Exhibit A: Summary of ARRL Studies of BPL Field Trial Areas

Ed Hare, ARRL Laboratory Manager
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ARRL has done extensive testing in four of the BPL trial areas. This testing showed a severe interference potential from the BPL implementations used in the trial areas. Highlights from this testing has been documented on a video that is available for download at http://www.arrl.org/tis/info/HTML/plc/#Video.

Test Method:

In its comments to the FCC, ARRL described calculations that show that radiated signals or noise at the present FCC radiated emissions limits for intentional emitters and carrier-current devices would cause significant degradation of the capability of nearby HF receivers. The ARRL has done additional testing in BPL field trial areas to document that these calculations are a reasonable approach to predicting the interference potential of radiated emissions. Although some measurements of field strength were performed, the primary purpose of ARRL's visits to the field trial areas was to use listening tests to demonstrate and document the applicability of ARRL's interference calculations to the real-world impact of BPL emissions on HF communications circuits.

To perform these measurements and tests, several different receivers were used with a mobile HF amateur station. The primary test antenna was a short, inductively loaded dipole antenna manufactured by W3FF Antennas, model Buddipole[1], installed on a tripod on the roof of a 1989 Subaru station wagon, a height of approximately 1 meter above the rooftop. The antenna was mounted on a mast that was extended to approximately 3 meters above the vehicle as necessary for some of these tests. This test setup represents a typical mobile HF amateur station. It was driven by Ed Hare, ARRL Laboratory Manager, to each of the tested locations. Listening tests and/or measurements were made at numerous street locations throughout the test area. In all tests except those that were made in motion, the vehicle was turned off.

In most cases, the power lines were located near the roads traveled, at typical heights and distances. In some cases, the station was located as much as about 50 meters from the lines, and strong interference was observed at these distances as well, although at a somewhat less intense level than that seen while driving down streets in the trial area[2]. At the same distances, the gain antennas typically used on HF by stations operating in the Amateur Radio Service would be more susceptible to BPL noise for longer distances than the modest test antennas conservatively used for this testing.

[1] ARRL had compared the gain of the test antenna against a half-wave dipole at the same height, and measured –3 dBd gain on 7 MHz and –1 dBd gain on 14 MHz.

[2] If it would be helpful to the FCC and BPL manufacturers, ARRL can bring a more typical HF installation consisting of small 3-element Yagi beam antenna to locations in two of the trial areas to demonstrate that the effects seen by ARRL in this testing were not caused by the proximity of the mobile installation to the street wiring.

ARRL also used commercial amateur transceivers to make subjective determinations of the amount of degradation to practical HF communications capability. The transceivers and antenna used comprise a reasonable HF mobile amateur station. This station experienced strong to severe interference during this testing. Four different receivers were used: A Kenwood model TS-440 and ICOM IC-756PRO were used in LSB, USB, CW and AM modes. An ICOM PCR-1000 computer controlled receiver was used to make field strength measurements at a few locations and for listening tests on VHF. A Rohde and Schwarz EMC receiver, model ESH-2, was also used to perform some of the listening tests on HF, in AM and SSB modes.

Field-Strength Measurements

To make field-strength measurements, ARRL used the test method developed for the ARRL Amateur Radio Interference Assessment project. This project was initiated by the ARRL Board of Directors in July 2001, significantly before the BPL NOI was brought forth. The ARIA project was previously described on July 7, 2003 to the FCC TAC in a breakout session presentation by Ed Hare, ARRL Laboratory Manager. In this testing, ARRL's ICOM PCR-1000 computer-controlled receiver was used, with test software written by Mr. Hare. This software controls the operating characteristics of the receiver and uses the computer's sound card to make measurements of the receiver audio output. The PCR-1000 receiver had been previously calibrated against a signal generator in the ARRL laboratory, with a measured noise floor of –133.4 dBm on 3.5 MHz, ranging to –129.5 dBm on 14 MHz. By using a step attenuator to keep a test signal within the linear range of the receiver, the receiver output can be used to compare a signal to the receiver's measured noise floor, then calculations can be done by the software to include the test-antenna gain, feed-line losses and the step attenuator setting to derive a field strength from this measured received signal level. A more complete description of this test method is included at the end of this report in the section of this document, "ARRL Amateur Radio Interference Assessment Project Information."

The field-strength measurements were not made to determine whether the systems comply with FCC Part 15 limits, although in the one case where ARRL was able to make measurements in cooperation with one of the BPL manufacturers involved in one of the trial areas, Ambient Corporation, ARRL's measured field strength agreed within 2 dB with the measurements made by Ambient using a calibrated EMC antenna and EMC spectrum analyzer[3]. ARRL's measurements of field strength at the test sites were made to determine that the emissions at the locations being evaluated were reasonably representative of the emissions that would be generated by any BPL system operating at the Part-15 emissions limits and that the evaluations being performed by ARRL were could be reasonably related to those limits.

Test Sites:

ARRL evaluated four BPL test sites and, for comparison, a typical location not in the trial areas. Test site #1 is located in Potomac, MD. ARRL did this testing independently, but an amateur

[3] To ARRL's knowledge, neither ARRL nor any of the BPL manufacturers have made testing at heights above the power lines to determine the true points of maximum emissions from the lines. These would have significant applicability to the impact of the radiated emissions on aeronautical communications, areas located above the lines on hilly terrain or to antennas located on towers that are taller than the lines.

located in the test area, Paul Alexander, made his station available to ARRL and at times set his computer to continuously download a streaming video for testing purposes. Mr. Alexander has filed separate comments in this proceeding. The Potomac testing was done on July 27, 2003, between 1200 and 1800 UTC. The test area is in a residential neighborhood, in an area of single-family homes. This is an area of overhead electrical distribution wiring.

Some limited testing was done at test site #2 on July 28 between 1400 and 1800 UTC in the City of Manassas, VA. ARRL was accompanied in Manassas by an area amateur, Frank Gentnes, who has also filed separate comments. This testing was done July 29, 2003, between 1400 and 1800 UTC. This is a neighborhood of single-family homes and all electrical wiring is underground.

Test site #3 is located in Emmaus, PA. ARRL was accompanied in this testing by Joel Gilly, a local amateur operator. This testing was peformed July 29 between 1400 and 1800 UTC, with additional testing done on August 15, 2003 from 1400 to 1800 UTC. The test area is in a residential neighborhood, in an area of single-family homes. There are areas of underground and overhead wiring involved in the Emmaus test area.

Test site #4 is located in Briarcliff Manor, NY. This testing was performed July 27-28, 2003 from 2000 to 0200 UTC and August 14, 2003, from 1400 to 0200 UTC. In the August portion of this testing, ARRL was accompanied by Frank Fallon, the ARRL Hudson Division Director, Jay Kolinsky, a local amateur operator; and Ron Barnes, a Connecticut amateur who works in the television broadcast industry. The BPL signals originate at an electric-utility substation, in an area of mixed single-family homes and some light industry. The lines then extend into areas of single-family homes. The distribution wiring is overhead in this test area.

Measured levels:

Measurements were made of the field strength present at several of the test locations. At test site #1, the user had linked his home computer to a streaming video site to provide a constant signal during testing at that location. On 12 MHz, the BPL-noise field strength at this location was measured as high as 23.0 dBuV/m with the short-dipole antenna located approximately 5 meters below the overhead power lines, with the mobile installation parked on the street. Another measurement was made on 5.3 MHz, using a 7-MHz half-wave dipole, matched to 5.3 MHz using an antenna-matching network. This antenna was located a height of approximately 6 meters, 3 meters in front of the house, approximately 12 meters from the street. This would be a reasonable amateur installation for that neighborhood of close-spaced houses. The level on 5.3 MHz at that antenna was 6.6 dBuV/m[4]. The measured ambient noise level when BPL signals could not be detected averaged around -6 dBuV/m on 5.3 MHz to -3 dBuV/m on 14 MHz.

At test site #3, measurements made from the street, across the street from the lines, ranged from +28 dBuV/m at one location measured from the vehicle parked across the street from overhead power lines to +35 dBuV/m at another where the antenna was raised to a height of about 5 meters above ground. In test site #4, ARRL measured +32 dBuV/m at one location about 10

[4] This system appears to be radiating at less than the permitted FCC limits. Clearly, under some circumstances, it is possible for BPL systems to operate well below the radiated emissions limits in the present rules, raising the question about why increases are being sought.

meters diagonally from the power lines, with the test antenna located at a height of about 3 meters[5].

Subjective measurements

Although the signal levels were measured at a few locations, most of the testing was done mobile, by stopping at various places in the BPL trial area or, in a few cases, in motion. Because the manufacturers are presently making measurements to the extent presently required by FCC regulations, ARRL does not dispute system compliance on the basis of ARRL measurements. At low antenna heights, the measurements ARRL made indicate that the systems are operating at levels somewhat below, or just about at, the permitted limits *at those heights*. The listening tests ARRL performed show what the laws of antenna physics predict – that these signal levels will cause harmful interference to nearby HF stations.

The listening that ARRL did in the trial areas was extensive. The video ARRL has prepared shows only representative examples of what was heard.

Control – Burlington, CT

The first part of the video recording shows the mobile station used for this testing. To allow the Commission to gauge the capability of this installation and to evaluate BPL-noise received signals with normal operation in the Amateur Radio Service, a short clip is included that shows that in a reasonably quiet location, this station is capable of receiving weak HF signals. In areas where BPL is not in use, the HF range is loaded with signals that are within the communications capability of this station. This recording was made on August 17, 2003 at 2000 UTC.

Test Area #1 – Potomac, MD

In this area, ARRL found strong interference to shortwave broadcasting, commercial and government spectrum, WWV reception and the amateur 5.3-MHz allocation, with these tests being primarily performed at the station of a local amateur in the trial area. ARRL also did some drive-around testing, finding a number of locations where BPL signals were clearly heard at strong levels. ARRL was at this location during the daytime during the workweek, a time when residential Internet use would normally be relatively light.

The video recording shows interference to 5.3 MHz and 10-MHz WWV reception. The interference sounds like rapid staccato pops or crackling, with occasional longer burst heard as the BPL modems download longer files or web pages, or become involved with collisions with other BPL modems.

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[5] At that point, the involved BPL manufacturer had also measured the field strength, obtaining a result that was 2 dB higher than ARRL's.

Test Area #2 – City of Manassas, VA

ARRL made only one visit to this trial area, so only limited testing was performed. In this area of underground wiring, the interference level was moderately strong. A single example of this is shown in the video documentation.

Test Area #3 – Emmaus, PA

In Emmaus, ARRL found very strong to severe interference to reception all across the HF range. In the area of underground wiring, when a test download was made at one location, ARRL heard strong interference. In the area of overhead wiring, a very strong BPL signal was heard everywhere the mobile station was driven in the areas of overhead lines. The video shows a number of examples of the signal levels encountered, as well as an example of what was found driving for a good distance down one of the streets in the trial area. In many instances, the signal levels were well above S9 on the receivers' signal meters, with S9 nominally representing a received signal level of –103 dBW.

In this area, the BPL signals also sound like rapid staccato pops or crackling, although on the areas where multiple signals are heard from the overhead lines, the number of BPL signals heard on the lines created a cacophony of random bursts described by one listener as sounding like a Geiger counter. Occasional longer bursts of noise were observed as modems downloaded larger files or web pages.

Test Area #4 – Briarcliff Manor, NY

In Briarcliff Manor, the BPL signals were also very strong to severe. They have a different sound from that heard in the other trial areas. On 14 MHz, the noise has a sound almost like a telephone ringing, turning on and off as data is send down the lines. On other parts of the spectrum, the signals sound like a collection of close-spaced carriers, entirely filling wide ranges of spectrum. Interference was observed across a number of portions of the HF bands. ARRL also noted moderately strong signals in low VHF, ranging from 32.8 to 42 MHz.

The video shows a number of examples of what was found in Briarcliff Manor. Recordings were made at a number of stops and locations, some located at least 15 meters from the power lines on the street. Even at this distance, the interference level was strong, with signal levels above S9 common. One portion of the video shows strong BPL signals being heard as the vehicle drove at about 40 mph down a long street, with BPL signals strong for about a kilometer past the test area. The vehicle can be seen driving past house after house while the receiver is tuned through a few MHz of range.

ARRL Amateur Radio Interference Assessment Project Information

Date: July 7, 2003
Prepared by:
ARRL Laboratory Manager, Ed Hare
225 Main St.
Newington, CT 06111
Tel: 860-594-0318
Email: w1rfi@arrl.org.

The ARRL Amateur Radio Interference Assessment (ARIA) project was initiated by the ARRL Board of Directors in July 2001. This project harnesses the resource of over 650,000 licensed amateur radio operators to help make a range of measurement that may be useful to spectrum planning and engineering.

Resources of the Amateur Radio Service

The operators within the Amateur Radio Service can provide the following resources to the ARIA project:

- Amateurs have knowledge of RF signals, antennas, propagation and can help identify many of the signal sources heard during testing
- Amateur receiving equipment and stations is very sensitive, able to make reasonable measurements of field strength, using the techniques described on this information sheet
- Some amateurs have access to professional-level test equipment that also can be used to make measurements
- Many amateurs have significant and relevant formal training and professional experience in making measurements of propagated signals

Use of Conventional Receivers to Make Measurements of Field Strength

Most field-strength measurement equipment uses a calibrated receiver or spectrum analyzer and antenna to make measurements. The calibrated receiver is an easy way to make these measurements, properly accounting for bandwidth and generally providing average, peak or quasi-peak measurements. Its bandwidth can generally be set to the values stipulated in various regulations and standards. The calibrated antenna provides a known and traceable standard response to magnetic or electric fields. Its gain and characteristics are precisely known across a wide frequency range and its manufacturer has generally translated this to an antenna factor that can be used to easily convert between dBuV at a receiver to dBuV/m in field strength. To make measurements of radiated emissions to demonstrate compliance, this type of equipment is generally a necessity.

However, the principles that allow this calibrated equipment to work well together also apply to conventional receivers and antennas. The relationship between received signal levels (RSL), field strength, frequency and receive antenna gain is precise in the far field region of antennas, and the following formulae can be used:

$$\mathbf{RSL_{dBW} = -107.2 + dBuV/m - 20log_{10}(F_{MHz}) + RcvAntGain_{dBi} - Losses_{dB}}$$ [6] **Eq. 1**[7]

$$\mathbf{dbuV/m = 107.2 + RSL_{dBW} + 20log_{10}(F_{MHz}) - RcvAntGain_{dBi} + Losses_{dB}}$$ **Eq. 2**

Antenna Gain

In most cases, antenna gain can be reasonably determined from manufacturer's data, antenna modeling or the use of standard gain antennas such as a half-wave dipole. Real-world antennas can also be compared by measurement to a standard reference antenna and a reasonable estimate of gain can be determined.

Many antennas respond to both electric and magnetic fields. The use of antenna gain to make measurements of RSL presumes that the measurement is being made in the far field of the source antenna and that the receive antenna is located farther than its Fresnel zone from the source. Measurements can be made at closer distances, but in general, the receive antenna will pick up a bit less energy from a given field than it would in the far-field region. This error is generally not more than a few dB.

Receiver Noise Floor as Reference

The noise floor or sensitivity of a modern receiver generally does not vary over time, although variation with gross changes in frequency is typical. If the noise floor is determined by measurement – easy to do with a signal generator and an RMS-reading voltmeter – this noise floor can be used as a reference for RSL measurements. If a signal at the input of the receiver can be kept within the linear range of the receiver – the level before receiver AGC limits the increase in receiver output, an RMS reading of the receiver output can be compared with an RMS reading of the receiver input noise floor and a determination of the average RSL can be determined.

Receiver AGC Level as a Measurement

If a receiver provides an output of its AGC level, either through a signal-strength meter or the ability to read the level by computer, if the AGC level is previously calibrated with an external signal generator, receiver AGC can be used to measure the RSL at the input of a receiver. In most cases, a receiver develops its AGC voltage in response to the peak level of the signal present in the receiver's final IF bandwidth.

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[6] Losses include the receive antenna feed line, connectors, etc.

[7] This formula assumes that the RSL is in the same bandwidth as the measurement bandwidth to determine the level in dBuV/m. If the bandwidths are different, then for uncorrelated signals (ie, noiselike) the following correction must be made to the RSL:

$RSL_{actual} = RSL_{measurement} – 10log_{10}$ (measurement bandwidth / receiver bandwidth).

RMS vs AGC vs Peak-to-Average

Most standards and regulations that seek to measure radiated emissions require that a peak or quasi-peak measurement of the emission be made. A true determination of the peak level of received signal can't be determined from an RMS measurement of a receiver output. However, most signals will fall into these categories:

- Unkeyed CW signals, whose peak-to-average ratio is 0 dB
- Noise-like signals, with a peak-to-average ratio of about 10 dB
- Other signals, which may have any peak-to-average ratio. Multi-carrier signals or OFDM signals will generally have a peak-to-average ratio greater than 10 dB.

A reasonable first cut at the peak signal level of a signal whose average power is known would be to add 0 dB for carriers and add 10 dB for signals that are complex.

The RMS voltmeter reading the receiver output can also be a device capable of peak measurement, such as a spectrum analyzer, storage oscilloscope or a computer sound card. If these instruments are used, a measurement of the peak signal, or peak-to-average ratio, can be made, allowing an estimate of the peak value of the measurement.

Bandwidth

In the US, most measurements are made in compliance with the IEEE/ANSI C63-4 measurement standard. This standard requires that quasi-peak measurements be made at various bandwidths. At RF, the more important are: 9 kHz bandwidth on HF, 100 kHz on VHF and 1 MHz above 1 GHz, with an average detector. The use of an EMC receiver or spectrum analyzer allows these bandwidths to be set exactly. Most communications SSB receivers have fixed bandwidth, typically 2.8 kHz. For noise-like signals, a reasonable estimate can be made by measuring in one bandwidth and adjusting the measurement by $10\log_{10}$(bandwidth ratio).

This correlation works well for signals that are uniform across the required measurement bandwidth. Naturally, it works better for bandwidths that are close to each other, such as a 2.8 kHz bandwidth receiver being used to make a measurement of a signal that is to be correlated to a 9 kHz bandwidth.

ARRL Software

This measurement and correlation can be performed under software control, using a soundcard as the measurement instrument. ARRL has written software to control an ICOM PCR-1000 computer controlled receiver. This software, now in its first beta trials, makes noise-floor and/or AGC-based measurements, saving the results to a file. The software is capable of timed or swept measurements and it can optionally read a GPS receiver and log the position of the measurement.

Volunteers

To date, ARRL has recruited a small team of volunteers to begin making measurements. ARRL Laboratory Manager Ed Hare has been using the techniques to make measurements of power-line noise and the emissions from Broadband Over Power Line field trials. Other volunteers are making measurements of their home amateur stations, using conventional equipment and/or their station receivers. ARRL expects to have this project well underway over the coming months and will present its first data near the end of the year.

Databases

The measurement software does save its raw sound-card data to disk, for any programmed number of milliseconds. (Saving sample of several seconds is entirely feasible.) This will allow a significant archive to be made of signals and tests results, all saved to file. From the data in these files, a large array of signals over a wide spectrum could be reconstructed, to allow an FFT analysis to do a more accurate analysis of occupied spectrum and to allow more sophisticated signal-analysis techniques to be made long after the measurements were complete. These files could be kept as an integral part of any database used to store results.

The Goal

If the goal of a measurement is to establish compliance with FCC or other regulations, then the use of non-standard equipment is not acceptable. If, however, the goal is to determine the effect of emissions and noise on real-world communications systems, then the use of such systems as measurement instrumentation is ideal, reasonably correlated to the measurement conditions in various regulations and standards. These test procedures can be used to obtain usable results without the need for open-area test sites or expensive equipment. Although they cannot generally be performed by untrained staff, anyone with familiarity with signals, propagation and antennas should be able to make measurements using these techniques.

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ARIA NOISE STUDY MEASUREMENT SOFTWARE: Version 07/02/03 de W1RFI

Enter command:
   (C)alibrate...                    <SPACEBAR> = Measure...
   (T)imed measure...                (X) stop timed measure...
   (A)ttenuation change...           (F)requency change...
   (L)ogging toggle ON/OFF...        (S)weep frequency toggle ON/OFF...
   (G)PS toggle ON/OFF…              (M) Soundcard (M)easure toggle ON/OFF)
   (N)ote (Add note to logfile.txt)  (H) Help for non-menu commands
   (Q)uit...
You must calibrate before making measurement.
Logging is OFF   GPS is OFF   Soundcard is ON
Initial frequency =  14.005 MHz
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