

## **SECTION 6 SUMMARY OF RESULTS**

### **6.1 INTRODUCTION**

The Commission's BPL Report and Order specified the rules and measurement guidelines for Access BPL systems. NTIA applied these rules and measurement guidelines in a number of analyses to evaluate their effectiveness at limiting the risk of interference to federal radiocommunication systems. The results of these analyses are summarized below.

### **6.2 PHASE 2 ANALYSES**

#### **6.2.1 Part 15 Rules and Measurement Guidelines**

In the NTIA Phase 1 Study, NTIA noted that adopting effective BPL measurement guidelines is critical to minimizing the risk of harmful interference to federal radiocommunications. NTIA further noted that emissions from Access BPL systems operating on overhead MV power lines were atypical of most Part 15 devices in that the peak field strength often occurs at heights significantly greater than 1 meter, and it may occur at various distances along the power line. The radiated field strength diminishes with distance from the source at a slower rate than that of a typical point source radiator. Measurements of BPL field strength are typically performed in the near field where the relationship between electric and magnetic field are not easily predicted. NTIA developed a number of power line models using the NEC software package to facilitate the analysis of these characteristics of BPL emissions when applying the new Access BPL measurement guidelines adopted by the Commission.

The results of NTIA's analysis of the characteristics of BPL emissions indicate that the peak field strength seen in close proximity to a BPL-energized overhead power line will occur at various heights, and often near the height of the power line. NTIA further analyzed the peak field strength using the specified measurement heights and found that at these measurement heights, the 80<sup>th</sup> percentile values of peak field strength at any height are effectively estimated by use of the Commission's measurement guidelines. As noted earlier, the 80<sup>th</sup> percentile values eliminate the localized peaks that are unlikely to be encountered by a radio receiver randomly located in close proximity to an Access BPL power line.

The measurement guidelines allow field strength measurements on overhead Access BPL power lines operating in the VHF band to be performed at a 1 meter height combined with application of a 5 dB height correction factor for BPL systems operating at or above 30 MHz. NTIA's analysis demonstrated that the peak field strength may be reasonably estimated after application of this height correction factor.

The FCC's measurement guidelines require field strength measurements to be performed at specific points along the power line within 1 wavelength of a BPL source.<sup>[75]</sup> When the electric field strength was scaled to be within the Part 15 limits using the Access BPL measurement guidelines, NTIA's NEC simulation results indicated that the percent of measurement points where the field strength exceeded the Part 15 limits was small.

NTIA evaluated the Commission's modification of the distance extrapolation rules, which replaced the use of the horizontal distance between the BPL device and the measurement antenna with the slant range distance between them. NTIA's NEC simulations in the 4 to 8 MHz frequency range exhibited somewhat slower rates of field strength decay with distance than would be expected by the distance extrapolation rate in the Part 15 rules for Access BPL systems. This difference was up to 6 dB less than the distance extrapolation rate. At or above 10 MHz, the simulation results show good agreement between the rate that field strength decays and the Part 15 distance extrapolation rate using the slant range distance to the Access BPL device and power lines. As noted earlier, the effect of the combination of direct and ground-reflected rays at the simulated distances becomes more pronounced at frequencies above 14 MHz.

One limitation with this methodology arises when measurements are to be performed at distances significantly beyond the specified 10 meter measurement distance called for in the Commission's measurement guidelines. In this case, the length of the slant range distance approaches that of the horizontal separation distance between the BPL device and measurement antenna, and the extrapolation rate effectively becomes the same as if the horizontal distance was used. The resulting extrapolation may overestimate the rate of field strength decay with distance and lead to the establishment of an operating level for the BPL device that exceeds Part 15 limits at 10 meters. It should also be noted that the Commission's rules state that measurements should not be performed at a distance greater than 30 meters unless it can be demonstrated that measurements at a distance of 30 meters or less are impractical.<sup>[76]</sup>

Below 30 MHz, electric field strength is determined by measurement of the peak magnetic field strength in the horizontal plane using a loop antenna situated 1 meter above the ground, and application of a magnetic to electric field conversion factor. As these measurements are performed at a distance of 10 meters from the BPL device and associated power lines, they fall well within the near field region where the relationship between magnetic and electric field strength is not easily predicted. NTIA's evaluation of the relationship between magnetic and electric field at this distance shows that use of the loop antenna with this conversion factor yields a reasonable approximation. NTIA simulations also show that, below 30 MHz, peak field strength consistently corresponded to the vertical electric field (horizontal magnetic field) polarization when measured at 10 meters from the power line. At or above 30 MHz, the guidelines specify that both the horizontal and vertical polarizations of electric field strength are to be measured. The simulations performed by NTIA indicate that the specified guidelines can be used to represent the electric field strength levels.

The measurement guidelines for Access BPL systems specify that *in-situ* testing shall be performed on three typical installations for both overhead and underground installations. NTIA field tests and NEC modeling of BPL power lines identified that, in addition to the BPL devices themselves, many features of MV power lines give rise to the strongest levels of radiated emissions. NTIA suggests that a variety of these features should exist in power lines chosen as representative sites for compliance measurement testing.

### **6.2.2 Special Protection Provisions**

As a result of NTIA's initial analysis, the Commission specified minimal sets of excluded frequency bands, exclusion zones and consultation areas needed to prevent BPL systems from interfering with critical federal radio operations in the 1.7 to 80 MHz frequency range.<sup>[77]</sup> NTIA extended the analyses for the recommended protection radii to include a more elaborate overhead power line model and a new underground power line model. NTIA analyzed the BPL emission levels that might be expected from MV overhead and underground power lines to determine the minimum radii of exclusion zones and consultation areas needed to meet the protection criteria for critical federal fixed and mobile radiocommunication systems, radar, and radioastronomy receivers.

These provisions provide an additional measure of protection beyond that afforded by field strength limits and compliance measurement provisions. These special exclusion zones and consultation areas place only a minimal constraint on BPL deployment, as they impact only about 2 percent of the spectrum between 1.7 to 80 MHz. Additional special protection provisions may be needed if, at some time in the future, Access BPL devices are permitted to operate outside the 1.7 to 80 MHz frequency range.

### **6.2.3 Case Study Applying the Access BPL Measurement Guidelines**

NTIA developed a simulation of an actual overhead MV Access BPL power line structure to illustrate application of the BPL measurement guidelines and assess the potential impact on nearby land mobile systems, as well as to fixed systems at greater distances from the power lines. The results of these simulations are consistent with those from NTIA's Phase 1 Study, and, as such, they indicate the Part 15 measurement procedures described in the BPL Report and Order appear to estimate adequately the peak field strength around the power line near ground level.<sup>[78]</sup>

### **6.2.4 Aggregation of Emissions Considering Ionospheric Propagation**

In its Comments on the BPL NPRM, NTIA presented a preliminary analysis of the aggregation of emissions via ionospheric (*i.e.*, "sky wave") propagation arising from a wide scale deployment of Access BPL devices on MV overhead power lines.<sup>[79]</sup> At that time, NTIA concluded that interference via this mechanism was not a near-term issue.

NTIA further developed its power line models to include an elaborate overhead power line model and an underground power line model. The radiation levels derived

from these models were scaled to Part 15 limits using the recently adopted compliance measurement methodology. Simulations of aggregation via ionospheric propagation were performed for high and low SSN conditions, with frequencies ranging from 2 to 30 MHz, and varying time of day and month of year.

### 6.3 CONCLUSION

The NTIA Phase 2 Study of Access BPL systems expanded upon the Phase 1 Study with additional modeling results and analyses that addressed the issues that had been identified as requiring further study. The Phase 2 Study applied the rules and measurement guidelines for Access BPL systems adopted by the FCC to evaluate their effectiveness in minimizing the potential for harmful interference to federal radiocommunication systems. The results of these analyses confirm that the Part 15 rules, measurement guidelines and special protection provisions applied to Access BPL deployment will limit the interference risks for federal radiocommunication systems.

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<sup>[1]</sup> See *Potential Interference from Broadband over Power Line (BPL) Systems to Federal Government Radiocommunications at 1.7 – 80 MHz*, NTIA Report 04-413, April 2004 (“NTIA Phase 1 Study”). In 47 C.F.R. § 15.3(ff), an Access BPL system is defined as “[a] carrier current system installed and operated on an electric utility service as an unintentional radiator that sends radio frequency energy on frequencies between 1.705 MHz and 80 MHz over medium voltage lines or over low voltage lines to provide broadband communications and is located on the supply side of the utility service’s points of interconnection with customer premises. Access BPL does not include power line carrier systems as defined in Section 15.3(t) or In-House BPL systems as defined in Section 15.3(gg).”

<sup>[2]</sup> See Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems, ET Docket 04-37, Notice of Proposed Rulemaking, FCC 04-29, released February 23, 2004, (“BPL NPRM”); Comments of the National Telecommunications and Information Administration (NTIA Comments) in ET Docket No. 04-37, June 4, 2004, (available at [www.ntia.doc.gov/ntiahome/fcc\\_filings/2004/BPLComments\\_06042004.pdf](http://www.ntia.doc.gov/ntiahome/fcc_filings/2004/BPLComments_06042004.pdf)) (“NTIA Comments”); Letter to Mr. Edmond J. Thomas, Chief, Office of Engineering and Technology, Federal Communications Commission, from Mr. Fredrick R. Wentland, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration, in ET Docket No. 04-37, September 13, 2004 (“NTIA September 13, 2004 Letter”); Letter to Mr. Edmond J. Thomas, Chief, Office of Engineering and Technology, Federal Communications Commission, from Mr. Fredrick R. Wentland, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration, in ET Docket No. 04-37, September 24, 2004 (“NTIA September 24, 2004 Letter”).

<sup>[3]</sup> See In the Matter of Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems, ET Docket No. 04-37, Carrier Current Systems, including Broadband over Power Line Systems, ET Docket No. 03-104, Report and Order, adopted October 14, 2004 (“BPL Report and Order”).

<sup>[4]</sup> NEC version 4.1 software is available through Lawrence Livermore National Laboratory. URL: <http://www.llnl.gov/IPandC/technology/software/softwaretitles/nec.php>.

<sup>[5]</sup> VOACAP is an HF statistical propagation prediction software program developed by NTIA Institute of Telecommunication Sciences (ITS). VOACAP is available from the NTIA Institute for Telecommunication Sciences, URL: <http://elbert.its.bldrdoc.gov/hf.html>.

<sup>[6]</sup> See NTIA Phase 1 Study, Vol. I, at sec. 9.3.2.

<sup>[7]</sup> *Id.* Vol. I, at sec. 5, 6; *See also* NTIA Comments, Technical Appendix, at sec. 2; NTIA September 24, 2004 Letter.

<sup>[8]</sup> In actual systems, all transformer impedances vary widely based upon varying loads in the system. However, preliminary calculations found that changing transformer impedances had little impact on the results.

<sup>[9]</sup> See BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 1.6.

<sup>[10]</sup> See BPL Report and Order, Appendix C, *Measurement Guidelines*.

<sup>[11]</sup> Below 30 MHz, the peak vertical electric field strength is calculated by scaling the peak horizontal magnetic field strength measured at a height of 1 meter by 377 ohms. Above 30 MHz, the peak electric field strength is calculated directly from the largest value in either the horizontal or vertical polarization at a measurement height of 1 to 4 meters. In both cases, the 80<sup>th</sup> percentile values are used as described above.

<sup>[12]</sup> See NTIA Comments, Technical Appendix, at pp. 2-18.

<sup>[13]</sup> See BPL Report and Order, Appendix C ¶ 2.b.2 (“Testing shall be performed at distances of 0, ¼, ½, ¾, and 1 wavelength down the line from the BPL injection point on the power line. Wavelength spacing is based on the mid-band frequency....”).

<sup>[14]</sup> See 47 C.F.R. § 15.31(g)-(k).

<sup>[15]</sup> See BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 2.b.2.

<sup>[16]</sup> *Id.* ¶ 2.b.4 (describing the slant range distance extrapolation methodology).

<sup>[17]</sup> See 47 C.F.R. § 15.31(f)(1)-(2).

<sup>[18]</sup> See NTIA BPL Phase 1 Study, Vol. II, at sec. D.3.3.

<sup>[19]</sup> See BPL Report and Order, at Appendix C ¶ 2.b.4.

<sup>[20]</sup> See NTIA September 24, 2004 Letter.

<sup>[21]</sup> Note that the results at or above 30 MHz presented herein assume an antenna height of 1 meter for illustration purposes only. The Part 15 measurement guidelines specify that the measurements are to be performed at antenna heights of 1 to 4 meters.

<sup>[22]</sup> See BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 2.a.

<sup>[23]</sup> See NTIA Phase 1 Study, Vol. I, at sec. 9.2.4; *id.*, Vol. II, at sec. D.3.2.

<sup>[24]</sup> See 47 C.F.R. § 15.31(f)(1)-(2).

<sup>[25]</sup> See NTIA Phase 1 Study, Vol. I, at Table 4-9.

<sup>[26]</sup> See NTIA Comments, at sec. III.

<sup>[27]</sup> See BPL Report and Order, at Appendix B (amending Part 15 to add a new Subpart G).

<sup>[28]</sup> See 47 C.F.R. § 15.615(f).

<sup>[29]</sup> NTIA Phase 1 Study, Vol. I, at sec. 5.3.6; NTIA Comments, at Technical Appendix sec. 2.3.

<sup>[30]</sup> See NTIA Phase 1 Study, Vol. II, at Appendix C.

<sup>[31]</sup> *Manual of Regulations and Procedures for Federal Radio Frequency Managers*, United States Department of Commerce, National Telecommunications and Information Administration, Washington, D.C., January 2004 Revision.

<sup>[32]</sup> In this description of noise floor increase, the term “I” is the interfering signal power at the receiver site associated with radiated BPL emissions, and the term “N” is the noise power that would be present at the receiver site in the absence of BPL emissions. The interference-plus-noise-to-noise [(I+N)/N] is used to determine the noise floor increase.

<sup>[33]</sup> For this analysis, the protection requirement for sensitive over-the-horizon (OTH) radar receivers was assumed to be the same as that used for the Very Large Array (VLA) radio astronomy receiver. Like radio astronomy receivers, radar receivers employ correlation techniques that enable reception of signals weaker than noise. The radioastronomy protection criterion is specified in Recommendation ITU-R RA.769-2, Table 1.

<sup>[34]</sup> See Recommendation ITU-R RA.769-2, Table 1 for the protection criteria in the 73.0-74.6 MHz frequency band. This frequency band is used at the Very Large Array (VLA) radioastronomy facility near Socorro, New Mexico.

<sup>[35]</sup> The Commission's rules specify an electric field strength limit of 30  $\mu\text{V}/\text{m}$  at a horizontal distance of 30 meters for radiated emissions in the 1.705 to 30 MHz band. 47 C.F.R. § 15.209(a).

<sup>[36]</sup> The modeled measurement heights ranged from 1 to 4 meters, in 0.5 meter increments.

<sup>[37]</sup> See NTIA Phase 1 Study, Vol. I, at Table 6-2.

<sup>[38]</sup> TCI Model 527, Super High Gain Log-Periodic Antenna data sheet.

<sup>[39]</sup> Noise power levels were determined using the NOISEDAT computer program, assuming a representative protected receiver location. NOISEDAT is available from the ITU website, url: <http://www.itu.int/ITU-R/software/study-groups/rsg3/databanks/ionosph/index.html>.

<sup>[40]</sup> *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, NTIA Report 82-100 (April 1982).

<sup>[41]</sup> See NTIA September 13, 2004 Letter, at Annex 1, sec. 2.2.

<sup>[42]</sup>  $BW_{\text{meas}}$  is 9 kHz for frequencies below 30 MHz, and 120 kHz for frequencies between 30 MHz and 80 MHz.

<sup>[43]</sup> See NTIA Phase 1 Study, Volume II, at pp. D-38 and D-39. The field measurements from the BPL Phase 1 Study indicated that 6 dB is an appropriate factor to convert between peak and RMS field strength for Access BPL systems.

<sup>[44]</sup> See NTIA September 13, 2004 Letter, at Annex 1, sec. 2.2.

<sup>[45]</sup> The frequency 25 MHz was chosen for this analysis due to simulation results showing that the power line may be a more efficient radiator at or near this frequency. See NTIA September 13, 2004 Letter, at 14.

<sup>[46]</sup> See Recommendation ITU-R RA.769-2, Table 1 for the protection criteria in the 73.0-74.6 MHz frequency band. This frequency band is used at the VLA radioastronomy facility near Socorro, New Mexico.

<sup>[47]</sup> See NTIA September 13, 2004 Letter, at Annex 1, sec. 2.2.

<sup>[48]</sup> The ITM program may yield inaccurate results due to ground clutter when an antenna height of less than 1 meter is used. When using a 0.2 meter antenna height, as was done for the underground BPL analysis, the results obtained by ITM can underestimate the path loss. In an actual underground BPL deployment, the values of path loss are expected to be greater, and the PFD at the boundary of the exclusion zones should be below the protection levels assumed in this analysis.

<sup>[49]</sup> See NTIA September 13, 2004 Letter, at Annex 1, sec. 3.1.

<sup>[50]</sup> See BPL Report and Order, at 71.

<sup>[51]</sup> Letter to Mr. Edmond J. Thomas, Chief, Office of Engineering and Technology, Federal Communications Commission, from Mr. Fredrick R. Wentland, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration in ET Docket No. 04-37, March 1, 2005 ("NTIA March 1, 2005 Letter"). For Access BPL on overhead MV power lines, NTIA requested a 65 km radius BPL exclusion zone centered at the coordinates of the VLA radioastronomy facility. This radius equates to 29 km beyond the 36 km radius of the antenna array. NTIA also requested a 47 km radius exclusion zone centered at the coordinates of the VLA for Access BPL systems operating on underground MV or overhead low voltage (LV) power lines.

<sup>[52]</sup> During its initial study of BPL systems, NTIA measured peak power emissions in close proximity to a transformer vault containing a BPL device. Most attempts to measure the peak power emanating from the underground BPL system resulted in levels below the minimum sensitivity of NTIA's Radio Spectrum Measurement System (RSMS-4). See NTIA Phase 1 Study, at Volume II, p. D-33.

<sup>[53]</sup> The Commission's rules specify an electric field strength limit of 30  $\mu\text{V}/\text{m}$  at a horizontal distance of 30 meters for radiated emissions in the 1.705 to 30 MHz band. 47 C.F.R. § 15.209(a).

<sup>[54]</sup> NOISEDAT is available from the ITU Website, URL: <http://www.itu.int/ITU-R/software/study-groups/rsg3/databanks/ionosph/index.html>.

<sup>[55]</sup> Noise floor increases of 3, 10, 20, 30, 40 and 50 dB were analyzed. This allows comparison with the results presented in the NTIA Phase 1 Study, Vol. I, at Table 6-1.

<sup>[56]</sup> The choice of quasi-peak-to-RMS measurement factor was based on the measurement data from the NTIA Phase 1 Study, which indicated that the BPL signal power measured using a quasi-peak detector typically exceeded the level measured using an average detector by 0 – 5 dB. *See* NTIA Phase 1 Study, Volume II, at sec. D.3.4.

<sup>[57]</sup> *See* NTIA September 13, 2004 Letter, at Annex 1, sec. 2.2.

<sup>[58]</sup> *See* NTIA Phase 1 Study, Vol. I, at pp. 6-11; NTIA September 13, 2004 Letter, at Annex 1.

<sup>[59]</sup> *See* NTIA Phase 1 Study, Vol. I, at sec. 5.2.2.

<sup>[60]</sup> *See* NTIA Comments, at Technical Appendix, sec. 4.

<sup>[61]</sup> *Id.* *See also* NTIA Phase 1 Study, Vol. I, at sec. 5.4.

<sup>[62]</sup> *See* NTIA Comments, at Technical Appendix, sec. 2.2.

<sup>[63]</sup> *See* BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 2.b.

<sup>[64]</sup> *See* BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 2.b.

<sup>[65]</sup> *See* BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 2.b.2, for a description of additional measurements that may be required if the mid-band frequency of the BPL signal is two or more times greater than the lowest BPL signal injected onto the power line.

<sup>[66]</sup> *Id.*

<sup>[67]</sup> *See* NTIA Comments, at Technical Appendix, sec. 4.2. *See also* County and City Data Book: 2000, U.S. Census Bureau, National Data Summary File 1, Table P-15.

<sup>[68]</sup> In this report, (I+N)/N is also referred to as “noise floor increase.”

<sup>[69]</sup> VOAAREA allows one to set the length of the vertical antenna either to a fixed value in meters or to allow it to vary with frequency. In this analysis, it was assumed that a receiver subject to potential interference at any given frequency would make use of an antenna designed for that frequency; therefore, the antenna in this case was set to quarter-wave length for each frequency (*e.g.*, 7.5 meters at 10 MHz). VOACAP automatically adjusts this length such that the receive pattern stays the same regardless of frequency. As is appropriate for a monopole antenna, the maximum gain for the antenna at any height was set to 3 dB above that of a dipole.

<sup>[70]</sup> Noise level used in this analysis is based on Recommendation ITU-R P.372-8, “Radio Noise” implemented in VOACAP/VOAAREA.

<sup>[71]</sup> *See* ITU-R Chairman's report on the meeting of Working Party 1C, Geneva, 11-15 October 2004, document #54, Annex 2, “Noise Measurements.”

<sup>[72]</sup> *See* NTIA Comments, at Technical Appendix, sec. 4.

<sup>[73]</sup> The choice of quasi-peak-to-RMS conversion factor was based on the measurement data from the NTIA Phase 1 Study, which indicated that the BPL signal power measured using a quasi-peak detector typically exceeded the level measured using an average detector by 0 – 5 dB. *See* NTIA Phase 1 Study, at Volume II, sec. D.3.4.

<sup>[74]</sup> As previously noted in Section 3.2.3, the term “I” refers to the interfering signal power associated with radiated BPL emissions.

<sup>[75]</sup> For wide bandwidth BPL signals, where the center frequency exceeds the lowest in-band frequency by at least a factor of two, additional measurements beyond 1 wavelength are required. *See* BPL Report and Order, at Appendix C, *Measurement Guidelines* ¶ 2.b.2.

<sup>[76]</sup> *See* 47 C.F.R. § 15.31(f)(1) for operation at or above 30 MHz. Between 1.705 MHz and 30 MHz, 47 C.F.R. § 15.209(a) defines the field strength limit at a measurement distance of 30 meters.

<sup>[77]</sup> See NTIA September 13, 2004 Letter, at Annex 1.

<sup>[78]</sup> See NTIA Phase 1 Study, Vol. I, at pp. 6-11.

<sup>[79]</sup> See NTIA Comments, at Technical Appendix, at sec. 4.