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Potomac, MD BPL Trial System Electromagnetic Emission Tests

Metavox, Inc.
May 29, 2004

INTRODUCTION

Metavox, Inc. conducted electromagnetic emission testing of the Potomac, MD BPL trial system. This effort was an independent measurements of the radiated emissions from overhead power line systems distributing Broadband over Power Line (BPL) service to residential subscribers.

BPL systems use digital signal communications of wide bandwidth. The systems are known to occupy spectrum in the frequency region from 1.7 MHz to 30 MHz, with harmonic content into the VHF spectrum. Some of these trial systems operate under Part 5 experimental licenses to conduct testing over a range of 1.7 MHz to 80 MHz.

The purpose of the test conducted here is to measure the field strength of radiated emissions from the BPL system in order to provide a quantitative basis for assessing the potential for interference to licensed radio systems operating in the same frequency range. Most BPL systems seek to operate under limits established by the FCC for Part 15 devices as unlicensed, unintentional emitters. The testing conducted here will assist in efforts to compare the observed BPL emissions to the emission limits established by FCC pertaining to unlicensed devices Specifically, FCC in Part 15 currently "requires that unlicensed devices operating below 30 MHz comply with a quasi-peak radiated emission limit of 30 μV/m at a distance of 30 meters at all frequencies over the range from 1.705 to 30 MHz."

On May 29th, 2004, measurements were taken at a BPL trial system located in Potomac, MD. The results of the Metavox tests are tabulated in Appendix 2: Test Data, a description of the testing and test sites is described in the following sections.

APPROACH

Metavox outfitted a mobile van with calibrated emission-measuring equipment (see Appendix 3: Equipment). The mobility is used in the area of a BPL system to first locate specific positions where the BPL radiated emission is clearly detectable. A picture at the Potomac-1 test site is shown in Figure 1. Figure 2 shows the electronics bench in the van interior with (from left to right on the bottom row of equipment) an HP 141T/8553L/8552A spectrum analyzer, a Tektronix 485 oscilloscope, and the Rohde & Schwarz ESH2 test receiver. Above them is a Boonton 92A-S2 RF millivoltmeter and a Teac RD-111T PCM instrumentation recorder.

Figure 1 Test Van Set Up at Potomac, MD Test Site

Figure 2 Test Bench Inside Metavox Test Van

For signal level measurements, the ARA BBH-500/B active loop antenna was about 5 to 10 meters from the vehicle as shown in Figure 1. The tripod positions the center of the loop at 160 cm above the ground. The full array of equipment is used in site selection to determine that the BPL signal is distinguishable and that the signal strength is adequately handled within the dynamic range of the instruments. However, in the test measurement process, only the active loop antenna, ARA model Model BBH-500/B and ESH2 receiver are used for taking data. These instruments are calibrated to standards traceable to National Institute for Standards and Technology (NIST).

Each field strength measurement is accurate within ± 1.5 dB since measurement accuracy is the combination of (uncorrelated) factors for the antenna (ARA model Model BBH-500/B) and the test receiver (Rohde & Schwarz ESH2) as given in the Appendix 2: Equipment.

Antenna placement and orientation was made considering all of the conductors of the surrounding power distribution system including the medium voltage power conductors, the secondary cable between transformers and the secondary cables to houses.

Figure 3 shows the array of overhead lines on a pole in the Potomac, MD neighborhood. The figure shows 3-phase medium voltage on top, the BPL equipment box with connection to one phase of each of the medium voltage lines. Also on the pole are fiber-optic cabling, media/TV cabling and telephone distribution cabling.

When possible, the antenna is placed such that the slant range from each one of the power conductors is at least 30 meters, and such that for the conductor closest to the antenna, the closest point to the antenna is:

-- near the center of the power line span between poles, and
-- at 30 meters slant range.

However, in this case no point exists that is both 30 meters from the line and also not closer to some other radiating lines. Therefore a distance of 10 meters was used.

A measurement of the output of the active loop is first made using a 300 MHz bandwidth Tektronix 485 oscilloscope to insure the active circuits are not overloaded by a strong signal.. Measurements were then taken at three orthogonal orientations of the antenna for each frequency. The data presents individual measurements on all three orientations along with the combined 3 axis RMS of the 3 voltages expressed in dB. This value represents the expected maximum if the antenna were orientated for the maximum level.

Figure 3 Potomac, MD Test Site Power Pole and Lines Including BPL Installation

TEST DESCRIPTION

Potomac-1

Testing was performed on a trial BPL system operating in Potomac, MD. (see Appendix 1: Sites, Potomac-1) on May 29, 2004. The detailed results are presented in Appendix 2: Test Data, Potomac-1. The far right hand column value represents the worst case interference level if the phases in all three axes were additive. This column contains those single composite values which best illustrate the interference experienced but may not represent non-compliance with FCC Part 15. The single axis measurements should be used to determine compliance.

For this test the H-field antenna was situated at 10 meters slant range from the nearest medium voltage power line conductor, 10 meters from the nearest low voltage line and at a height of 1.6 meters above ground. 30 meters distance would have been preferred to allow direct measurement of the FCC Part 15 limit but the geometries in the neighborhood precluded this. Three orthogonal orientations of the antenna were used: the antenna axis horizontal and parallel to the power lines, horizontal and perpendicular to the power lines, and vertical. Data was taken at 21 frequencies from 2.0 MHz through 14.67 MHz. These 21 frequencies were chosen on site as the BPL signal maximums free of other signals observed in a preliminary scan of the spectrum from 1.7 to 30 MHz. The BPL signal at this site was impulsive, distinctive and clearly distinguishable from 60 Hz power line noise. The HomePlug system design notches out the radio amateur bands and no BPL noise was heard in these bands.

The trial BPL systems seemed to be lightly loaded and very few data bursts would be heard or observed. Access to the BPL system allowed us to set up streaming audio from a broadcast station to create an ongoing data stream to better represent a more fully loaded system.

Measurements were made using the receiver's CISPR mode. The CISPR measurement mode provides an objective measure of the effect of an interference on the reception of radio telephony.

CONCLUSIONS

In general, positioning a test antenna at 30 meters from a radiating power line while also avoiding other radiating lines is difficult. Streets tend to be about 10 meters wide with overhead power lines running down one or both sides. Moving more than 10 meters puts the test antenna off of the public right of way and onto private properties. Even then, the antenna will end up closer than 30 meters from internal house wiring and overhead low voltage lines that will likely carry BPL signals. For this test, a distance of 10 meters was dictated.

The measured interference levels were below the FCC Part 15 limits extrapolated for the 10 meter distance. This extrapolation was based on a 1/r formula so the 30 microvolts per meter limit extrapolates to 90 microvolts per meter. This is a level of 39 dB above one microvolt per meter. The BPL interference was not heard below 5.5 MHz nor above 14.6 MHz.. Also this interference was not heard in the 40, 30 or 20 meter amateur bands. This probably reflects the HomePlug notching of those frequency bands in the design. The HomePlug design does not notch the 60 meter amateur frequencies but other factors attenuated this energy sufficiently to make the interference undetectable at the test antenna position.

Since the amateur radio bands are notched, the interference is lower there than outside the notched frequency bands. The BPL interference observed in the testing outside the notches could be troublesome for reception of international short wave broadcasting and other HF signals.

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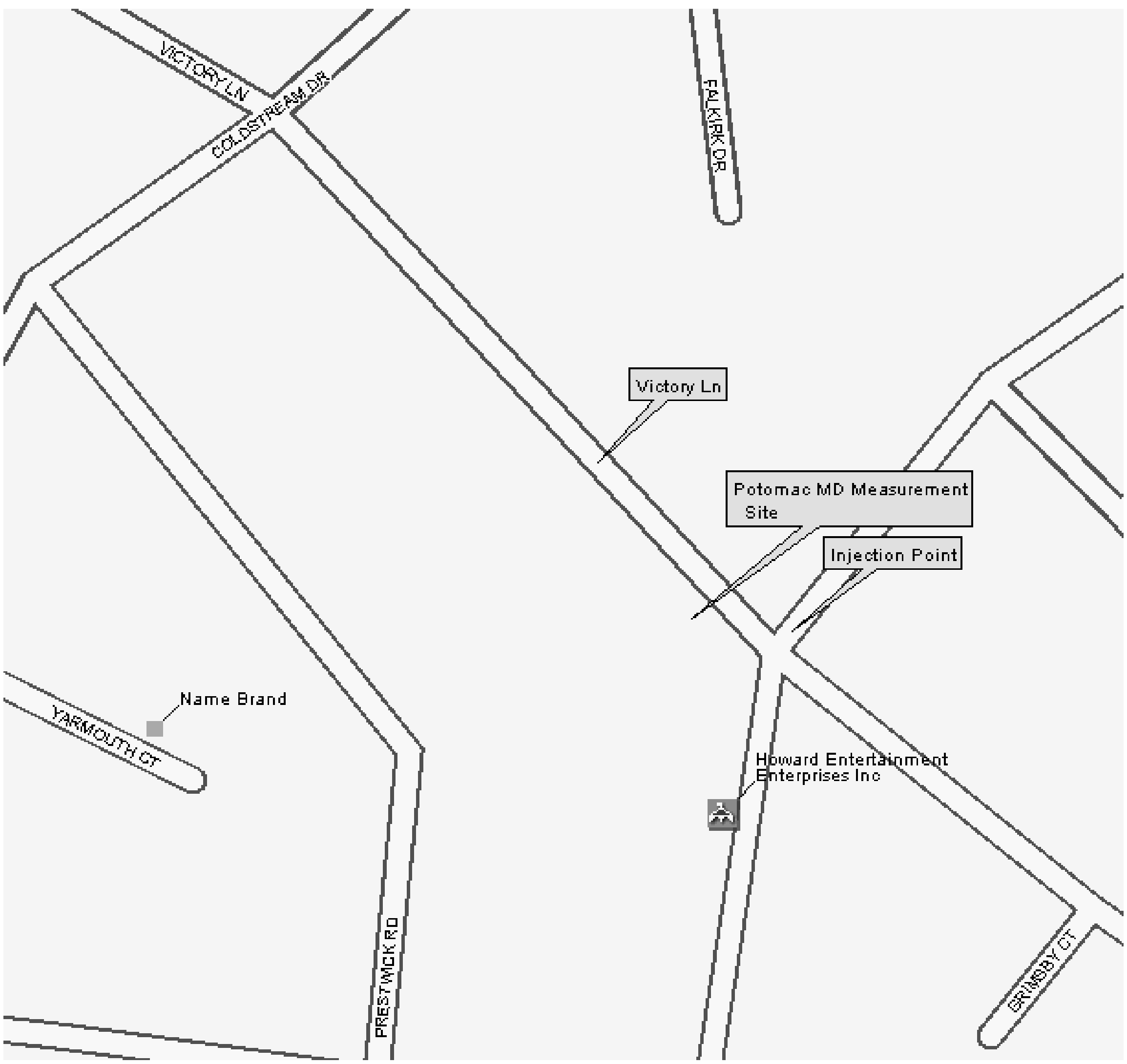
Appendix 1: Sites

Potomac-1

The Potomac test site is along Victory Lane in Potomac Maryland. The properties on this street are suburban residential served by utility lines along Victory Lane with a cross street at Oak Post. At the utility pole at the intersection of Victory Lane and Oak Post the medium voltage 3-phase power line on Victory Lane crosses a medium voltage 3-phase line going along Oak Post. See Figure 3. A number of cable television, telephone utility lines and a fiber optic line also run along these lines. The fiber optic cable is likely carrying the broadband Internet communications to the BPL system. The fiber enters a series of boxes and then cables connect onto one of the medium voltage lines of the 3-phase lines running on both streets. This is likely the point where the fiber optic Internet signals are injected onto the power lines as BPL signals. The connection from the fiber optic processing boxes are carried to clamshell devices attached to the medium voltage lines. It is suspected these clamshell devices contain an RF current transformer much like the design of a clamp-on ammeter. Thus the BPL can be installed on the medium voltage lines by opening the clamshell and closing with the line inside. A close-up of the clamshell device attached to the medium voltage line is shown in Figure 4.



Site Potomac-1

Figure 4 Clamshell Device Attached to the Medium Voltage Line

Site: **Potomac-1**

Saturday, May 29, 2004' Opposite power line; 10m from MV line, 1.6m above ground

8704 Victory Lane

Potomac, MD **H-Probe Antenna**: ARA Model BBH-500/B

			Receiver Indicated Strength						**Field Strength**			
	|| Cable	[||Antenna Factor (equiv. electrical, interpolated)]										RMS
	|| #1	||	// to Line		| to Line		Vertical		// to Line	| to Line	Vertical	(3-axis)
Freq	⇓	⇓	Gain dBμV		Gain dBμV		Gain dBμV		dBμV/m	dBμV/m	dBμV/m	dBμV/m
MHz	dB loss	dB1/meter	base+meter		base+meter		base+meter					
2.00	1.2	-4.05	10	11.0	10	14.0	10	10.0	18.2	21.2	17.2	
3.00	1.2	-5.83	10	13.0	10	19.0	10	12.0	16.4	24.4	17.4	
4.00	1.2	-6.35	10	14.0	10	14.0	10	10.0	17.9	18.9	14.9	
5.00	1.2	-6.87	10	11.0	10	12.0	10	11.0	18.3	16.3	15.3	
5.50	1.2	-6.87	10	16.0	20	5.0	10	12.0	**17.3** i	**19.3** i	**16.3** i	**22.6**
6.00	1.4	-6.87	10	20.0	20	6.0	10	6.0	**20.5** i	**20.5** i	**10.5** i	**23.8**
6.80	1.4	-6.87	10	20.0	20	6.0	10	10.0	**20.5** i	**20.5** i	**14.5** i	**24.1**
6.90	1.4	-6.87	10	11.0	20	4.0	10	10.0	24.5	18.5	14.5	
7.00	1.5	-6.87	10	10.0	20	3.0	10	10.0	14.6	17.6	14.6	
7.30	1.5	-6.87	10	10.0	20	2.0	10	9.0	14.6	16.6	13.6	
7.60	1.6	-6.87	10	14.0	10	10.0	10	9.0	**18.7** i	**14.7** i	**13.7** i	**21.1**
8.00	1.8	-6.87	20	4.0	10	12.0	10	10.0	**18.9** i	**16.9** i	**14.9** i	**22.0**
9.00	1.6	-6.87	10	9.0	20	4.0	10	8.0	13.7	18.7	12.7	
10.01	1.4	-6.87	10	8.0	20	3.0	10	9.0	12.5	17.5	13.5	
11.00	1.6	-6.55	10	10.0	20	16.0	10	12.0	**15.1** i	**31.1** i	**17.1** i	**31.3**
12.25	1.8	-6.14	20	20.0	30	10.0	10	10.0	**35.7** i	**35.7** i	**15.7** i	**38.7**
12.70	1.8	-6.14	20	22.0	30	6.0	10	10.0	**35.7** i	**31.7** i	**15.7** i	**37.1**
13.00	1.9	-5.90	10	10.0	20	6.0	10	6.0	**16.0** i	**22.0** i	**12.0** i	**23.3**
13.29	2.0	-5.80	10	20.0	20	6.0	10	10.0	**26.2** i	**22.2** i	**16.2** i	**28.0**
14.00	2.0	-5.57	10	8.0	10	10.0	10	6.0	14.4	16.4	12.4	
14.67	2.0	-5.36	20	3.0	20	10.0	10	8.0	**19.6** i	**26.6** i	**14.6** i	**27.7**

Site Monitor:	antenna output scope (peak-peak)
typical:	0.1
maximum:	0.1

Notes:

i:BPL Impulses

Bold numbers indicate BPL signal field strengths.

FCC limit of 30 uv/meter is 29.5 dB/uv/m

Appendix 3: Equipment

Metavox tests used equipment calibrated to standards traceable to National Institute for Standards and Technology (NIST):

- Amplified magnetic-field antenna
- Receiver capable of tuning the HF band, with quasi-peak detection matching CISPR specifications.

Amplified H-Field Antenna: ARA Technologies, Inc., Model BBH-500/B, Serial Number 311

Reference: "Data Book, Magnetic Field Antennas, BBH-500/B", page 42; Antenna Research Associates, Inc, Beltsville, Maryland, 20705

The BBH series of broadband magnetic field (H field) receiving antennas are designed to provide maximum sensitivity for receiving magnetic field signals in the VLF, 100 Hz, through VHF, 100MHz, spectrum. These antennas are responsive primarily to the magnetic component of an electromagnetic field with practically no sensitivity to the electric component. The electrical balance with respect to ground and cable renders them almost immune to common mode interference. They exhibit remarkably clean reception in environments of locally generated man-made noise.

The far-field receiving pattern is that of an elementary dipole with nulls of approximately –20 dB occurring off the ends of the rod. Integral active networks ensure the highest possible sensitivity. The BBH antennas yield much greater accuracy in measuring the tangential field of a source at close range than is possible with typical air core loops.

An internal power supply and rechargeable batteries in these antennas minimize disturbances and permit operation under practically any condition.

Magnetic field strength indication from the H-field antenna device is converted to electric field strength by the free space impedance with the common value of 377Ω:

$$af^{electric}{}_{(dB/m)} = af^{magnetic}{}_{(dB/m)} + 51.35_{dB\Omega}$$

The noise floor of the H-field antenna using the manufacturer's specifications, and scaled to the CISPR bandwidth of 9kHz, (i.e. 9.54 dB relative to 1kHz) is:

Frequency, MHz:	1	3	10	30
Noise Floor Field Strength, $dB_{\mu V/m}$:	34.9	5.9	2.9	10.9

Calibration: The Antenna Research Associates Model BBH-500/B, Serial Number 311, was calibrated by Liberty Laboratories Inc., 1346 Yellowwood Road, Kimberton, IA 51543, on Thursday, February 19, 2004, with Certification number: 2004021814 issued to Metavox, Inc.

Traceability: Certificates of Liberty Laboratories state that:

All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to traceability is on file and is available for examination upon request. Measurement procedures per Military Handbook 52A as guidance for Military Standard (MIL-STD) 45662A, ANSI/NCSL Z540-1-1994, ISO/IEC 17025 and Liberty Labs,Inc. procedure OP-2.

Accuracy: The electrical equivalent antenna factor $af^{electric}_{BBH\ (dB/m)}$ is accurate within 0.9 dB for the frequency range from 1 to 30 MHz and certified by the calibration.

Receiver: Rohde and Schwarz Model ESH2, Serial Number 831436/006

Reference: "Data Sheet, Test Receiver ESH 2", Rohde & Schwarz, Republic of Germany.

The Test Receiver ESH 2 is a manually operated, highly sensitive and overload-protected test receiver offering a very wide dynamic range. Compact design, the wide range of power supplies that can be used, and low power consumption make the receiver suitable for use in fixed stations as well as for mobile and portable applications, such as field-strength measurements.

The ESH 2 can tune from 9kHz to 30MHz and operates as a selective voltmeter in a level range from –30 to +137 $dB_{\mu V}$ in 50 Ω systems. Overload of the input or of other important circuits is detected and signaled by the test receiver.

Selection of "CISPR quasi-peak weighted" detection provides an IF bandwidth (-6 dB) for measurements according to CISPR Publications 1 and 3 with 9kHz bandwidth for the HF frequency range.

Calibration: The Rohde & Schwarz Model ESH2, Serial Number 831436/006, was calibrated by Industrial Process Measurement, Inc, Edison, NJ,08820, on February, 5, 2004, with Certificate number 23725-01.

Accuracy: The frequency accuracy in the range of 1-30 MHz is +/- 0.00050 MHz.

The frequency response over the 0.01-30 MHz range, at a signal level of 80.0 $dB_{\mu V,}$ is accurate to +/- 1 $dB_{\mu V}$ and certified by the calibration.