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Measured Radio Frequency Emissions
From

Hyperlink/Clarion Extended Range Radio
Model B10
(Transmitter)

Report No. 415031-828
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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. 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 April 6-7 and June 8, 1998, the device tested in the worst case met the allowed FCC specifications for radiated emissions in restricted bands by 0.3 dB (see pp. 7-8). The conducted emissions, Class B, were met by 1.2 dB (see p. 9).

1. Introduction

HyperLink/Clarion Extended Range Radio, Model B10, 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, band-pass fitter, a lightning protector, 50-foot coax cable, and a choice on eight 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 only need to test for emissions in restricted bands and test for max. exposure levels. Except for 2483.5 MHz, all the other emissions were unmeasurable, even at a 1 m distance.

The DUT was designed and will be 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: B10
SN: Proto2
FCC ID: AX2JX4000

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
Lightning Arrestor, HyperLink Model: CLLN	SN: none FCC ID: n/a
Lightning Arrestor with filter, HyperLink Model: CLLN-F	SN: none FCC ID: n/a
Banpass Filter, Hyperlink, 5-pole Model: FLT-2400C01	SN: none FCC ID: n/a

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, Yaggi with radome, V/H-pol
Model: HG 2415Y, 13.5 dBi

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

Antenna, Reflector, V/H-pol
Model: HG 2424G, 24.0 dBi

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

3.1 EMI Relevent Modifications

During testing the use band-pass filters 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 (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 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 0.3 dB at 2483.5 MHz.

6. Other Measurements and Computations

6.1 Peak-to-Average Ratio

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

For signal measurements from The DUT, the the worst case ratio was 10.4 dB, and when no signal was detected (noise floor), the worst case ratio was 14.1 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, and in the worst case, with HG2424G antenna, measured 1.7 dBm which corresponds to 0.04 mW/cm2. This was measured right at the feed element.

6.3 Conducted Emission Tests

A different (second source) power supply was evaluated for use with Clarion Radio. Measured conducted emissions are presented in Table 6.1, where it shows it meats Class B limits by 1.2 dB.

NOTE: There were negligible, radiated emissions eminatind from this power supply.

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Table 5.1 Highest Emissions Measured

Radiated Emissions											HyperLink, Mod. B10
#	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 lightning arrestor (CLLN), 50 ft coax										
1	2483.5	HornS	H/V	-82.4	Ave	21.5	- 0.6	46.7	54.0	**7.3**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-89.1	Ave	25.5	- 0.7	34.6	54.0	19.4	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-81.3	Ave	25.0	- 0.8	42.0	54.0	12.0	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	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
	Ant. HG2412U; with lightning arrestor (CLLN), 50 ft coax										
1	2483.5	HornS	H/V	-80.8	Ave	21.5	- 0.6	48.3	54.0	**5.7**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-85.6	Ave	25.5	- 0.7	38.1	54.0	15.9	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	-74.5	Ave	30.9	17.3	36.6	54.0	17.4	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-69.2	Ave	32.3	32.0	28.6	54.0	25.4	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
	Ant. HG2414Y; with lightning arrestor (CLLN), 50 ft coax										
1	2483.5	HornS	H/V	-77.5	Ave	21.5	- 0.6	51.6	54.0	**2.4**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-89.1	Ave	25.5	- 0.7	34.6	54.0	19.4	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-81.3	Ave	25.0	- 0.8	42.0	54.0	12.0	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	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
	Ant. HG2415G; with lightning arrestor, BP filter (FLT-2400C01), 50 ft coax										
1	2483.5	HornS	H/V	-85.4	Ave	21.5	- 0.6	43.7	54.0	**10.3**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-85.6	Ave	25.5	- 0.7	38.1	54.0	15.9	noise floor, 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	-74.5	Ave	30.9	17.3	36.6	54.0	17.4	noise floor, meas. at 1 m
5	19536.0	HornK	H/V	-93.6	Ave	32.3	32.0	4.2	54.0	49.8	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
		* Ave: measured with 1 MHz Res BW and 100 Hz Video BW									

Meas. 4/6,7;6/8/98; U of Mich.

Table 5.2 Highest Emissions Measured

Radiated Emissions											HyperLink, Mod. B10
#	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. HG2415Y; lightning arrestor (CLLN-F), 50 ft coax										
1	2483.5	HornS	H/V	-75.4	Ave	21.5	- 0.6	53.7	54.0	**0.3**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-89.1	Ave	25.5	- 0.7	34.6	54.0	19.4	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-81.3	Ave	25.0	- 0.8	42.0	54.0	12.0	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	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
	Ant. HG2419G; with lightning arrestor (CLLN), BP filter (FLT-2400C01), 50 ft coax										
1	2483.5	HornS	H/V	-83.9	Ave	21.5	- 0.6	45.2	54.0	**8.8**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-85.6	Ave	25.5	- 0.7	38.1	54.0	15.9	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-80.2	Ave	25.0	- 0.8	43.1	54.0	10.9	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	-69.5	Ave	32.3	32.0	28.3	54.0	25.7	noise floor, meas. at 1 m
6	21978.0	HornK	H/V	-67.4	Ave	32.8	32.5	30.4	54.0	23.6	noise floor, meas. at 1 m
	Ant. HG2424G; with lightning arrestor (CLLN), BP filter (FLT-2400C01), 50 ft coax										
1	2483.5	HornS	H/V	-81.9	Ave	21.5	- 0.6	47.2	54.0	**6.8**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-89.1	Ave	25.5	- 0.7	34.6	54.0	19.4	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-81.3	Ave	25.0	- 0.8	42.0	54.0	12.0	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	-67.5	Ave	32.8	32.5	30.3	54.0	23.7	noise floor, meas. at 1 m
	Ant. HG2424GC; with lightning arrestor (CLLN), BP filter (FLT-2400C01), 50 ft coax										
1	2483.5	HornS	H/V	-80.1	Ave	21.5	- 0.6	49.0	54.0	**5.0**	real signal, meas. at 3m
2	4884.0	HornC	H/V	-89.1	Ave	25.5	- 0.7	34.6	54.0	19.4	noise floor, meas. at 1 m
3	7326.0	HornXN	H/V	-81.3	Ave	25.0	- 0.8	42.0	54.0	12.0	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	-67.5	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. 4/6,7;6/8/98; U of Mich

Table 6.1 Highest Conducted Emissions Measured

HyperLink PS; FCC Class B

#	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	0.50	Lo	42.5	48.0	5.5		48.0					
2	0.80	Lo	44.0	48.0	4.0		48.0					
3	1.00	Lo	42.0	48.0	6.0		48.0					
4	1.70	Lo	41.0	48.0	7.0		48.0					
5	1.90	Lo	40.0	48.0	8.0		48.0					
6	6.00	Lo	46.0	48.0	2.0		48.0					
7	11.50	Lo	46.7	48.0	1.3		48.0					
8	22.00	Lo	45.0	48.0	3.0		48.0					
9	0.50	Hi	46.0	48.0	2.0		48.0					
10	0.80	Hi	44.0	48.0	4.0		48.0					
11	1.00	Hi	42.0	48.0	6.0		48.0					
12	1.70	Hi	41.0	48.0	7.0		48.0					
13	2.00	Hi	40.0	48.0	8.0		48.0					
14	7.00	Hi	44.0	48.0	4.0		48.0					
15	11.10	Hi	46.8	48.0	**1.2**		48.0					
16	22.00	Hi	46.0	48.0	2.0		48.0					

**QP limit*

Since Vpeak >= Vqp, the Vqplim is met.

Meas. 3/6/98; U of Mich.

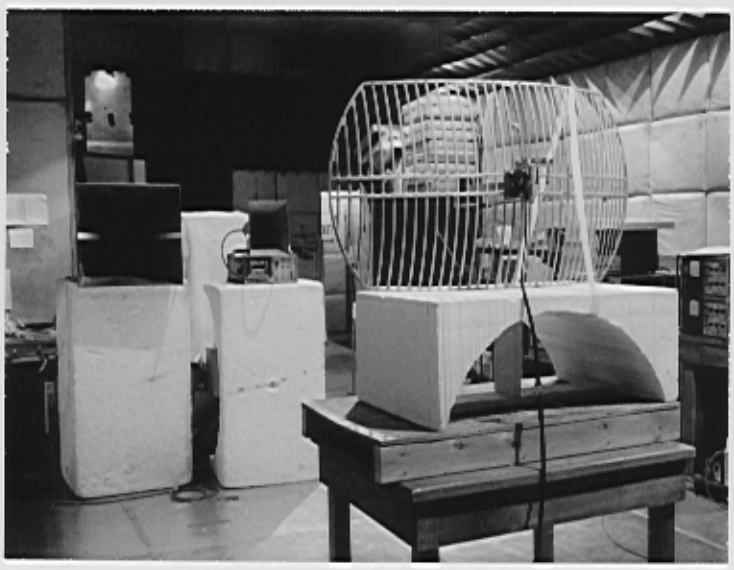

Figure 5.1. Measurement set-up in the chamber. Antenna used is to the right.