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Raleigh, NC BPL Trial System Electromagnetic Emission Tests

Metavox, Inc.

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INTRODUCTION

Metavox, Inc conducted electromagnetic emission testing of the Raleigh, NC 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 June 7th, 2004, measurements were taken at a BPL trial system located on Holland Chapel Hill Road at the intersection with Elsie Lorraine Drive. 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 Raleigh 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 Raleigh, NC 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 overhead line on a pole along Holland Chapel Road at the intersection with Elsie Lorraine Drive. The figure shows medium voltage on top, the BPL equipment box with connection to the medium voltage line.

When possible, the antenna is placed such that the horizontal range from the medium voltage power conductors is 30 meters. An additional set of measurements were desired at a horizontal distance of 10 meters but this was the middle of Holland Chapel Road which was considered too busy for this placement. A distance of 15 meters was used instead.

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 Raleigh, NC Test Site Power Pole and Lines Including BPL Installation

TEST DESCRIPTION

Raleigh-1

Testing was performed on a trial BPL system operating at Raleigh, NC. (see Appendix 1: Sites, Raleigh-1) on June 7th, 2004. The detailed results are presented in Appendix 2: Test Data, Raleigh-1 for the 30 meter distance and Raleigh-2 for the 15 meter distance. The far right hand column values 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 these tests the H-field antenna was situated at 30 and 15 meters horizontal range from the medium voltage power line conductor. 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 frequencies from 14.3 MHz through 19.92 MHz. These frequencies were chosen on site as BPL signal measurement points 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 a series of carriers, distinctive and clearly distinguishable from other users or 60 Hz power line noise.

Underneath the power line, carriers were heard in the top end of the amateur 20 meter band from 14.20 to 14.35 MHz. While not measurable with the test equipment, these carriers would interfere with weak signal communications. These carriers represent a clear example of interference to radio amateurs from from signals below FCC Part 15 limits. 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

Efforts by Progress Energy have been ongoing since October 2003 to reduce interference to the radio amateurs. This location seems to represent their best concerted efforts to adjust the system to limit interference. They have stated that they have done everything possible and no further improvements can be made. Still, interference occurs within the 20 meter band.

Local amateurs report hearing these BPL signals over distances of several blocks. No provision is made to block the BPL signal from continuing along the medium voltage lines once the desired segment is covered. As a result, the BPL interference is conducted for significant distances beyond the subscriber area. In this instance the system design should include devices to block further propagation of the interference at the end of the subscribed lines. This system design does not couple the BPL signal from the medium voltage line to the low voltage lines as in several other systems. Instead, the BPL signal is converted to a WiFi type signal for connection into the homes of the subscribers. This feature reduces the interference in the home since the BPL interference is not conducted into the house wiring. The measured interference levels exceeded the FCC Part 15 limits by as much as 4.6 dB at the 30 meter distance. Since a significant effort has already been expended to reduce interference expending additional efforts are not expected to bring the system interference levels down significantly.

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Raleigh-1

The Raleigh test site is on Holland Chapel Road at the intersection with Elsie Lorraine Drive. A single phase overhead medium voltage line runs along the road. This power line is where the BPL test system is installed. The land adjacent to Holland Chapel Road is farm land on one side with sparse housing on the road. A community of permanently installed house trailers is along Elsie Lorraine Drive.

The BPL injection point appears to get its Internet connection over a WiFi connection from a site several poles up the road where a microwave dish appears to connect to some remote terrestrial site.

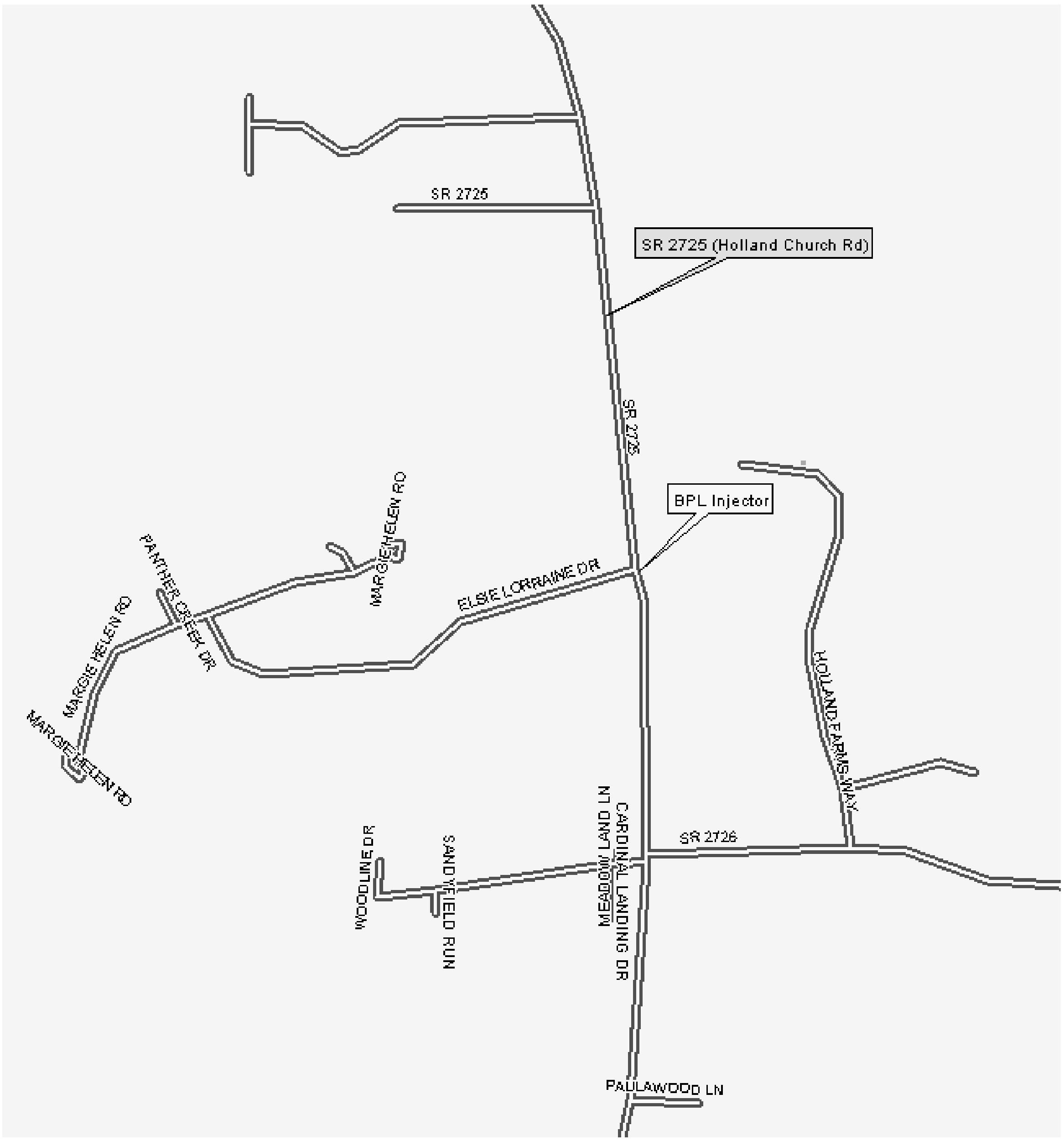

Figure 4 Holland Church Road Injection Node

Appendix 2: Test Data

Site: **Raleigh-1**

June 7, 2004 Across Holland Chapel Road from power line; 30m from MV line, 1.6m above ground

Holland Chapel Rd and Elsie Lorraine Dr

Raleigh, NC **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					
14.39	2.03	-5.50										
14.75	2.03	-5.00	10	14.0	20	5.0	10	13.0	**21.0** i	**22.0** i	**20.0** i	**25.9**
16.24	2.12	-4.80	10	10.0	20	3.0	10	7.0	**17.3** i	**20.3** i	**14.3** i	**22.8**
16.36	2.13	-4.80	10	13.0	20	5.0	10	6.0	**20.3** i	**22.3** i	**13.3** i	**24.8**
17.50	2.17	-4.40	20	7.0	20	7.0	10	16.0	**24.8** i	**24.8** i	**23.8** i	**29.2**
18.25	2.20	-4.10	10	8.0	20	12.0	20	6.0	**16.1** i	**30.1** i	**24.1** i	**31.2**
18.37	2.20	-4.10	10	6.0	20	16.0	20	3.0	**14.1** i	**34.1** i	**21.1** i	**34.4**
19.92	2.20	-3.60	10	5.0	20	6.0	10	8.0	**13.6** i	**24.6** i	**16.6** i	**25.5**

Site Monitor: antenna output
scope (peak-peak)
Maximum 50 mv

Notes:
i: BPL impulse
Bold indicates BPL signal field strength
FCC limit of 30 uv/m is 29.5 dBuV/m

Site: **Raleigh-2**

June 7, 2004 Across Chapel Hill Road from power line; 15m from MV line, 1.6m above ground

Holland Chapel Rd and Elsie Lorraine Dr

Raleigh, NC **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					
14.30	2.03	-5.30	20	2.0	20	3.0	20	2.0	**18.7** i	**19.7** i	**18.7** i	**23.9**
14.75	2.03	-5.50	20	4.0	20	2.0	20	1.0	**20.5** i	**18.5** i	**17.5** i	**23.8**
15.06	2.05	-5.10	20	3.0	20	2.0	10	8.0	**20.0** i	**19.0** i	**15.0** i	**23.2**
15.28	2.06	-5.05	20	6.0	20	12.0	10	12.0	**23.0** i	**29.0** i	**19.0** i	**30.3**
16.24	2.10	-4.90	20	2.0	20	6.0	20	6.0	**19.2** i	**23.2** i	**23.2** i	**27.0**
16.36	2.10	-4.90	20	3.0	20	7.0	20	8.0	**20.2** i	**24.2** i	**25.2** i	**28.4**
17.50	2.18	-4.40	20	9.0	20	12.0	20	6.0	**26.8** i	**29.8** i	**23.8** i	**32.2**
18.25	2.20	-4.05	20	10.0	20	8.0	20	8.0	**28.2** i	**26.2** i	**26.2** i	**31.7**
18.37	2.20	-4.05	20	6.0	20		20	4.0	**24.2** i	**18.2** i	**22.2** i	**26.9**
19.92	2.20	-3.60	20	4.0	20	6.0	20	6.0	**22.6** i	**24.6** i	**24.6** i	**28.8**

Site Monitor: antenna output

scope (peak-peak)

Maximum 50 mv

Notes:

i: BPL impulse

Bold indicates BPL signal field strength

FCC limit of 30 uv/m at 30m is 29.5 dBuV/m

Extrapolation using 1/r to 15 meters

Limit is 35.5 dBuV/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.