April 28, 2009

Christopher D. Imlay
General Counsel
American Radio Relay League, Inc.
Booth, Freret, Imlay & Tepper, P.C.
14356 Cape May Road
Silver Spring, MD 20904-6011

FOIA Control No. 2009-311

Dear Mr. Imlay,

This is in reply to your letter dated March 31, 2009, in which you invoke the Freedom of Information Act (FOIA) (5 U.S.C. 552). You seek "the unredacted versions of certain documents and technical studies included in the record in redacted form in ET Docket No. 04-37 by the Office of Engineering and Technology on or about December 22, 2004." (Emphasis in original.) You further identify these records as those specified for public inspection by the D.C. Circuit Court of Appeals in its decision, American Radio Relay League, Inc. v. FCC, 524 F.3d 227 (D.C. Cir., 2008).

Attached are the responsive documents you request. For your information, they are being submitted simultaneously into the record of the underlying proceeding, ET Docket No. 04-37. Note that certain slide numbers and dates appear to be out of sequence, due to repeat printing of files to generate unredacted versions of pages previously redacted.

The Court's decision in the above-referenced case required the Commission to provide an opportunity for public comment on the unredacted versions of the report. The Court also remanded to the Commission for further justification of the extrapolation factor used for determining compliance with the Commission's standards for BPL systems. The Commission will respond to the Court's direction separately.

You may seek review of this disposition of your request by the Commission by filing an application for review with the Office of General Counsel within 30 days of the date of this letter. See 47 C.F.R. § 0.461(j).

Sincerely,

[Signature]
Julius P. Knapp
Chief,
Office of Engineering & Technology

Enclosures
URGENT
Freedom of Information Act Request
Priority processing required under the provisions of the
Freedom of Information Act
Records not routinely available

2009-311
FOIA Control Number

OET
Bureau Office Assigned (Primary B/O)

04/28/09
Date Time Limits Expires

Coordinating Bureaus/Offices:

Coordinating B/Os must forward all applicable responsive materials or report negative finding to primary B/O.

Contact Person: ___________________________ Telephone #: ___________________________

Coordinating B/O Due Date to Primary B/O:

Name of Requester: CHRISTOPHER D. IMLAY

Classification of Requester:

☐ All Others ☐ Commercial ☐ News Media / Educational
Boxes ☐ Non-commercial Scientific

☐ Yes ☐ No Fee waiver requested. This FOIA has been forwarded to OGC.

☐ Yes ☐ No High profile media request. Primary B/O is requested to send a copy of the response and attachments to OMR for informational purposes prior to release of response.

☐ Yes ☐ No Expedited processing requested. DETERMINATION DUE: 04/10/09

☐ Yes ☐ No Other: ___________________________
March 31, 2009

Via Courier (paper copies) and e-mail delivery
fola@fcc.gov

Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445-12th Street, S.W.
Washington, D.C. 20554

Attention: Office of the Managing Director
FOIA Control Office

Re: FREEDOM OF INFORMATION ACT REQUEST AND REQUEST FOR EXPEDITED PROCESSING

Dear Ms. Dortch:

This is a Freedom of Information Act (FOIA) request filed pursuant to Section 0.451 of the Commission’s Rules. This request is being filed on paper in duplicate and as well by e-mail pursuant to Section 0.461(d)(1) of the Commission’s Rules. The documents requested herein and described below are not routinely available for public inspection and are not now available for public inspection. They are, however, documents that have been ordered to be produced by the Commission for public inspection by the United States Court of Appeals for the District of Columbia Circuit. See, American Radio Relay League, Inc. v. FCC, 524 F.3d 227 (D.C. Cir. 2008).

This request is filed on behalf of the American Radio Relay League, Incorporated (ARRL). The undersigned serves as General Counsel for ARRL and as such is the requestor. The telephone number of the requestor is (301) 384-5525.

Description of Records. The records to be produced are in the custody of the Chief, Office of Engineering and Technology, who is for this purpose the custodian of the records. The records requested are the unredacted versions of certain documents and technical studies included in the record in redacted form in ET Docket No. 04-37 by the Office of Engineering and Technology on or about December 22, 2004. These documents are more particularly described in a document entitled “Submission by the Office of
Engineering and Technology, Federal Communications Commission" authored by Bruce Romano, Associate Chief, Office of Engineering and Technology (OET), bearing a date stamp of the Commission's Office of the Secretary of December 22, 2004, which lists the documents herein requested in unredacted form. A copy of Mr. Romano's cover pleading is attached hereto.

Portions of the documents to be produced (i.e. portions of documents referenced in the attached OET submission) were, according to Mr. Romano's pleading, "redacted, as they represent preliminary or partial results or staff opinions that were part of the deliberative process. Moreover, the redacted information was not relied on by the Commission in making its decision. The redacted portions are indicated by grey shading in place of the subject text." It is the entirety of the documents which had been redacted by the Commission, in their unredacted form, that is the subject of this FOIA request.

Statement of Reasons for Inspection pursuant to Section 0.461(c). Though the Commission earlier refused to disclose the redacted portions of these documents pursuant to one of ARRL's earlier FOIA requests for these same documents (See, FOIA Control Number 2004-591), the United States Court of Appeals for the District of Columbia Circuit ordered on April 25, 2008 that the unredacted documents be produced by the Commission [together with any other documents that the Commission relied on in reaching its decision in ET Docket 04-37]. See, American Radio Relay League, Inc. v. FCC (supra): "On remand, the Commission shall make available for notice and comment the unredacted 'technical studies and data that it has employed in reaching [its] decisions,'(citations omitted) and shall make them part of the rulemaking record." (Id., slip op. at 19). To date, the Commission has not yet complied with that order. However, the documents may not, as the result of this Court order, be withheld in their unredacted form. ARRL requires these unredacted documents in order to participate fully in the remand proceeding that was ordered by the Court.

Fees. ARRL herein specifies no maximum search fee for this request and is willing to pay a search fee for the documents. However, ARRL requests that no fee be imposed for three reasons: (1) the Commission is obligated by the aforementioned remand order of the United States Court of Appeals for the District of Columbia Circuit to disclose this information publicly, and this request was necessitated by the Commission's failure, over a period of eleven months, to comply with the Court's specific instruction; (2) there should be no search for the requested documents since the Associate Chief, Office of Engineering and Technology, specifically identified and caused to be redacted the same documents sought to be produced in their entire, unredacted form now; and (3) ARRL is a Section 501(c)(3) charitable, educational and
Marlene H. Dortch, Secretary  
FREEDOM OF INFORMATION ACT REQUEST  
March 31, 2009  
Page Three  

scientific organization which is seeking the materials exclusively in order to prepare to participate in further Commission rulemaking proceedings relative to ET Docket 04-37.

Request for Expedited Processing. It is respectfully submitted that no justification exists for any extension of time beyond the 20 working days afforded the Commission pursuant to Section 0.461(g) of the Commission’s rules. The Commission has been aware of the affirmative obligation that it has to release the unredacted version of the requested documents for eleven months now. ARRL expects the Commission to adhere specifically to the disclosure deadline. For this same reason, and because the disclosure of the unredacted portions of the technical studies sought to be produced hereunder will necessitate technical review in order to permit ARRL to participate further in ET Docket No. 04-37 on remand from the Court of Appeals, ARRL requires these documents on an expedited basis pursuant to Section 0.461(h) of the Commission’s Rules. Furthermore, the release of the unredacted documents should have been done pursuant to the Court’s remand order well before now, and the location of the documents is clearly not an issue since the custodian of the records itself caused the redactions in the documents previously placed in the record.

Should any question arise concerning this FOIA request, kindly contact the undersigned requestor.

Yours very truly,

Christopher D. Imlay  
General Counsel  
American Radio Relay League, Incorporated

Cc: Mr. Bruce Romano  
Mr. Julius Knapp  
(via courier and e-mail)  
Enclosure (as indicated)
In the Matter of
Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems

Carrier Current Systems, including Broadband over Power Line Systems

SUBMISSION BY THE OFFICE OF ENGINEERING AND TECHNOLOGY, FEDERAL COMMUNICATIONS COMMISSION

The following documents are submitted for inclusion in the record of ET Docket No. 04-37, "Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems; Carrier Current Systems, including Broadband over Power Line Systems," ET Docket No. 03-104. These documents comprise internally-generated information upon which the Commission relied, in part, in reaching its determination in the Report and Order in this proceeding.

1) A presentation representing data collected during a field test of the Amperion and Main.Net BPL installations in Allentown, Pennsylvania, conducted to familiarize the FCC with the BPL operations and to develop measurement techniques;

2) A presentation representing data collected during a field test of the Current Technologies BPL installation in Potomac, Maryland, conducted to familiarize the FCC with the BPL operations and to develop measurement techniques;

3) A presentation representing data collected in a field investigation by FCC personnel of the BPL system in Briarcliff Manor, New York, which has been the subject of an interference complaint;

4) A presentation representing data collected in a field investigation by FCC personnel of the Progress Energy BPL system near Raleigh, North Carolina, which has been the subject of an interference complaint;

5) Spreadsheets with the data underlying each of items 1-4; and

6) Emails, letters, and test reports related to each of the complaints the Commission received regarding various BPL operations.
For items 1-4 above, certain portions of those presentations have been redacted, as they represent preliminary or partial results or staff opinions that were part of the deliberative process. Moreover, the redacted information was not relied on by the Commission in making its decision. The redacted portions are indicated by grey shading in place of the subject text.

Bruce Romano
Associate Chief
Office of Engineering and Technology
Broadband Over Power-Line (BPL) Measurements in Allentown, PA

Results of Radiated Emissions Tests Conducted May 19-22, 2003

June 13, 2003
Steve Martin & Andy Leimer
Technical Research Branch
FCC Laboratory
System Descriptions
(PROPRIETARY)

AMPERION

- **Signal Structure**
  - OFDM, 3 MHz bandwidth
  - Separate channels for nearby links

- **Injection Level**
  - Set before installation

- **Backhaul Connection**
  - Wireless link (802.11b) to fiber or T1

- **Customer connection**
  - Wireless link (802.11b)

- **BPL Coupling**
  - Inductively couples to one line--usually phase

- **Device Types**
  - "Injector"--BPL-to-backhaul wireless
  - "Extractor"--BPL-to-customer wireless
  - "Repeater"--BPL repeater & wireless to customer

- **Injection Duty Factor**
  - 100% for Injector & outbound Repeater
  - 25-100% (data dependent) for Extractor & inbound Repeater

MAIN.NET

- **Signal Structure**
  - DSSS, One channel, 3-20 MHz
  - TDM for nearby links

- **Injection Level**
  - Set by software over internet

- **Backhaul Connection**
  - BPL to fiber or T1

- **Customer Connection**
  - Proprietary low-voltage BPL

- **BPL Coupling**
  - Inductively couples to two lines--phase & neutral--using opposite polarities

- **Device Types**
  - "Concentrator"--BPL at backhaul
  - "Repeater"--BPL repeater

- **Injection Duty Factor**
  - Data dependent
Major Conclusions

Compliance w/Part 15 Emission Limits in Intended Band of Operation

- The following comply—to the extent tested:
  - Amperion Overhead Injector & Extractor
    - Caveat about operation > 30 MHz & untested operating frequencies
  - Amperion Underground Repeater
  - Main.Net Underground Repeater

- The following does not comply*
  - Main.Net Overhead Repeater (3 dB over the limit)
    - Power level set higher than in submitted test report
    - *Marginal compliance could be argued by distance scaling from ground wire

Characteristics

- Overhead devices do not act as point sources (virtually no decay 230 m from coupler)
- Differential two-wire signal injection affects the polarization of radiated emissions from overhead devices
Amperion
Overhead System
Amperion's Overhead System

- "Good Times, Great Oldies"
- Less Dynamic Range For BPL Emission Measurements

5000 Watts

Substation/Backhaul Point

Optical Fiber

Wireless (802.11b) ~700 ft

1.6 mi

"Injector"

DUT A1

Power Supply

"Extractor"

DUT A2

CUSTOMERS

Wireless (802.11b)

~750 ft

Non-Public -- For Internal Use Only -- Contains Proprietary Information
Measurement Locations

Made measurements at 18 antenna locations around the Amperion overhead BPL system
DUT A1
Midpoint Between DUTs
AM TOWERS VISIBLE FROM MEASUREMENT SITE
DUT A2

802.11b Antenna
Under DUT A1

Field Strength in 9-kHz RBW (dBuV/m)

Frequency (MHz)

1.5 m down line from A1
4.5 m down line from A1
7.5 m down line from A1

DUT A2 - EXTRACTOR
DUT A1 - INJECTOR
Under Midpoint Between DUTs

Field Strength in 9-kHz RBW (dBuV/m)

- 115 m down line from A1
- 112 m down line from A1
- 118 m down line from A1

Frequency (MHz)

DUT A2 - EXTRACTOR

DUT A1 - INJECTOR

S. Martin

Non-Public -- For Internal Use Only -- Contains Proprietary Information
Emissions from DUT A1 exceed those from DUT A2, even when measured at DUT A2.
Under-Line Field Strength vs Distance Down Line

* Plotted field strength is 95th percentile spectral bin within emission band of specified DUT for average

Field Strength* in 9-kHz RBW (dBuV/m)

Distance Down Line From DUT

DUT A1—Under Line
DUT A2—Under Line
Under-Line Field Strength vs Distance Down Line

* Plotted field strength is 95th percentile spectral bin within emission band of specified DUT for average

*** NOT A POINT SOURCE ***
Emissions exhibit no noticeable decay 230 m down line from coupler

 Indicates measurements at 8.5 m horizontal distance from line but extrapolated 10 m based on 40
Quasi Peak of DUT A1:
10 m from line near DUT A1

DUT A1: 13 dB Margin

PART 15 LIMIT (QUASI PEAK)

- 10 m horizontal distance from line, 3 m up line from DUT A1 (away from DUT A2)
- Distance extrapolation at 40 log R based on slant range to power line

Field Strength Extrapolated to 30m Range (dBUV/m)

Frequency (MHz)
Quasi Peak of DUTs A1 & A2:
Under line near DUT A2

--Measured under line, 2 m down line from DUT A2 (toward DUT A1)
--Distance extrapolation at 40 log R
based on slant range to power line

DUT A1: 11 dB Margin
DUT A2: 17 dB Margin

11 dB Margin

PART 15 LIMIT (QUASI PEAK)

Field Strength Extrapolated to 30m Range (dBUV/m)

Frequency (MHz)

23 23.5 24 24.5 25 25.5 26 26.5 27 27.5 28

17 dB Margin
Max Hold
Quasi Peak
Avg

DUT A2--EXTRACTOR
DUT A1 INJECTOR

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Quasi Peak of DUTs A1 & A2:
8.5 m from line near DUT A2

Field Strength Extrapolated to 30m Range (dBiV/m)

-8.5 m horizontal distance from line,
  8 m down line from DUT A2 (toward DUT A1)
--Distance extrapolation at 40 log R based on slant range to power line

PART 15 LIMIT (QUASI PEAK)

DUT A1:
11 dB Margin below 30 MHz

DUT A2 EXTRACTOR

DUT A1 INJECTOR

Frequency (MHz)
Amperion
Ground-Based System
Amperion's Ground-Based System

- **Extractor**
- **Ground-Based Injector**
- **Repeater**
  - 802.11 Antenna
- **Substation**
  - 802.11 Antenna
- **Overhead Injector**

Non-Public -- For Internal Use Only -- Contains Proprietary Information
Ground-Based Repeater (DUT A3)

- Tested at 3 m distance to achieve adequate SNR
- Tested 4 radials: 90°, 45°, 0°, & -45° (CW from street)
- Highest emissions at 45° (as shown)
Average Spectra of DUT A3

- Signal ~8 dB above broadband noise
- In-band narrowband ambients exceed signal by 42 dB

Power average spectra measured 3 m from transformer housing, on highest
Quasi Peak of DUT A3

PART 15 LIMIT (QUASI PEAK)

Field Strength, Extrapolated to 30m Range (dBuV/m)

- Max Hold
- Quasi Peak
- Avg
- Part 15 Limit

Spectra measured 3 m from transformer housing, on highest radial & extrapolated to 30 m at 40 dB/decade

27 dB Margin

Frequency (MHz)

Non-Public -- For Internal Use Only -- Contains Proprietary Information
Conclusions Regarding Amperion

- **Compliance**
  - Overhead devices (Injector and Extractor)
    - Measurements were within limits
      - Maximum observed radiated emission below 30 MHz in the intended band of operation was 11 dB below the Part 15 quasi-peak emission limit devices for underground wiring
  - Ground-based device (Repeater)
    - Measurements were within limits
      - Maximum observed radiated emission below 30 MHz in the intended band of operation was 27 dB below the Part 15 quasi-peak emission limit

- **Caveat**
  - Measurements were not intended to ensure compliance
    - Emissions of the Injector device extended above 30 MHz. E-field antenna measurements necessary to ensure compliance with Class B limits above 30 MHz were not performed
    - Testing was limited to intended operating bands of devices. Compliance was not tested over the full range of frequencies required by rules.
    - Testing was not performed on 3 installations or over a full set of radials
    - No conducted testing was performed
Recommendations for Amperion

- **Frequency Bands**
  - Compliance testing on overhead lines should include lowest, highest, and mid-band intended operating channels.

- **Highest Band**
  - Operation on channel extending above 30 MHz should be avoided unless compliance with Class B limits is demonstrated or waiver is obtained.
Main.Net
Allentown Deployment
- 8 Concentrators
- 300 overhead repeaters
- 50 underground repeaters
- 1700 homes passed
Main.Net
Overhead System
Main.Net Overhead Repeater (DUT M1)

Differential system:
Couples to both phase and to neutral with opposite polarities

Electronics

Coupler to Phase

Coupler to Neutral
Main.Net Overhead Repeater (DUT M1)
Ambients and BPL Signal at Two Polarizations

- Ambients make results difficult to interpret
- Loop axis perpendicular to power line gives higher level at most freq's

10-m horizontal distance from power line:
- Avg w/loop axis perpendicular to power line
- Avg w/loop axis parallel to power line
- Ambient—15 m from line, w/no intentional coms

Field Strength in 9 kHz RBW (dBU/m)

Frequency (MHz)

Intended Operating Band

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Temporal Measurements

- Duty factor of primary signal was 85%
- Required 20 Hz pulse rate for quasi peak was achieved
- Source of higher level pulses 17.7 ms intervals was not determined, but did not impact quasi peak measurements

Measured with 3-MHz resolution bandwidth centered at 8.36 MHz
Average and Peak

![Graph showing maximum field strength vs. frequency](#)

- **Average**
- **Max Hold**

**10-m horizontal distance from power line–Loop**

**Peak-to-Average Ratio suggests high duty factor**

---

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12/22/2004 - Slide 15
Moving Down the Line Under the Line

Change in field strength measured under line with distance down line (log-average from 6-20 MHz relative to measurement under coupler):

-8 dB at 50 meters downline from coupler
-10 dB at 100 meters downline from coupler
Moving Down the Line 10 m to the Side

Change in field strength measured at 10-m horizontal offset from line with distance down line (log-average from 6-20 MHz relative to measurement under coupler):
0 dB at 50 meters downline from coupler
Under and Adjacent to the Coupler

When measured at coupler (0-m downline), field strength is 9 dB lower at 10-m horizontal offset from line than directly under line (log-average from 6-20 MHz)

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Under & 10 m to the Side, 50m Down Line

When measured at 50-m downline from coupler, field strength is 1 dB lower at 10-m horizontal offset from line than directly under line (log-average from 6-20 MHz)

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Summary of Relative Average Levels

Results suggest the following:

- Signal decay in moving down line is small—in the range of 0 to 2 dB in 50 m.
- Amplitude measured under coupler is anomalously high—possibly due to RF current in the pole ground wire.
Quasi Peak

Field Strength Extrapolated to 30 m Range (dBUV/m)

3 dB Over Limit

PART 15 LIMIT (QUASI PEAK)

* Emission is 3 dB over limit (at power setting 5) if distance is extrapolated from nearest point of system (electronics box) as shown.

Other extrapolations:
-- Nearest line conductor (neutral), 4 dB over limit
-- Pole ground, 1 dB below limit

10-m horizontal distance from power line and coupler

Frequency (MHz)

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Main.Net
Ground-Based System
Main.Net Ground-Based Repeater (DUT M2)

- Tested at 10 m distance
- Tested 6 radials and selected two for quasi peak processing: radial w/highest emission (over power cable) and radial w/highest emission but not near power cable (as shown)
Effect of Buried Power Cable

Higher emission levels are observed when measuring above buried power cable.

10-m horizontal distance from transformer housing.
Quasi Peak Above Buried Power Cable

PART 15 LIMIT (QUASI PEAK)

3 dB Margin

Maximum emission measured above the underground power cable is at least 3 dB below the limit when extrapolated to 30 m based on 10-m distance to the transformer housing.
Quasi Peak away from Buried Power Cable

Maximum emission measured away from the underground power cable is 13 dB below the limit when extrapolated to 30 m based on 10-m distance to the transformer housing.
Conclusions Regarding Main.Net

- Compliance
  - Overhead device (Repeater on medium voltage lines)
    - Measured emissions exceeded the Part 15 limit
      - Maximum observed radiated emission was 3 dB over the limit
      - Tested unit was said to be set to power level 5. Submitted test report was based on power level 4
      - If distance scaling were based on distance to the pole ground wire rather than the nearest part of the BPL system (a suggestion made by Main.Net's CTO, but which we consider to be invalid), measurements would have passed with 1 dB margin at the selected quasi-peak measurement location
  - Ground-based device (Repeater on medium voltage lines)
    - Measurements were within limits
      - Maximum observed radiated emission was 13 dB below the Part 15 limit when measured in the street
      - Maximum observed radiated emission was 3 dB below the Part 15 limit when measured over the buried power cable

- Caveats
  - Measurements were not intended to ensure compliance
    - Testing was limited to intended operating bands of devices. Compliance was not tested over the full range of frequencies required by rules.
    - Testing was not performed on 3 installations or over a full set of radials
    - No conducted testing was performed

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Recommendations for Main.Net

- Don’t operate overhead units above power level 4
Conclusions Regarding Access BPL

- The tested overhead PLC devices do not act as point sources
  - Emission from line shows virtually no decay 230 m from coupler
- Differential two-wire signal injection affects the polarization of radiated emissions from overhead devices
Conclusions Regarding Testing

• **Test Issues**
  - Underground systems
    • Buried power cable influences emission measurements in its vicinity. Should testing in its immediate vicinity be avoided?
  - Overhead systems
    • Pole ground wire appears to be a source of radiation for an overhead system that couples to neutral, but we don’t believe that it should be a considered part of the system for distance scaling purposes
  - Ambients that exceed limits will be present & must be excluded based on bandwidth

• **Future Test Considerations**
  - Need notch or high-pass filter to attenuate AM radio signals
  - Average spectra work well for finding peak emission locations
  - Achieving high duty factor is important but time consuming.
    • It can take several hours to get the right signal with cooperation from system developer
    • Control computer needs rebooting & no one is in facility
    • Control computer facility is being moved by the power company to another room.
      Need to wait for lineman to access system through another transformer.
  - Testing in a cold rain is not fun
Other Issues

- NTIA (Alaka Paul from Office of Spectrum Management) has requested the following
  - Results from Allentown measurements
  - Possible NTIA participation in any future tests

- Amperion & Main.Net may request briefing on results
Emission Measurements on Current Technologies Medium Voltage BPL System

22 April 2003
Steve Martin
Technical Research Branch
FCC Laboratory
We thank Current Technologies for the excellent support they provided for these tests
FCC Lab Objectives for Access Systems

- **Overarching Objectives**
  - Support FCC in decisions regarding emission limits
  - Develop a measurement procedure for access BPL systems

- **Specific Test Objectives**
  - Provide an understanding of
    - Access BPL radiated emission characteristics
      - Average, quasi-peak, and peak levels
      - Temporal characteristics
      - Variation in field strength with receive antenna height
      - Field strength down line (point radiator versus distributed radiator)
    - Measurement issues
      - Ambient signals
      - Use of pre-filters
      - Other
Test Limitations

- Testing was not intended for certification or verification
- Testing was limited to:
  - Two DUTs
  - 1 – 2 radials
  - One polarization for 1\(^{st}\) DUT
  - Intended operating frequency band of the system
- Ambient impulse noise affected results for DUT 2
Communication Conditions

• **Objective**
  - Create data transmission representative of high rate transmissions from the DUT. For medium voltage coupler outside home, this means communication in upload direction.
  - Achieve the \( \geq 20 \) Hz pulse rate required for CISPR quasi-peak measurements [CFR 47, 15.35(a)(note)]

• **Three communication conditions were tried**
  - Pings
  - FTP
  - 1.5 Mbps upload created with TTCPW (a software tool to measure network performance)

• **Only the latter technique met the objective, so it was used for all testing**
Test Setup

Notes:
- BPF = Bandpass Filter; LPF = Lowpass Filter
- All filter, amplifier, and cable gains, losses, and impedance mismatch effects are calibrated out
- 30 – 50 MHz BPF was custom built and provided by Current Technologies for the test. Measured insertion loss of filter with 50-ohm source and 50-ohm load was 1.4 to 2.3 dB over the frequency range from 31 to 48 MHz.
- LPF needed to reduce UHF TV signal transmission through 30-50 MHz BPF lobe and direct pickup through unshielded 30-50 MHz BPF
Calibration and Data Scaling

- All results converted to field strength units using two frequency-dependent calibration curves:
  - Antenna factor curve
  - Electronics calibration curve measured as shown above
    - Includes losses, gains, and impedance mismatch effects of all filters, amplifier, and cables, measured as shown above
    - Any mismatch effects between antenna and filter input are not included. (Control of this effect by addition of an attenuator or preamp between the antenna and 1st filter was not implemented due to concerns of increasing the noise floor or overdriving the preamp.)
    - Tracking generator was calibrated by connecting a short cable between tracking generator output and analyzer input.

- Distance scaling: 20 dB/decade of range based on slant range to coupler
DUTs

- **DUT 1**: Active coupler with fiber optic connection to bridge
- **DUT 2**: Passive coupler with transformer coupling to bridge (newer design)
DUT Coupler Heights

DUT 1: Height ≈ 11.1 m

DUT 2: Height ≈ 10.9 m

DUT heights measured by comparison on photos to 4.34 m test mast
Measurement Sites

Site 1
- Chosen to maximize SNR
- Directly under power line, ~2 m down line from DUT 1 coupler
- AL siding & 2nd coupler prevented selection of representative compliance location

Site 2a
- Chosen as representative compliance measurement location
- Directly across street from DUT 2 coupler; 14.1 m horizontal distance from power line and coupler

Site 2b
- Chosen to measure emission reduction down line
- Across street from DUT 2 and 25.4 m down line; 12 m horizontal distance from power line

Site 2b not shown. Antenna mast was located on same side of street as shown for 2a, but to the left by ~25 m.
Rx Antenna Height Selection
Rx Antenna Height: Rules and Procedures

Current rules and procedures don’t address DUT mounted 11 m off ground

- **ANSI C63.4-2001** …Measurement of...Emissions from Low-Voltage...Equipment...
  - 8.1 Radiated Emission Measurement Requirements:
    - "...height such that the maximum radiated emissions level shall be detected."
  - 8.2 Antenna Selection, Location, And Measuring Distance
    - 8.2.1 Magnetic Field Radiated Emissions (9 kHz to 30 MHz): “center of the loop ... 1 m above the ground”
    - 8.2.3 **Electric Field** Radiated Emissions (30 MHz to 1 GHz): “varied from 1 m to 4 m”
  - 8.3 Radiated Emission Measurement Procedures:
    - 8.3.1 Measurements **On A Test Site**: “scanned between 1 m and 4 m” (8.3.1.2)
    - 8.3.2 **On-site** measurements: “...heights as normally required... For further guidance, see IEEE Std 139-1988.”

- **IEEE Std 139-1988**—IEEE Recommended Practice for the Measurement of RF Emission from ISM Equipment Installed on User’s Premises
  - 2.6 Determine the RF Spectrum: “measurements ... around, and, if possible, above the EUT. ...if possible, determine if there is significant emission directed upward from the EUT on, or near, frequencies used locally for aircraft beacons or aircraft communications.”
  - 2.8 Measure Radiated Emission: “… moving the antenna ... Vertically from 1 m above the ground up to 4 m, (preferably even higher) if practical, (for measurements at frequencies above 30 MHz).
  - 2.8.2 Overhead Measurements. “If ... possibility of aircraft communications or navigation interference, measure the emission in a line extending up from the EUT, vertically and at several points near vertically above the EUT.... This measurement can be made ... on the roof over the equipment.”

  - 2.2.5 Antenna height variation
    - **Loop** antenna: “height ... around 2 meters” but not in a null.
    - For a **dipole** or equivalent antenna: 1-4 m at distances ≤10 m; 2-6 m at distances > 10 m
Rx Antenna Height:
Theoretical Effect at Center Frequency

At Site 2, 3 m height should result in 3 dB higher emission level than 1.5 m height and 5.5 dB higher than 1 m height.

40 MHz
11 m Tx Height
1 dB Reflection Loss

Tx-to-Rx Horizontal Separation:
- - 0 m
- - 14.1 m
Effect of Rx Antenna Height at Site 1: Max-Hold Spectra for H Polarization

Selected 2-m Rx height based on max-hold spectra
Effect of Rx Antenna Height at Site 1: Peak Spectrum Level

Selected 2-m Rx height based on max-hold spectra

Highest Pk in 32-48 MHz vs Rx Height

Horizontal Polarization
Effect of Rx Antenna Height at Site 2a: Max-Hold Spectra for V Polarization

Peak Field Strength Extrapolated to 10m (dBU/m)

Frequency (MHz)

Legend:
- V Pol, 4m Rx Height
- V Pol, 3m Rx Height
- V Pol, 2m Rx Height
- V Pol, 1m Rx Height
Effect of Rx Antenna Height at Site 2a: Max-Hold Spectra for H Polarization

Selected horizontal polarization and 3-m Rx height based on max-hold spectra
Effect of Rx Antenna Height at Site 2a: Peak Spectrum Level

Highest Peak from 34-48 MHz (excluding 36.6-36.8 & 39-40) vs Polarization & Rx Height

Selected horizontal polarization and 3-m Rx height based on max-hold spectra, but results probably represent ambient impulse noise.
Temporal Measurements
Temporal Measurements:
DUT 1, Site 1

- Desired measurement conditions achieved
  - Requirement for >20 Hz rep-rate achieved
  - Percentage of 61-μs temporal bins containing BPL signals = 69% (avg of three, 0.5-second intervals, with signal presence defined by threshold 10 dB below peak)

- Measurement Setup
  - Test Config. 2
  - Analyzer settings
    - RBW=3 MHz, VBW=3 MHz
    - Center frequency 36.3 MHz (set to encompass broadband spectral peak)
    - 8192-point sweep with duration 0.5 seconds (61 μsec bin width)
Temporal Measurements: DUT 2, Site 2a

- Impulse noise exceeds signal level by ~ 15 dB (peak)
- Desired PLC signal conditions achieved
  - Requirement for >20 Hz rep-rate achieved
  - Percentage of 61-μs temporal bins containing BPL signals = 77% (single 0.5-second trace, with signal presence defined by threshold 22 dB below max impulse peak)

- Measurement Setup
  - Test Config. 2
  - Analyzer settings
    - RBW=3 MHz, VBW=3 MHz
    - Center frequency 42.7 MHz (set to encompass broadband spectral peak)
    - 8192-point sweep with duration 0.5 seconds (61 μsec bin width)
Site 2b—Impulse Noise Measurement (BPL coms terminated)

- Impulse noise source not identified
  - High level when measured at Site 2a (25-m downline from DUT), with coms terminated, and outside BPL operating band suggested DUT was not the source
- Characteristics
  - 120-Hz burst rate
  - 4.0 kHz pulse rate within a burst
  - 1.3% of 10-μs temporal bins contain impulse signals (82 ms trace, based on threshold 15 dB below max impulse peak)
- Measurement Setup
  - Test Config. 1, less the bandpass filter
  - Analyzer settings
    - RBW=3 MHz, VBW=3 MHz, Center frequency 50 MHz (set to encompass broadband spectral peak)
    - 8192-point sweep with duration 81.9 ms (10 μsec bin width)
Site-1 Spectra
Site 1—Full-Band Quasi-Peak and Average Spectra

- 33-minute QP sweep time (lunch)
- ~15 dB average SNR
Site 1—Expanded Spectrum Comparison

Field Strength in 120-kHz RBW (dBuV/m)

Peak, QP, and average spectrum comparison

Frequency (MHz)

Power Average (80 Traces)
Power Average w/no PLB coms (80 Traces)
Peak Detect, Max Hold
Quasi-Peak

Site 1
Rx Height: 2 m
Site 1—Full-Band Quasi Peak Spectra and Limits

- Meas. Config 1
- Meas. Config 2
- Class A Limit Extrapolated to Meas. Distance
- Class B Limit Extrapolated to Meas. Distance

Selected 36.9 MHz center for Config-2 measurements
Site 1—Expanded Quasi Peak Spectra and Limits

- Config's 1 & 2 yielded similar results
- 3 - 4 dB over limit, but unconventional measurement location

- Meas. Config 1
- Meas. Config 2
- Class A Limit Extrapolated to Meas. Distance
- Class B Limit Extrapolated to Meas. Distance

Non-Public -- For Internal Use Only
Site-2 Spectra
Site 2a—Three Max-Hold Spectra

Selected 42.7 MHz center frequency for Config-2 measurements

Field Strength in 120-kHz RBW (dBUV/m)

Frequency (MHz)

Site 2a
Rx Height: 3 m
Site 2a—Expanded Max-Hold and Average Spectra

OFDM carriers visible on average spectra

Peak-Detect, Max Hold

Power Average Spectra (100 traces)

Dip shows that impulse noise did not noticeably impact average spectra but did affect peak-detect, max-hold results
Site 2a — Comparison of Max-Hold, Quasi-Peak, and Average Spectra

Site 2a
Rx Height: 3 m

Field Strength in 120-kHz RBW (dBuV/m)

Frequency (MHz)

Site-2a QP may have been affected by impulse noise:
- QP ~9 dB above power average at Site 2a, versus ~5 dB at Site 1.
- Carriers less visible in QP
Effect of Distance Down Line

**Results Inconclusive:**
- Carriers not visible in Site-2b spectrum due to bin size
- Carrier gap not observed

- **Rx Height:** 3 m

- **Site 2a:** 14 m from line and DUT
- **Site 2b:** 12 m from line, 25 m down line from DUT

**Field Strength in 120-kHz RBW (dBuV/m)**

- **Frequency (MHz):** 42.0 to 45.0
Conclusions

- Communication conditions for measurement were achieved
  - > 20 pps rate & high duty factor communications
- Impulse noise at 2nd site corrupted peak-detect/max-hold & probably quasi-peak results
  - Power average spectra not affected
- Receive antenna height has a significant effect
  - Under power line, maximum over 1 – 4 meter scan occurred at 2 m
  - For typical geometries, maximum over 1 – 4 meter scan occurred at 3 – 4 m, but results were influenced by impulse noise
  - Maximization using average spectrum measurements would have eliminated impulse noise effect
- Effect of distance down line (point source versus distributed source) was not determined conclusively
- No conclusions regarding compliance with levels requested in waiver
  - Full compliance testing not performed
  - Site 1 measurement was 3-4 dB over Class A limit, but was not the preferred geometry for compliance testing
  - Site 2a quasi-peak results may have been influenced by impulse noise
Recommended Future FCC Tests
(To understand technology)

- **Effect of Rx Antenna Height**
  - Use power-average spectra, full-band, but increase # of spectral points to show individual carriers
  - Measure for < 30 MHz and > 30 MHz
    - < 30 MHz: Set coms to download-- maximizing pole-mounted HomePlug emissions; minimize indoor HomePlug emissions during test

- **Effect of Distance Down-Line**
  - Use power-average spectra, full-band, but increase # of spectral points to show individual carriers
  - Measure under line to maximize SNR
  - Measure at several distances down line
  - Antenna orientation based on current in line

- **Extend QP measurements to frequencies with no BPL carriers**
  - To allow assessment of QP measurement SNR

- **Cal Issues**
  - New antenna calibration
  - Use attenuator (and amplifier if necessary) between antenna & filter for impedance matching (if possible while maintaining adequate SNR and headroom for ambients)
BPL Summary
After Briarcliff Manor, NY Test

To OET
September 8, 2004
Steve Martin & Andy Leimer – FCC Laboratory

On site support provided by Ambient during emission testing
Briarcliff Manor BPL Test Results wrt Interference Complaint in Notched Amateur Band

- Tested one device
- Compliant w/emission limits within measurement uncertainty
- Notch performed poorly
  - Vendor forgot to notch device 0.7 miles away
  - Vendor admitted bug in notching & plans a fix
Frequency Allocations and Briarcliff Manor BPL Bands

- BPL
- Complainant Band
- Unnotched Test
- LAND MOBILE BANDS
- AMATEUR BANDS

FREQUENCY (MHZ)
Interference to Mobile Radio in Un-Notched Bands
Van and HF Amateur Antenna

Power line height – 10.6 m
Antenna center height – 3 m
Briarcliff Manor Signal Strength Map at 21.2 MHz
(Unnotched Amateur Band)
Briarcliff Manor Signal Strength Map at 21.2 MHz
(Unnotched Amateur Band)
Briarcliff Manor Received Levels at 21.2 MHz
(Unnotched Amateur Band)

Signal Strength (dBm in 5.5 kHz bandwidth)

-60  -70  -80  -90  -100  -110

Run 7  Run b  In-Band BPL Device

57 dB  41 dB  30 dB

Straight Line Distance From Intersection of N. State & Pleasantville Rds (m)

Pleasantville Rd  N State Rd

FCC Lab/TRB/S. Martin

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**Raleigh Received Levels at 23.2 MHz From One Overhead Injector**

- Noise floor measurement prevented by inefficient antenna
  - Designed for 27-MHz

- **Yellow levels** (0.6 mi of James Slaughter Rd & Old Powell Rd)
  - 14 to 23 dB above measurement floor
  - \(\sim 27 - 36\) dB above probable ambient noise floor

- **Red levels**
  - 24 to 38 dB above measurement floor
  - \(\sim 37\) to 51 dB above probable ambient noise floor

  *s* level observed on *s*-meter during much of test, is \(\sim 13\) dB below floor of digital output indicator (-114 dBm)

---

**Probable noise floor increases are comparable to Briarcliff Manor:**

- 30 dB for \(\sim 0.5\) mile of road per in-band BPL device
- Larger increases occur near the device
Part 15 Emission Limits and ITU Noise Curves
Part 15 Emission Limits Extrapolated to Land Mobile Distances From Power Lines

- Near lane (3 m)
- 2nd Lane (6 m)
- 3rd lane (9 m)

Average Field Strength (dBuV/m in 9 kHz bandwidth)

Frequency (MHz)

BUSINESS
RESIDENTIAL
RURAL
QUIET RURAL
GALACTIC
Mobile Radio Noise Floor Rise ([I+N]/N)
Permitted by Current BPL Emission Limits
NTIA Results

- NTIA predictions are consistent w/FCC measurements
  - In ITU *Residential* noise, BPL increases noise floor for land mobile <15 meters horizontal distance from power line by
    - 30 dB at mid/upper HF
    - 10 dB above 30 MHz

% of Points Exceeding Specified Interference Level for Land-mobile Receiver
Along 340-meter BPL Power Line (NTIA Report Vol I, Table 6-3)

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>3 dB (I+N)/N</th>
<th>10 dB (I+N)/N</th>
<th>20 dB (I+N)/N</th>
<th>30 dB (I+N)/N</th>
<th>40 dB (I+N)/N</th>
<th>50 dB (I+N)/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>99.3%</td>
<td>93.2%</td>
<td>54.7%</td>
<td>6.2%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>15</td>
<td>99.8%</td>
<td>99.7%</td>
<td>95.7%</td>
<td>59.5%</td>
<td>4.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>25</td>
<td>99.8%</td>
<td>99.0%</td>
<td>92.1%</td>
<td>58.5%</td>
<td>18.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>40</td>
<td>87.9%</td>
<td>49.2%</td>
<td>10.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

- NTIA measurements: ambient noise levels < ITU *Residential*
Hence, BPL increases noise by more than predicted above

"The occasional sampling of environmental noise power levels ... with the BPL system turned off were lower than the levels predicted by ITU-R Recommendation P.372-8. Thus, ... use of the higher noise power levels predicted by ITU-R Recommendation P.372-8 in our analyses may bias results toward underestimation of interference levels."

- NTIA would have argued to protect it's HF mobile assets, but...
# of Part 90 Land Mobile Licensees
by Band in 2-MHz Increments

- E.g., Customs Over-the-Horizon Enforcement Network (land mobile in residential neighborhoods)
Other Issues
Skywave (<30 MHz)

- NTIA Tech Appendix:
  - "it would take hundreds of thousands of Access BPL devices [nationwide] operating under existing rules to cause a 1 dB increase in median noise."

- This assumed ITU Residential noise levels

- With Quiet Rural/Galactic noise levels, ...
  - # of devices is reduced by a factor of ~24
  - Factoring uncertainty, problems could occur as soon as next year

NTIA sees need for a follow-on NPRM to possibly limit deployment densities or impose other restrictions on Access BPL in HF (<30 MHz)
Strong fields follow the power line for 0.5 mile. Not a point source.

Emerging ARINC / PHONEX carrier-current case [for internal FCC discussion only]
- ARINC interference now traced to carrier current devices. Interference distance at least 5 miles
- ARINC and *most FCC DF stations are affected*
- Emissions are believed to exceed limits, but compliant BPL may be worse, because...

<table>
<thead>
<tr>
<th>Radiator</th>
<th>Phonex Carrier Current</th>
<th>Access BPL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>House wiring → 20-30 m extent</td>
<td>Overhead power lines → 800 m extent</td>
</tr>
<tr>
<td># of com channels overlapped</td>
<td>2</td>
<td>~1500</td>
</tr>
</tbody>
</table>
What To Do
HF Issues and Options

1a) Ban BPL in HF on overhead MV lines
   (Permit in-house and underground access BPL in HF)
   - Protects HF land mobile
     - NTIA did not request protection of federal HF nationwide networks, but...
   -Eliminates skywave risk
   -Eliminates interference between HF in-house BPL and access BPL

2a) Impose 5 dB height correction & 20 log R extrapolation
    (6-dB hit)
   - Postpones skywave problem
   - Reduces interference to fixed stations

3a) No change

Note: w/options 2a or 3a, NTIA sees need for a follow-on NPRM to possibly limit deployment densities or impose other restrictions
Low VHF Options

30 – 50 MHz

1b) Require *notching* for some or all local public safety
2b) Require *coordination* for some or all local public safety

50 – 54 MHz (amateur band; 51 – 54 MHz is used mobile)

1c) ?
# BPL Spectrum Tradeoffs and Proposal

## Proposal
- **Near Term**
  - Overhead BPL
  - Underground BPL
- **Far Term**
  - Allocate a VHF band for BPL (e.g., abandoned low-VHF TV channels)
  - Raise emission limits in that band

---

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**Rules & Physics**

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>2-8</th>
<th>8-30</th>
<th>30-50</th>
<th>50-54</th>
<th>54-72</th>
</tr>
</thead>
<tbody>
<tr>
<td>[L + N] N for Mobile Radio</td>
<td>High</td>
<td>Very High</td>
<td>Moderately High</td>
<td>Moderately High</td>
<td>Moderately High</td>
</tr>
<tr>
<td>Skywave Propagation</td>
<td>Yes</td>
<td>Yes</td>
<td>Very Little</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>[BPL device] for Residential</td>
<td>62 m</td>
<td>400 m</td>
<td>54 m</td>
<td>54 m</td>
<td>54 m</td>
</tr>
</tbody>
</table>

**Potential Local Victims**

<table>
<thead>
<tr>
<th>Category</th>
<th>Public Safety Mobile</th>
<th>Other Mobile</th>
<th>Federal Mobile</th>
<th>Amateurs, Broadcast Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licenses</td>
<td>356</td>
<td>750</td>
<td>10's of thousands in CONUS</td>
<td>Shortwave</td>
</tr>
<tr>
<td>Authorized</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Priority</td>
<td>High</td>
<td>High</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

---

**Original Unredacted**
BPL Emission Tests
Near Raleigh, North Carolina
June 28 – July 2, 2004

August 4, 2004
Steve Martin & Andy Leimer – FCC Laboratory

On site support: Joe Hunsay & Luther Bolden – FCC Norfolk Resident Agent Office
Radio, GPS, S/W, & expertise: Dave Larrabe & Jim Higgins – FCC Monitoring Station
Outline

- Introduction
- Compliance with Emission Limits
- Emissions at Unprotected (Un-notched) Frequencies
- BPL Notch Effectiveness
- Fixed Amateur Sites
Introduction

- Tests of emissions from BPL systems deployed near Raleigh, NC were performed in response to complaints of interference to
  - mobile amateur radio in the vicinity of three BPL installations
  - three fixed amateur installations at homes located 0.4 to 0.7 miles from overhead BPL installations
Amperion/Progress-Energy
BPL Deployments Near Raleigh

**RALEIGH**

**TOTALS**
- BPL Devices:
  - 6 overhead
  - 31 underground
  - ~430 homes passed

**Whitehurst**
- BPL Devices:
  - 0 overhead
  - 10 underground
  - ~90 homes passed

**Woodchase**
- BPL Devices:
  - 2 overhead
  - 11 underground
  - ~200 homes passed

**Holland Meadows**
- BPL Devices:
  - 4 overhead
  - 10 underground
  - ~140 homes passed
BPL Device Frequencies in Raleigh Deployments

- Only ~1 in 8 devices occupies any given frequency
- No frequency overlap of overhead devices
- Underground BPL not notched
- Overhead BPL avoids amateur bands—mostly by truncating one end of band. Only one complete notch.

Frequency (MHz)

- Holland Meadows OH
- Holland Meadows UG
- WhiteHurst UG
- WoodChase OH
- WoodChase UG
- Amateur Bands

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Amperion BPL System

• Unusual Design Characteristics
  – Frequency division multiplexing with relatively small bandwidth per device (2.75 or 3.75 MHz)
  – WiFi link to customers—No use of low voltage lines
    • Minimal emissions from building wiring ➔ few above-ground emission sources where power lines are underground

• Other Characteristics
  – OFDM
  – Remote band selection & Remote “notching” by omitting OFDM carriers
Network Topology at Holland Meadows

Backhaul ↔ U-NII Radio Link ↔ OH BPL ↔ WiFi ↔ UG BPL ↔ WiFi ↔ Customer
Amperion BPL Hardware

OVERHEAD INJECTOR
- Coupler
- Electronics
- U-NII Antenna

OVERHEAD EXTRACTOR
- Coupler
- WiFi Antenna
- Housing for in-ground BPL device w/internal WiFi antenna
Compliance with Emission Limits
Test Description for Compliance Measurements

- Calibration
  - The combination of all cables & filters was calibrated, as a function of frequency, using the spectrum analyzer's tracking generator.

- Measurement locations
  - Antenna height: 1 meter
  - Horizontal offset from the power line on which the BPL signals were injected: 10-meters (on the tobacco-field side of the power line, rather than on the road side, for physical safety)
  - Distance down line from BPL coupler: 0, 0.25, 0.5, 0.75, & 1* wavelength (southwest of coupler at Woodchase; south of coupler at Holland Meadows)
    * At Woodchase, the final measurement was 0.87 wavelength down line, due to a large mud puddle at one wavelength. Wavelengths were based on the BPL device center frequencies of 23.2 MHz at Woodchase and 19.2 MHz at Holland Meadows.
  - Antenna orientations
    - Two orientations used at both sites: (1) Plane of loop vertical & parallel to power line, (2) plane of loop vertical & perpendicular to power line
    - Third orientation (plane of loop horizontal) was tested at only one Woodchase location and yielded lower field strengths

- Procedure
  - Power average spectra were measured at each antenna location & orientation. Antenna was returned to the location exhibiting the maximum field strength and power average spectrum was repeated. CISPR quasi-peak measurement was performed in limited band around frequency of maximum emission.

- Distance extrapolation to 30-meter distance at which emission limit is specified
  - 40 log of slant range from antenna to power line, based on optically-measured power line heights of 10.9 m at Whitehurst and 10.5 m at Holland Meadows
  - Extrapolation was applied to the emission limit rather than to the measured data, so that the plots indicate actual field strength observed at the antenna location.
Compliance Tests on Overhead Injector on Slaughter Rd at Woodchase

Average Field Strength (dBuV/m)

Frequency (MHz)

- Parallel / 0m
- Perp / 0m
- Horiz / 0m
- Parallel / 3.2m
- Perp / 3.2m
- Parallel / 6.5m
- Perp / 6.5m
- Parallel / 9.7m
- Perp / 9.7m
- Parallel / 11.2m
- Perp / 11.2m

FCC Lab/TRB/S. Martin

12/22/2004 - Slide 11
Compliance Tests on OverheadInjector on Slaughter Rd at Woodchase

Extrapolated Emission Limit
Quasi Peak
Power Average

Measured Margin = 0.4 dB
Compliance Tests on 19.2-MHz Overhead Injector on Holland Church Rd

- Region B: Measured emissions exceeded limit by 1.3 dB but overage was within measurement uncertainty
- Region C: Accidental quasi-peak measurement intended for region A
- Region A: Highest emission region. Since average spectrum exceeded region C by ~1 dB (neglecting narrow-band ambients), quasi-peak is expected to be ~2.3 dB over the limit, but expected overage is within measurement uncertainty
Compliance with Emission Limits

• Compliance results
  – BPL devices on overhead power lines
    • Tested two overhead "injectors" (in-band emissions only) –
      Emission levels are at compliant (within measurement uncertainty) BPL devices on
      underground power lines
    • Not tested, but compliance expected based on radio tests, which indicated much
      lower emissions from underground wiring than overhead wiring
Interference Potential
Outside of Notches
Test Description
for Mobile Radio Measurements

- Signal strength and position logging and mapping for driving tests
  - Signal strength and GPS coordinates were logged at 2-second intervals to comma-delimited .CSV files.
  - When necessary to prevent excessive overlap of data points on maps, logged data was thinned by combining data points within a fixed distance of each other into a single point having a signal strength equal to maximum signal strength of the combined points.

- Signal strength
  - Signal strength monitored using the serial port of the receiver. Output has a lower bound of -114 dBm, even when actual signal strength is lower. During much of the testing outside of BPL areas, the S-meter was at ~s0, which should nominally correspond to -127 dBm; hence the lowest amplitude range on all map plots is shown as -127 to -114 dBm.
  - Antenna and receiver are uncalibrated, and antenna is not tuned to specific frequencies used in tests. Intent of tests are to show relative signal strengths.

- Receiver mode
  - AM with 5.5 kHz bandwidth

- Frequency selection
  - Receiver was tuned while away from the BPL area to a frequency having no active transmissions
  - Frequency was selected within the intended injection band of an overhead injector
• Underground BPL emissions are audible for short distances; e.g., at 23.2 MHz,
  – Fundamental emissions were audible along 320 m (0.2 mi) of road around a BPL device
  – Emissions attributed to 3rd harmonic from another device were audible along 25 m of road
    (Black lines mark edges of audibility)
Effect of Single BPL Overhead Injector

- BPL audible (AM detector) between black lines
  - 3.5 miles of roadway outside of the subdivision served
  - 0.9 mi downline from coupler
  - 0.8 mi straight line distance from coupler
  - 0.19 mi (300m) from power line near coupler
- Interference distance < audible distance
  - Distance depends on strength of desired signal, type of modulation, and margin required by listener or detector
Test Description for Audio/Video Collection of Mobile Radio Measurements

- **Receiver mode**
  - AM with 5.5 kHz bandwidth except where SSB is specified

- **Recording**
  - Audio was recorded on a Olympus DM-1 pocket-sized digital voice recorder by direct connection to the receiver audio output
  - Video was recorded through the windshield using a Canon Model ES75A Hi8 camcorder; audio from the receiver's speaker was recorded through the built-in microphone of the camcorder

- **Frequency selection**
  - For both tests, the receiver was tuned to an un-notched frequency within the injection band of the overhead BPL injector
  - For the audio-only test, the receiver was tuned to 23.185 MHz, a frequency having no obvious transmissions (except for BPL)
  - For the video test, the radio was tuned to 21.639 MHz, where a foreign language broadcast station was received

- **Signal strength and position logging and mapping for driving tests**
  - As described previously
  - The cable between the ICOM receiver and the laptop computer was inadvertently disconnected throughout the video listening test. Signal strength data plotted on the map is from a subsequent test run while tuned off of the shortwave station to a frequency of 21.718 MHz
BPL Notching
Equipment Setup for Notch-Depth Measurements

- Active loop antenna: ETS Lindgren Model 6507 S/N 1500
- Biconical antenna: Singer Model 94455-1 S/N 0366

Passive Filters

- Calibration
  - The combination of all cables and filters was calibrated, as a function of frequency, using the tracking generator in the spectrum analyzer
  - Biconical antenna data is uncalibrated below 20 MHz

- Device under test
  - Overhead Injector centered at 19.2 MHz at Holland Meadows

- Measurement location
  - Antenna placed directly under power line, 7.7 meters down line (south) from BPL coupler
  - Antenna height: 4.36 meters (active loop); 4.05 meters (biconical antenna)
Notch depth of only unit with complete notch (19.2 MHz injector on Holland Church Rd) was measured in two ways

- Evaluated spectrum band averages in two moderate-resolution (9 kHz) spectra from bicon antenna
- Evaluated OFDM peaks in high resolution (1-kHz) spectra from loop antenna

Results ranged from 23.4 to 25.0 dB, with an average of 24 dB

Carrier structure indicates that bottom of notch was filled in by BPL signal—not by ambients or general power line noise.

**Notch Depth is 24 dB**
Predicted Effect of Notch
Overhead Injector at Woodchase

Signal Strength in 5.5kHz band at 19.2 MHz (dBm)
- -85 to -76
- -90 to -86
- -95 to -91
- -100 to -96
- -105 to -101
- -110 to -106
- -113 to -111
- -127 to -114

Computed Effect of 24-dB Reduction Due to Notch

Highest emission from BPL is reduced to -100 dBm, 4-dB lower than the maximum seen in driving past the substation and 14 to 27 dB above ambient.

Interference distances are greatly reduced; >= 110 dBm (blue) occurs for only ~120 m of road.
Comparison of Notched BPL Signal Strength with Signal Strength in Non-BPL Regions

Signal Strength in 5.5kHz band at 19.2 MHz (dBm)
- -85 to -76
- -90 to -86
- -95 to -91
- -100 to -96
- -105 to -101
- -110 to -106
- -113 to -111
- -127 to -114

Computed Effect of 24 dB Reduction Due to Notch in Overhead BPL Region Near Woodchase

To compare BPL emissions to other sources, signal strength at 23.2 MHz was monitored on 22.4 miles of road
- Drive included expressway, business, and suburban areas
- Monitored frequency was in un-notched band of overhead injector in Woodchase & an underground device in Whitehurst

Of 18.6 miles of non-BPL roads:
- 94% of road miles were at “white levels” (< -110 dBm)
- 4% of road miles were at “blue levels”
- 2% of road miles were at “yellow” or “red” (>=100 dBm)

Signal Strength in 5.5kHz band at 23.2 MHz (dBm)
- -85 to -76
- -90 to -86
- -95 to -91
- -100 to -96
- -105 to -101
- -110 to -106
- -113 to -111
- -127 to -114

Areas affected by un-notched BPL

Data file 22.csv

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Radio Tests of Notch Effectiveness

Full-length, (¼ wavelength) CB whip magnetically mounted to top of minivan. Top of antenna tied back to reduce clearance

ICOM Receiver
Model R-8500
S/N 1201

Hi8 Video Camcorder (Canon ES75A)

• Procedure
  - Receiver was manually tuned from the 15-meter amateur band through the 10-meter amateur band while recording sound and video of receiver
  - Test was performed at two sites

• Receiver mode
  - AM with 5.5 kHz bandwidth
  - SSB upper sideband with 2.2 kHz bandwidth
Radio Tests of Notch Effectiveness
Site 1 – Shoulder of James Slaughter Rd

Site 1—Shoulder of James Slaughter Rd across street from power line:
16 m from power line
390 m from injector
620 m from extractor
Radio Tests of Notch Effectiveness
Site 2 – Food Lion Parking Entrance

Site 2–Food Lion Parking Entrance:
31 m from power line on Rte 55
0.3 miles downline from extractor
0.5 miles downline from injector

To BPL
To Food Lion

FCC Lab/TRB/S. Martin
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Effectiveness of BPL Notches

Results

Injectors and Extractor

21.0 MHz  Amateur & Overhead BPL Bands at Woodchase  29.7 MHz

Qualitative observations of BPL signal encroachment on amateur bands based on listening in SSB mode

<table>
<thead>
<tr>
<th>Band</th>
<th>SITE 1 (Video files V-AM-S1 &amp; V-SSB-S1)</th>
<th>SITE 2 (Video files V-AM-S2 &amp; V-SSB-S2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 m</td>
<td>Moderate in upper 15kHz; Weak elsewhere</td>
<td>NONE</td>
</tr>
<tr>
<td>12 m</td>
<td>Moderate in lower half; Weak in upper half</td>
<td>NONE</td>
</tr>
<tr>
<td>10 m</td>
<td>Strong in lower 130kHz; Weak elsewhere</td>
<td>Moderate in lower 100kHz; Weak in next 30kHz; None elsewhere</td>
</tr>
</tbody>
</table>

 Recommendation: Increase notch width by 100 kHz at low end of 10m band (28 MHz)
Fixed Amateur Sites
Fixed Amateurs

- Fixed amateur locations included in complaint
  - 1 5813 Heathill Ct.
  - 2 509 Wyndham Dr
  - 3 201 Wilbon Rd 301B

- Interference not audible w/mobile antenna at 1 & 2, even outside of notches

- 3 not visited due to a mapping error. Location uncertain, but may be close enough to overhead lines on Rte 55 to detect un-notched BPL signals on mobile unit.

- No testing was performed with the fixed HF amateur antennas at any of the locations