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Measured Radio Frequency Emissions From

Hyperlink/Clarion Extended Range Radio Model B10A (Transmitter)

Report No. 415031-830
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For:
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Summary

Tests for compliance with FCC Regulations subject to Part 15 were performed on HyperLink spread spectrum RF link with amplifier. 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 Clarion radio, but with added different antennas and rf cables. Here we report on measurements of radiated emissions in restricted bands, using new antennas and cables, and on measurements of conducted emissions for a second source power supply for the Clarion Radio.

In testing performed on June 8, 1998, the device tested in the worst case met the allowed FCC specifications for radiated emissions in restricted bands by 0.4 dB (see pp. 8-9). The amplifier power supply conducted emissions, Class A, were met by 0.9 dB (see p. 10).

1. Introduction

HyperLink/Clarion Extended Range Radio, Model B10A, 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	July1997/HP
Spectrum Analyzer (9kHz-26GHz)	X	Hewlett-Packard 8593E SN: 3107A01131	June1997/HP
Spectrum Analyzer (0.1-1500 MHz)		Hewlett-Packard 182T/8558B SN: 1529A01114/543592	August 1997/U of M Rad Lab
Preamplifier (5-1000MHz)		Watkins-Johnson A11 -1 plus A25-1S	May 1996/U of M Rad Lab
Preamplifier (5-4000 MHz)		Avantek	Nov. 1992/ U of M Rad Lab
Power Meter w/ Thermistor		Hewlett-Packard 432A Hewlett-Packard 478A	August 1996/U of M Rad Lab
Broadband Bicone (20-200 MHz)		University of Michigan	July 1988/U of M Rad Lab
Broadband Bicone (200-1000 MHz)		University of Michigan	June 1993/U of M Rad Lab
Dipole Antenna Set (30-1000 MHz)		EMCO 3121C SN: 992	February 1994/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	February 1991/U of M Rad Lab
LISN Box	X	University of Michigan	May 1994/U of M Rad Lab
Signal Cables	X	Assorted	January 1993/U of M Rad Lab
X-Y Recorder		Hewlett-Packard 7046A	During Use/U of M Rad Lab
Signal Generator (0.1-990 MHz)		Hewlett-Packard 8656A	January 1990/U of M Rad Lab
EMI/Fld Int. Meter (30-1000 MHz)		Stoddard NM-37/57A SN: 0606-80119	August 1989/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 a laptop computer, Clarion radio, power feed/ lightning protector, 50-foot coax cable, amplifier, band-pass filter, and a choice six antennas.

The DUT operates at 2436 Mhz, with some 27 MHz spread. Since the self-contained Clarion radio already has been previously certified as an rf device, here we need not test for the processing gain.

The DUT was designed and manufactured by Hyperlink Technologies Inc., 1200 Clint Moore Rd., Suite 14, Boca Raton, FL 33687. It is identified as:

HyperLink/Clarion Extended Range Radio
Model: B10A
SN: Proto5
FCC ID: MYF-HYPER24CLA

Components evaluated:

Clarion JX4000 Radio	SN: 00606FC01A8 FCC ID: AX2JX4000
Power Supply for Clarion Radio (second source) SINPRO, Model: SPU-24-1-1	SN: 010111615
Jetbook, Laptop	SN: 1484430200 FCC ID: IQ7486C2
Amplifier, HyperLink Model: HA2400ASE	SN: 803190 FCC ID: n/a
Banpass Filter, Hyperlink, 5-pole Model: FLT-2400C01	SN: none FCC ID: n/a
Power Supply for HyperLink amlifier DVE, Model: SDSA-0301-12	SN: 5097
Power Injector/ Lightning Arrestor HyperLink, PN:BT-CL01	SN: none

Cables

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

Pigtail cable, between Clarion radio and
lightning arrestor, 4-feet, custom

Antennas

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

Antenna, Omni, V-pol
Model: HG 2412U, 12.4 dBi

Antenna, Yaggi, V/H-pol
Model: HG 2414Y, 13.5 dBi

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

Antennas (cont.)
Antenna, Parabolic, V/H-pol
Model: HG 2419G, 19.0 dBi

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

3.1 EMI Relevent Modifications

During testing the attenuator values were selected to meet the FCC emission 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 harmonis, 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	Fundamental Ave. E_{lim} (3m)		Spurious* Ave. E_{lim} (3m)	
(MHz)	(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 (MHz)	Class A ds = 10 m		Class B ds = 3 m	
	(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 (MHz)	Class A ds = 10 m		Class B ds = 3 m	
	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 receicer (horn) antennas were placed on a styrofoam block, at about 1.2 m hight, 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 5.2. There we see that in the worst case the DUT meets the limit by 0.4 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 the worst case ratio was 12.0 dB, and when no signal was detected (a noise floor), the worst case ratio was 14.5 dB.

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 each of the six antennas connected in the system transmitting CW emission. In the worst case, with the HG2408U antenna, we measured 10.6 dBm which corresponds to 0.30 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. 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	
2.436	22.1 dBm	(Limit 30 dBm)

We also measured the max. peak power with the spectrum analyzer with RBW=3 MHz (max. available), and there read 19.5 dBm. Obviously, the value is lower due to a reduced receiving bandwidth. See also Figure 6.1.

6.4 Power Line Conducted Emissiosn (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 A limit by 0.9 dB. See Table 6.1.

The radio and the laptop conducted emissions were not measured, since they are already at least Class A 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
2.4360 GHz	27.0 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. Tha 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 -28.6 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	
2.434 GHz	-6.54 dBm	(Limit 8.0 dBm)

The spectrum line spacing was 4.5 kHz. See Figure 6.5.

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Table 5.1 Highest Emissions Measured

Radiated Emissions											HyperLink, Mod. B10A
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr** dBm	Det.* Used	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Ant. HG2408U; with 0.0 dB attn., power feed/ lightning arrestor, 50 ft coax, amplifier, filter										
1	2483.5	HornS	H/V	-77.9	Ave	21.5	- 0.6	51.2	54.0	**2.8**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-81.8	Ave	25.5	- 0.7	41.9	54.0	12.1	real signal, meas. at 1 m
3	7326.0	HornXN	H/V	-80.4	Ave	25.0	- 0.8	42.9	54.0	11.1	noise floor, meas. at 1 m
4	14500.0	HornKu	H/V	-74.7	Ave	30.9	17.3	36.4	54.0	17.6	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.4	Ave	32.3	32.0	28.4	54.0	25.6	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.2	Ave	32.8	32.5	30.6	54.0	23.4	noise floor, meas. at 1 m
	Ant. HG2412U; with 1.0 dB attn., power feed/ lightning arrestor, 50 ft coax, amplifier, filter										
1	2483.5	HornS	H/V	-76.9	Ave	21.5	- 0.6	52.2	54.0	**1.8**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-84.3	Ave	25.5	- 0.7	39.4	54.0	14.6	real signal, meas. at 1 m
3	7326.0	HornXN	H/V	-80.3	Ave	25.0	- 0.8	43.0	54.0	11.0	noise floor, meas. at 1 m
4	14500.0	HornKu	H/V	-74.6	Ave	30.9	17.3	36.5	54.0	17.5	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.4	Ave	32.3	32.0	28.4	54.0	25.6	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
	Ant. HG2414Y; with 4.0 dB attn., power feed/ lightning arrestor, 50 ft coax, amplifier, filter										
1	2483.5	HornS	H/V	-76.6	Ave	21.5	- 0.6	52.5	54.0	**1.5**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-85.2	Ave	25.5	- 0.7	38.5	54.0	15.5	real signal, meas. at 1 m
3	7326.0	HornXN	H/V	-80.3	Ave	25.0	- 0.8	43.0	54.0	11.0	noise floor, meas. at 1 m
4	14500.0	HornKu	H/V	-74.4	Ave	30.9	17.3	36.7	54.0	17.3	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.2	Ave	32.3	32.0	28.6	54.0	25.4	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.4	Ave	32.8	32.5	30.4	54.0	23.6	noise floor, meas. at 1 m
	Ant. HG2415G; with 5.0 dB attn., power feed/ lightning arrestor, 50 ft coax, amplifier, filter										
1	2483.5	HornS	H/V	-75.9	Ave	21.5	- 0.6	53.2	54.0	**0.8**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-85.0	Ave	25.5	- 0.7	38.7	54.0	15.3	real signal, meas. at 1 m
3	7326.0	HornXN	H/V	-80.3	Ave	25.0	- 0.8	43.0	54.0	11.0	noise floor, meas. at 1 m
4	14500.0	HornKu	H/V	-74.5	Ave	30.9	17.3	36.6	54.0	17.4	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.3	Ave	32.3	32.0	28.5	54.0	25.5	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
		* Ave: measured with 1 MHz Res BW and 100 Hz Video BW									

Meas. 6/8/98; U of Mich.

Table 5.2 Highest Emissions Measured

Radiated Emissions											HyperLink, Mod. B10A
#	Freq. MHz	Ant. Used	Ant. Pol.	Pr** dBm	Det.* Used	Ka dB/m	Kg dB	E3 dBµV/m	E3lim dBµV/m	Pass dB	Comments
	Ant. HG2419G; with 9.0 dB attn., power feed/ lightning arrestor, 50 ft coax, amplifier, filter										
1	2483.5	HornS	H/V	-75.5	Ave	21.5	- 0.6	53.6	54.0	**0.4**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-84.9	Ave	25.5	- 0.7	38.8	54.0	15.2	real signal, meas. at 1 m
3	7326.0	HornXN	H/V	-80.3	Ave	25.0	- 0.8	43.0	54.0	11.0	noise floor, meas. at 1 m
4	14500.0	HornKu	H/V	-74.5	Ave	30.9	17.3	36.6	54.0	17.4	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.5	Ave	32.3	32.0	28.3	54.0	25.7	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.2	Ave	32.8	32.5	30.6	54.0	23.4	noise floor, meas. at 1 m
	Ant. HG2424GC; with 14.0 dB attn., power feed/ lightning arrestor, 50 ft coax, amplifier, filter										
1	2483.5	HornS	H/V	-78.3	Ave	21.5	- 0.6	50.8	54.0	**3.2**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-88.3	Ave	25.5	- 0.7	35.4	54.0	18.6	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-80.3	Ave	25.0	- 0.8	43.0	54.0	11.0	noise floor, meas. at 1 m
4	14500.0	HornKu	H/V	-74.9	Ave	30.9	17.3	36.2	54.0	17.8	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.5	Ave	32.3	32.0	28.3	54.0	25.7	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.3	Ave	32.8	32.5	30.5	54.0	23.5	noise floor, meas. at 1 m
		* Ave: measured with 1 MHz Res BW and 100 Hz Video BW									

Meas. 6/8/98; U of Mich

Table 6.1 Highest Conducted Emissions Measured

												HyperLink PS; FCC Class A
#	Freq. MHz	Line Side	Peak Det., dBµV Vtest	Vlim*	Pass dB*	QP Det., dBµV Vtest	Vlim	Pass dB	Ave. Det., dBµV Vtest	Vlim	Pass dB	Comments
1	0.50	Lo	57.0	60.0	3.0		60.0					
2	0.80	Lo	55.0	60.0	5.0		60.0					
3	1.00	Lo	53.0	60.0	7.0		60.0		Not Applicable			
4	1.30	Lo	46.0	60.0	14.0		60.0					
5	1.70	Lo	47.0	60.0	13.0		60.0					
6	6.80	Lo	40.0	69.6	29.6		69.6					
7	12.75	Lo	46.9	69.6	22.7		69.6					
8	14.50	Lo	38.0	69.6	31.6		69.6					
9	21.75	Lo	43.0	69.6	26.6		69.6					
10	0.50	Hi	59.1	60.0	**0.9**		60.0					
11	0.80	Hi	55.0	60.0	5.0		60.0					
12	1.00	Hi	52.0	60.0	8.0		60.0					
13	1.40	Hi	48.0	60.0	12.0		60.0					
14	3.50	Hi	42.0	69.6	27.6		69.6					
15	9.50	Hi	35.0	69.6	34.6		69.6					
16	12.60	Hi	44.6	69.6	25.0		69.6					
17	22.00	Hi	40.5	69.6	29.1		69.6					
18	24.80	Hi	44.0	69.6	25.6		69.6					

**QP limit*

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Since Vpeak >= Vqp, the Vqplim is met.

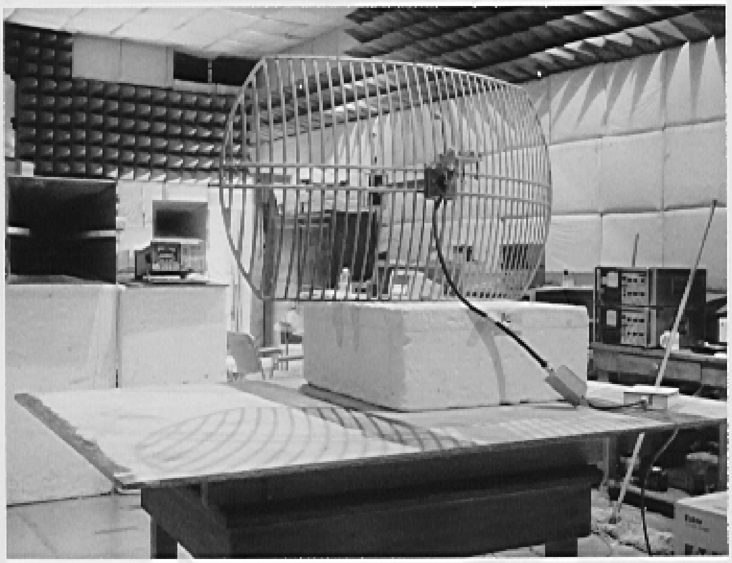


Figure 5.1. Measurement set-up in the chamber. Antenna used is to the right.

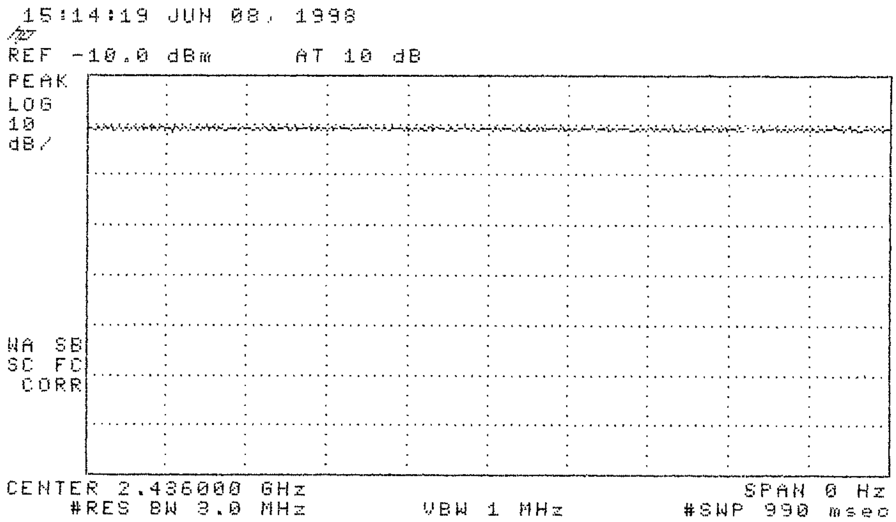


Figure 6.1 Measurement of duty factor.

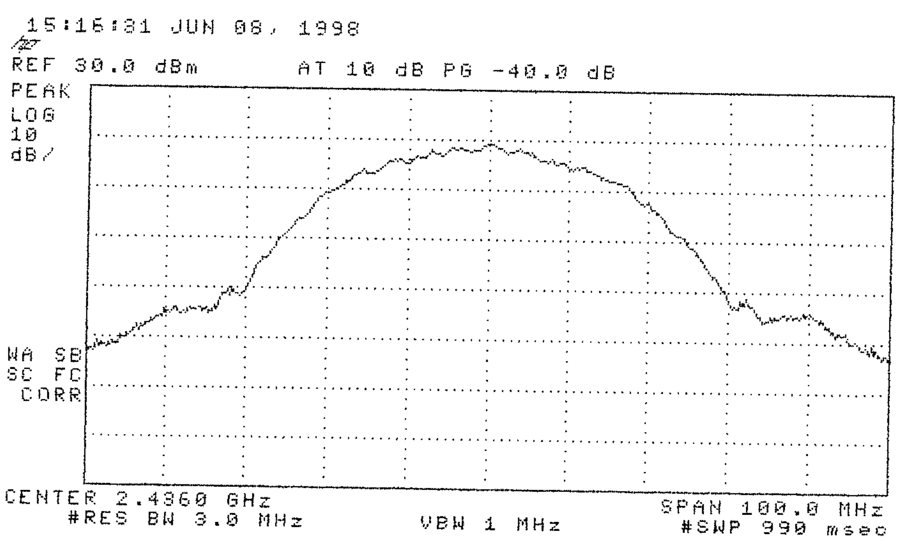


Figure 6.2. Measurement of max. peak power. Since the RBW< signal BW, this is not a valid measurement. Use power meter data.

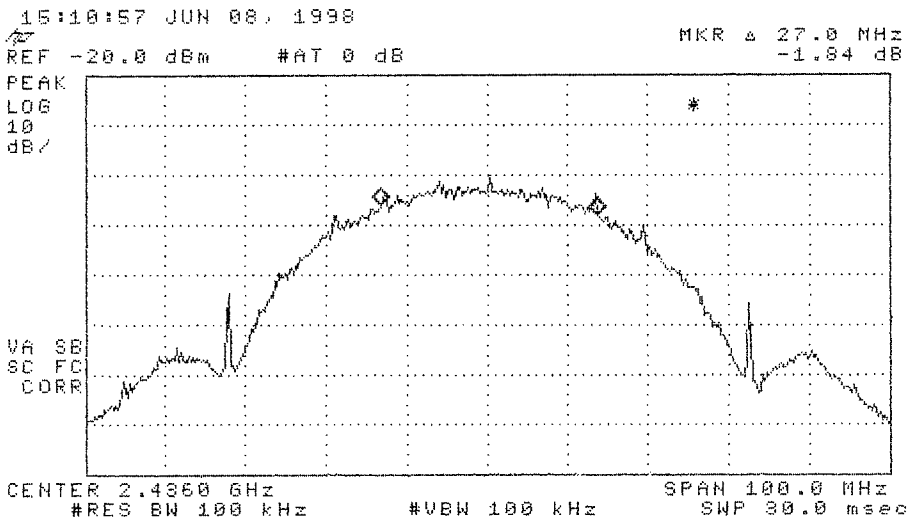


Figure 6.3. 6 dB-point bandwidth measurement.

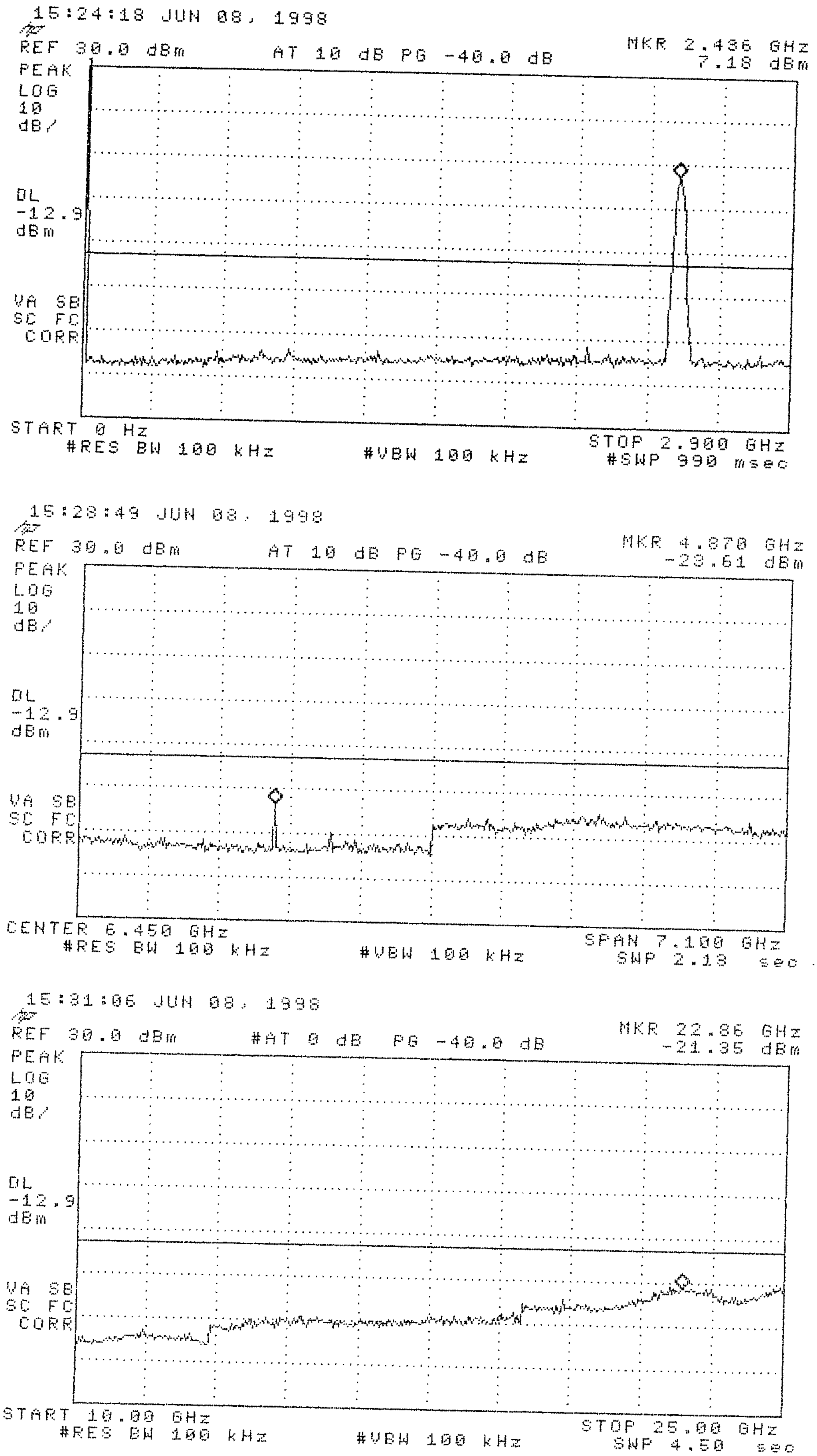


Figure 6.4.
Antenna conducted
spurious emissions.

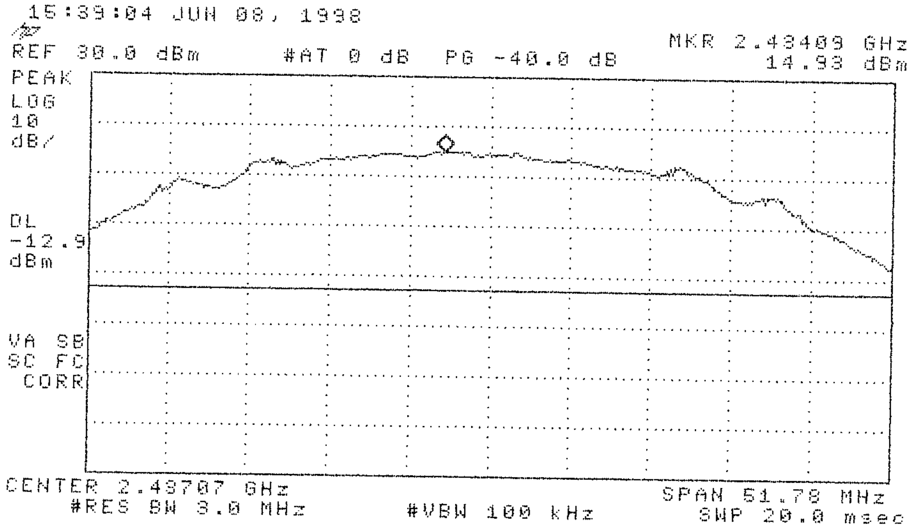
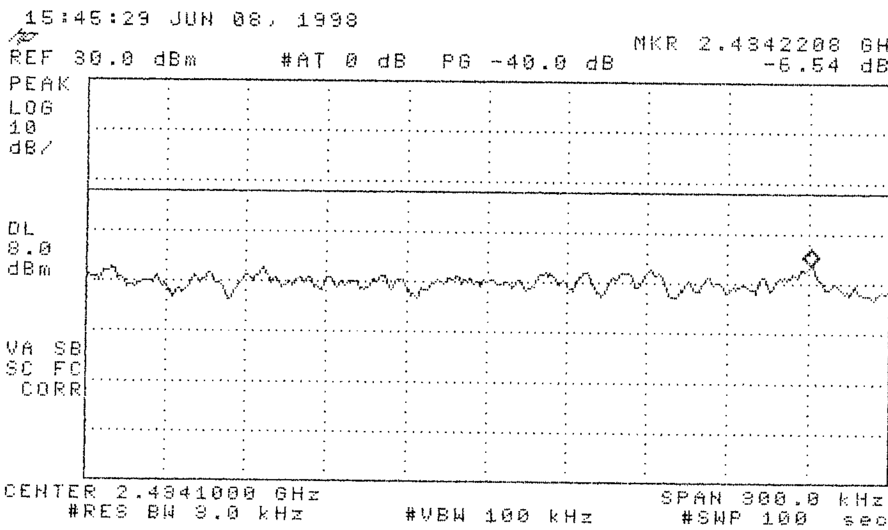
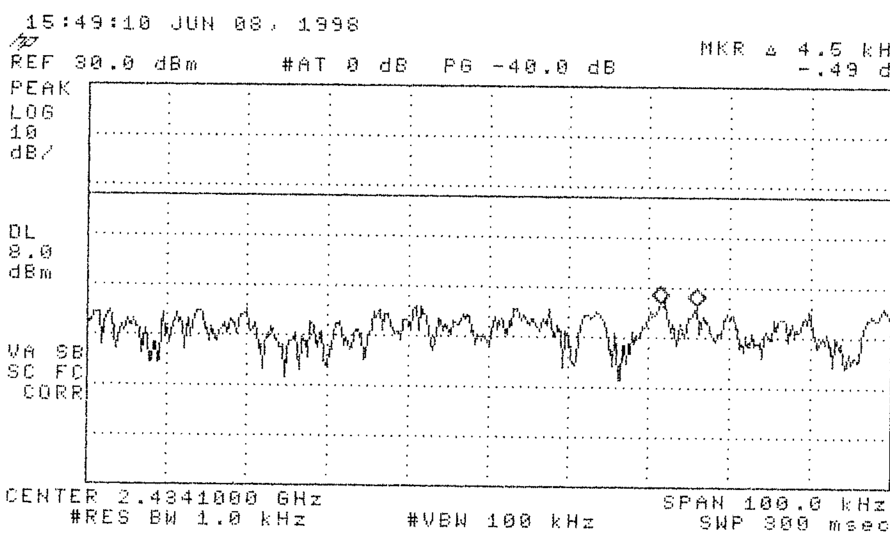


Figure 6.5.
Spectrum scan



Spectral Density



Line spacing.