	53.5	54.0	0.5	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-76.5	-70.7	21.5	- 0.6	52.6	54.0	1.4	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-76.4	-70.0	21.5	- 0.6	52.7	54.0	1.3	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-80.3	-70.5	25.5	- 0.7	43.4	54.0	10.6	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-84.0	-70.5	25.5	- 0.7	39.7	54.0	14.3	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-83.3	-70.5	25.5	- 0.7	40.4	54.0	13.6	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-79.8	-66.2	25.0	- 0.8	43.5	54.0	10.5	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-79.7	-66.2	25.0	- 0.8	43.6	54.0	10.4	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-79.8	-66.2	25.0	- 0.8	43.5	54.0	10.5	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-74.2	-60.4	30.9	17.3	36.9	54.0	17.1	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-69	-57.2	32.3	32.0	28.8	54.0	25.2	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-66.6	-69.5	32.3	32.0	31.2	54.0	22.8	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-66.6	-69.5	32.3	32.0	31.2	54.0	22.8	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		- 2.0	0.6			0.02	1.0		17.9	
2	Channel 6:		- 2.0	0.6			0.02	1.0		17.9	
3	Channel 9:		- 2.8	0.5			0.01	1.0		18.7	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 5.8 Highest Emissions Measured

Radiated Emissions											HyperLink/WaveLAN-Hyperamp
#	Freq. MHz	Ant. Used	Ant. Pol.	Ave dBm	Peak dBm	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Antenna: 2424G; 50 ft coax, 12dB attenuator										
1	2390.0	HornS	H/V	-76.5	-71.5	21.5	- 0.6	52.6	54.0	1.4	CH 3; meas. at 3m
1	2390.0	HornS	H/V	-76.9	-71.5	21.5	- 0.6	52.2	54.0	1.8	CH 6; meas. at 3m
1	2390.0	HornS	H/V	-77.0	-71.1	21.5	- 0.6	52.1	54.0	1.9	CH 9; meas. at 3m
2	2483.5	HornS	H/V	-75.8	-70.6	21.5	- 0.6	53.3	54.0	0.7	CH 3; meas. at 3m
2	2483.5	HornS	H/V	-75.6	-70.7	21.5	- 0.6	53.5	54.0	0.5	CH 6; meas. at 3m
2	2483.5	HornS	H/V	-76.1	-70.0	21.5	- 0.6	53.0	54.0	1.0	CH 9; meas. at 3m
3	4844.0	HornC	H/V	-83.2	-70.5	25.5	- 0.7	40.5	54.0	13.5	CH 3; meas. 1 m, noise floor
3	4874.0	HornC	H/V	-83.3	-70.5	25.5	- 0.7	40.4	54.0	13.6	CH 6; meas. 1 m, noise floor
3	4904.0	HornC	H/V	-84.2	-70.5	25.5	- 0.7	39.5	54.0	14.5	CH 9; meas. 1 m, noise floor
4	7266.0	HornXN	H/V	-79.6	-66.2	25.0	- 0.8	43.7	54.0	10.3	CH 3; meas. 1 m, noise floor
4	7311.0	HornXN	H/V	-79.7	-66.2	25.0	- 0.8	43.6	54.0	10.4	CH 6; meas. 1 m, noise floor
4	7356.0	HornXN	H/V	-79.9	-66.2	25.0	- 0.8	43.4	54.0	10.6	CH 9; meas. 1 m, noise floor
6	14532.0	HornKu	H/V	-73.4	-59.9	30.9	17.3	37.7	54.0	16.3	CH 3; meas. 1 m, noise floor
7	19376.0	HornK	H/V	-69.1	-57.2	32.3	32.0	28.7	54.0	25.3	CH 3; meas. 1 m, noise floor
7	19496.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 6; meas. 1 m, noise floor
7	19616.0	HornK	H/V	-69.0	-57.2	32.3	32.0	28.8	54.0	25.2	CH 9; meas. 1 m, noise floor
8	21798.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 3; meas. 1 m, noise floor
8	21933.0	HornK	H/V	-66.6	-69.5	32.3	32.0	31.2	54.0	22.8	CH 6; meas. 1 m, noise floor
8	22068.0	HornK	H/V	-66.5	-69.5	32.3	32.0	31.3	54.0	22.7	CH 9; meas. 1 m, noise floor
			Pr	Pr			Pr	Limit		dB	
	Health Hazard:		dBm	mW			mW/cm2	mW/cm2		Below	
1	Channel 3:		- 6.6	0.2			0.01	1.0		22.5	
2	Channel 6:		- 7.0	0.2			0.01	1.0		22.9	
3	Channel 9:		- 7.1	0.2			0.01	1.0		23.0	
			* Ave: measured with 1 MHz RBW and 100 Hz VBW								
			* Peak: measured with 1 MHz RBW and 3 MHz VBW								

Meas. 05/10/00; U of Mich

Table 6.1 Highest Conducted Emissions Measured

HyperLink/WaveLAN - DVE; FCC Class B												
	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	1.50	Lo	42.0	48.0	6.0		48.0					
2	3.00	Lo	1.5	48.0	46.5		48.0					
3	4.50	Lo	46.0	48.0	2.0		48.0		Not Applicable			
4	5.60	Lo	46.5	48.0	1.5		48.0					
5	9.50	Lo	40.0	48.0	8.0		48.0					
6	13.20	Lo	43.0	48.0	5.0		48.0					
7	14.00	Lo	41.2	48.0	6.8		48.0					
8	20.00	Lo	38.0	48.0	10.0		48.0					
9	30.00	Lo	43.1	48.0	4.9		48.0					
10	3.20	Hi	46.0	48.0	2.0		48.0					
11	4.50	Hi	47.0	48.0	1.0		48.0					
12	5.90	Hi		48.0		47.1	48.0	0.9				
13	7.00	Hi	46.5	48.0	1.5		48.0					
14	12.00	Hi	45.5	48.0	2.5		48.0					
15	14.50	Hi	45.0	48.0	3.0		48.0					
16	18.00	Hi	41.0	48.0	7.0		48.0					
17	25.50	Hi	37.0	48.0	11.0		48.0					
18	29.00	Hi	31.0	48.0	17.0		48.0					

**QP limit*

Meas. 5/10/00; U of Mich.

Since Vpeak >= Vqp, the Vqplim is met.

Table 6.2 Highest Conducted Emissions Measured

HyperLink/WaveLan - Sunfone; FCC Class A

#	Freq. MHz	Line Side	Peak Det., dBµV Vtest	Peak Det., dBµV Vlim*	Pass dB*	QP Det., dBµV Vtest	QP Det., dBµV Vlim	Pass dB	Ave. Det., dBµV Vtest	Ave. Det., dBµV Vlim	Pass dB	Comments
1	0.45	Lo	55.0	60.0	5.0		60.0					
2	4.00	Lo	68.0	69.6	1.6		69.6					
3	6.00	Lo	41.0	69.6	28.6		69.6		Not Applicable			
4	9.00	Lo	42.0	69.6	27.6		69.6					
5	12.00	Lo	34.0	69.6	35.6		69.6					
6	13.50	Lo	38.0	69.6	31.6		69.6					
7	17.00	Lo	37.0	69.6	32.6		69.6					
8	22.50	Lo	31.0	69.6	38.6		69.6					
9	27.00	Lo	28.0	69.6	41.6		69.6					
10	0.40	Hi		60.0		54.5	60.0	5.5				
11	4.00	Hi	57.0	69.6	12.6		69.6					
12	7.50	Hi	37.0	69.6	32.6		69.6					
13	12.00	Hi	41.0	69.6	28.6		69.6					
14	13.80	Hi	39.0	69.6	30.6		69.6					
15	18.50	Hi	40.0	69.6	29.6		69.6					
16	21.50	Hi	31.0	69.6	38.6		69.6					
17	25.50	Hi	27.0	69.6	42.6		69.6					
18	28.00	Hi	28.0	69.6	41.6		69.6					

**QP limit*

Meas. 5/10/00; U of Mich.

Since Vpeak >= Vqp, the Vqplim is met.

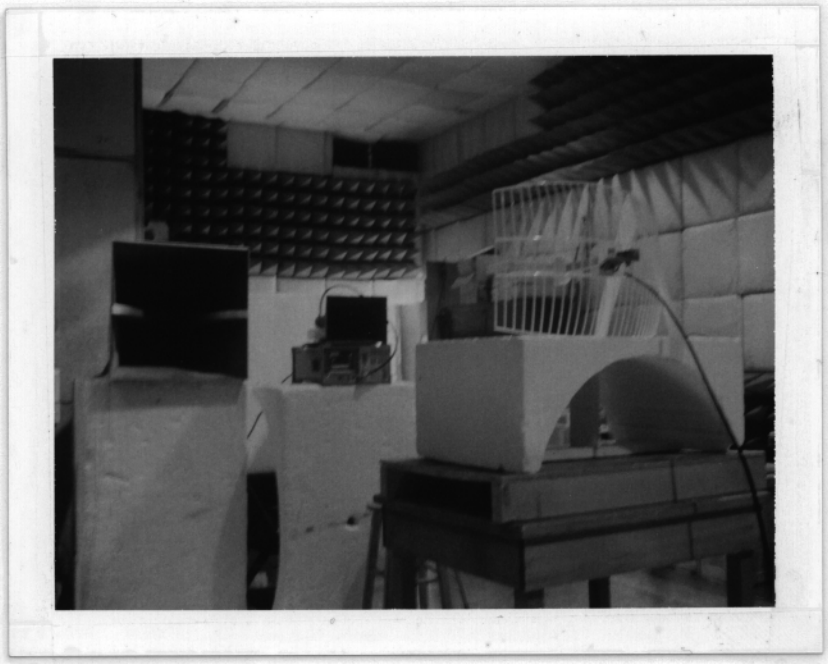


Figure 5.1. Measurement set-up in the chamber. Antenna used is to the right.

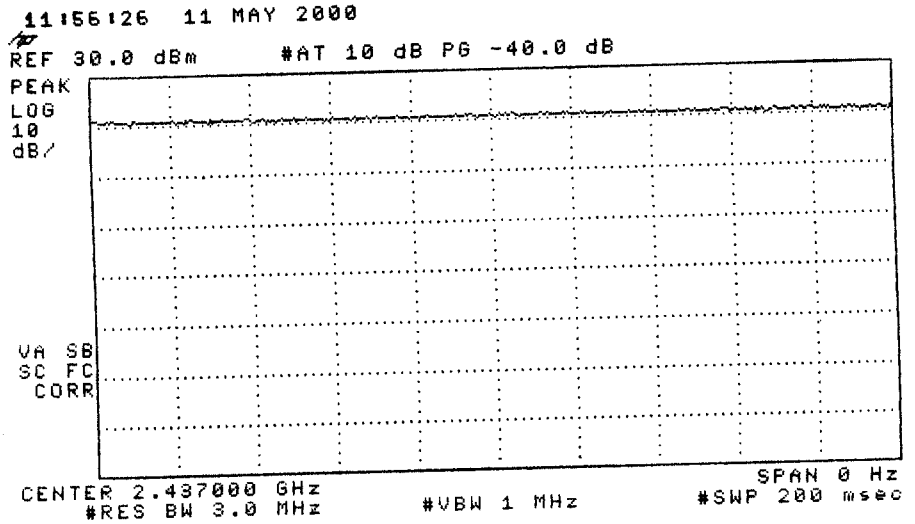


Figure 6.1 Measurement of duty factor.

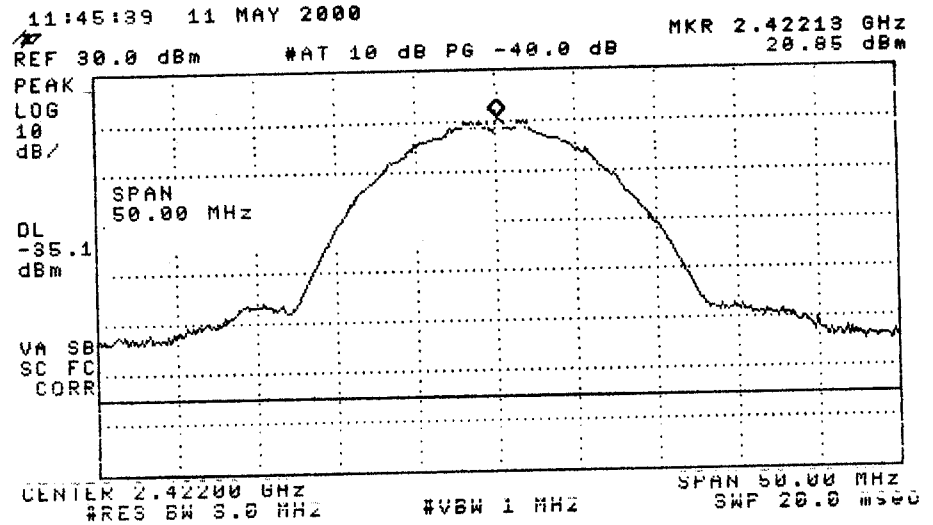


Figure 6.2. Measurement of maximum peak power. Since the RBW< signal BW, this is not a valid measurement. Use power meter data.

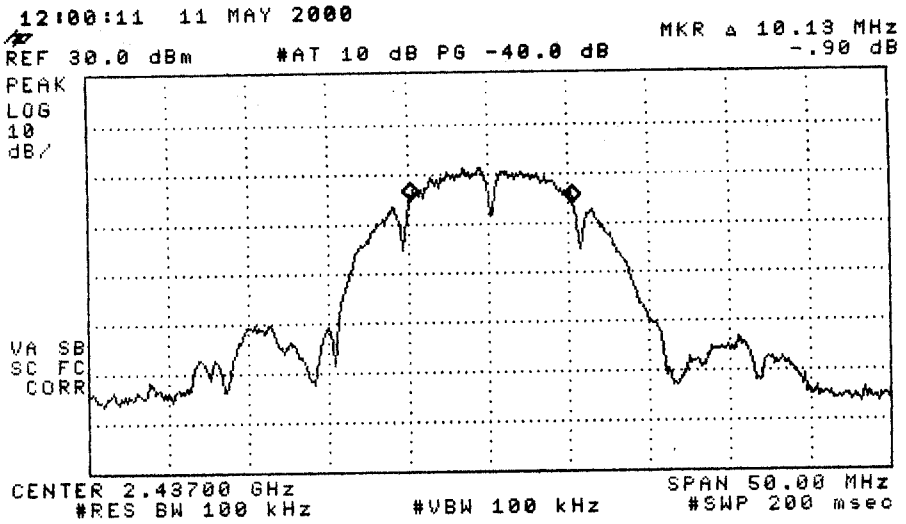
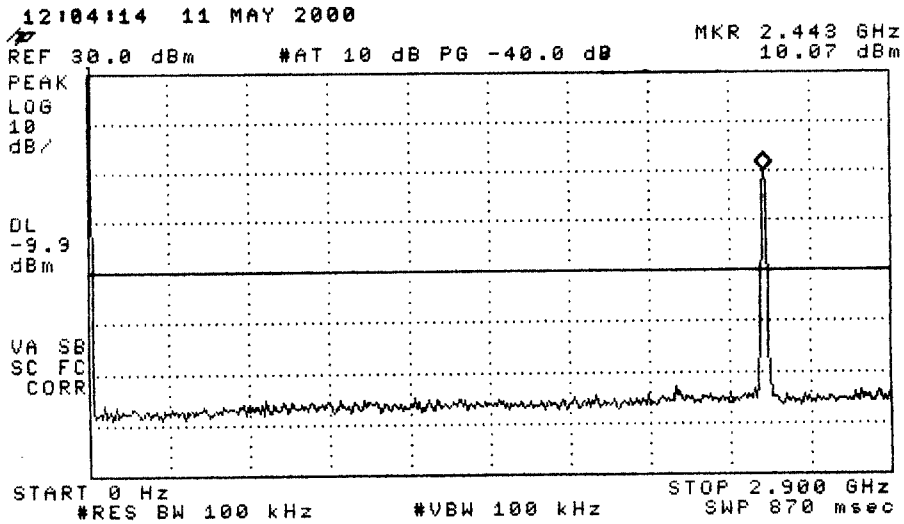
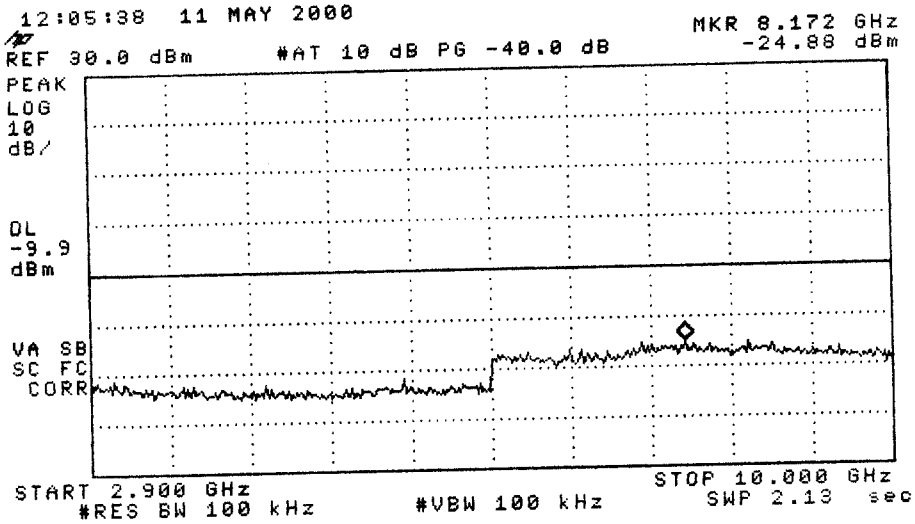


Figure 6.3. 6 dB-point bandwidth measurement.





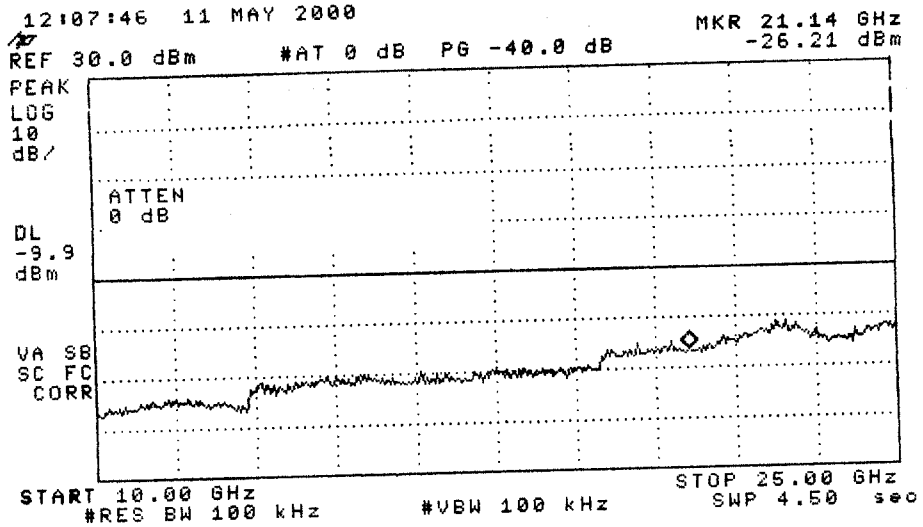


Figure 6.4.
Antenna conducted spurious emissions

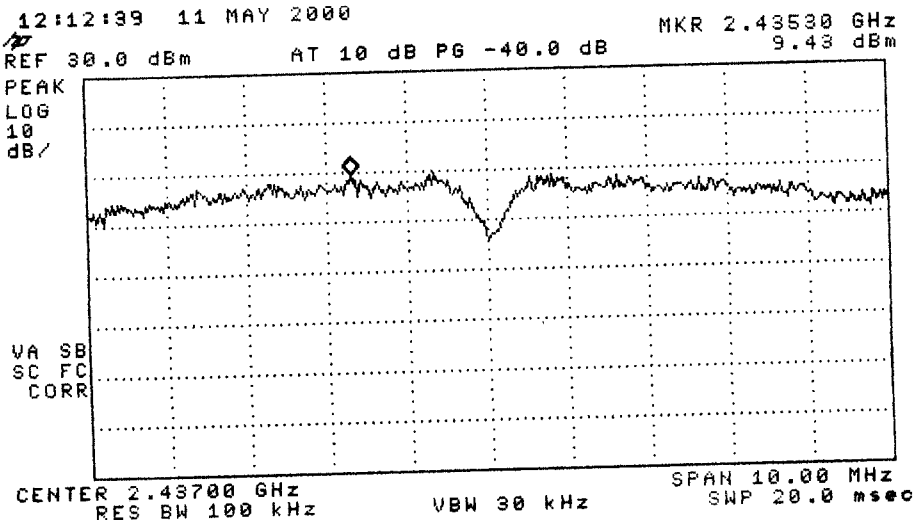
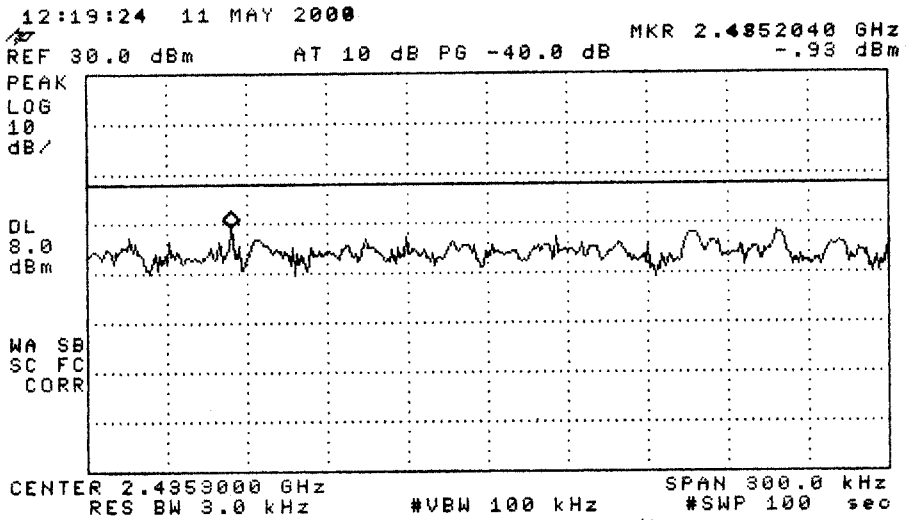
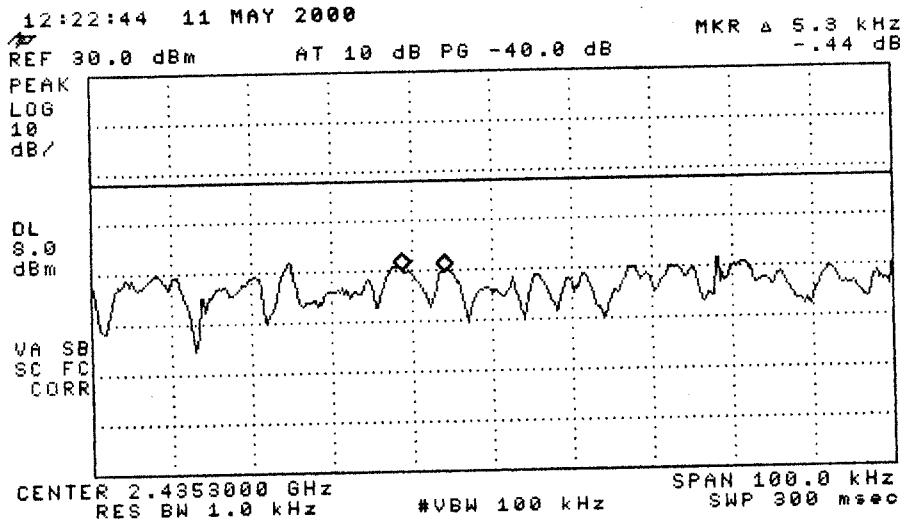


Figure 6.5.

Spectrum Scan



Spectral Density



Line Spacing