SECTION 3
BPL RELATED STUDIES AND REGULATIONS

3.1 INTRODUCTION

This section describes regulations applicable to BPL systems and studies conducted by various parties to investigate the characteristics of BPL emissions. The regulations include both the established and proposed radiation limits applicable to BPL systems.

3.2 REGULATIONS

3.2.1 Part 15 of the Commission's Rules

Appendix A of this report delineates key field strength and compliance measurement provisions of Part 15 applicable to BPL systems. The Part 15 field strength limits are shown in Table 3-1, below. BPL systems fall under the Part 15 definition of carrier current systems.[17] BPL systems are designed to transmit RF energy over the power line wiring by conduction; therefore, these systems are treated as unintentional radiators and the restricted bands of operation defined in 47 C.F.R. §15.205 do not apply.

Although Part 15 emission limits are intended to limit the risk of harmful interference to licensed services, compliance measurement procedures are equally important to the risk of interference because measurement uncertainty may ultimately result in BPL operation at field strength levels that are significantly higher or lower than the limits.

---

[17] *See* 47 C.F.R. §15.3(f). Carrier current system. A system, or part of a system, that transmits radio frequency energy by conduction over the electric power lines. A carrier current system can be designed such that the signals are received by conduction directly from connection to the electric power lines (unintentional radiator)…

Table 3-1: FCC Part 15 Radiated Emission Limits Relevant to BPL

Usage	Frequency (MHz)	Field Strength (µV/meter)	Measurement Distance (meters)	Measurement Bandwidth (kHz)	Detector	Source
Carrier Current Systems	1.705-30.0	30	30	9	quasi-peak	15.209
Class A, in commercial, business, and industrial areas	30-88	90	10	120	quasi-peak	15.109
Class B, marketed for use in residential areas	30-88	100	3	120	quasi-peak	15.109

3.2.2 Foreign Regulations

Some administrations have established rules or regulations for BPL implementation or have deferred BPL implementation pending the results of on-going studies. BPL has been successfully implemented in some countries, while other administrations have postponed BPL implementation while further interference studies are being conducted. Still others have implemented BPL, experienced interference problems, and then prohibited BPL operation at least for the time being. Regionally, emission rules have been proposed for evaluation. Some of these are presented here. Note that information collected here is not comprehensive and may not be current in light of the rapid pace of BPL studies and development. In the summaries presented in this section, the acronyms BPL (for Broadband on Power Line), PLC (for Power Line Communications), and PLT (for Power Line Telecommunications or Technologies) will be used in accordance with each original report.

3.2.2.1 Administrative Rulings on BPL

As summarized in Table 3-2, several administrations reportedly have already established rules applicable to BPL implementations.

Table 3-2: Countries and Their Rulings on BPL Implementations

Country	Ruling or Ruling Rationale	Source of Information
Australia	ACA has no mandatory standards for BPL equipment for frequencies above 525 kHz.	http://www.aca.gov.au/consumer_info/fact_sheets/industry_fact_sheets/fsi23.pdf
Austria	The Ministry of Traffic has terminated pilot projects on PLC. It concluded that the interference caused by PLC to communications in the frequency range 2 - 30 MHz could not be reduced to acceptable levels.	http://futurezone.orf.at/futurezone.orf?read=detail&id=205693&tmp=4659
Finland	FICORA Annual Report 2001: From measurement results, it decided that PLC technology can be accommodated only after interference and security problems have been solved and when the technology complies with official requirements. Favors compliance with NB30 until a pan-European norm is specified.	http://www.ficora.fi/2001/VV_vsk2001.pdf
Germany	NB30 (see Table 3-3)	http://www.darc.de/referate/emv/plc/c3.4-rev1-PLC5RPRT.pdf
Japan	The MPHPT of Japan has determined that at this stage, increasing the bandwidth to be used for power line communications would be difficult. Proposed feasibility tests promoting modem research and development.	http://www.soumu.go.jp/joho_tsusin/eng/Releases/Telecommunications/news020809_3.html
U.K.	No official position yet for the range 1.6 MHz to 30 MHz.	http://www.radio.gov.uk/publication/mpt/mpt_pdf/mpt1570.pdf

ACA: Australian Communications Authority
BBC: British Broadcasting Corporation
DARC: Deutscher Amateur-Radio-Club
EN: European Standard NF
FICORA: Finnish Communications Regulatory Authority
IEC: International Electrotechnical Commission
MPHPT: Ministry of Public Management Home Affaires, Post and Telecommunications of Japan
NB30: Usage Provision 30, issued by German RegTP in January 1999. It contains a limiting curve for the radiation of telecommunications services in and alongside of cables (including Cable TV, xDSL, and PLC) for the frequency range from 9 kHz to 3 GHz.
RA: Radiocommunications Agency of U.K.
RegTP: The Regulating Administration for Telecommunications and Posts of Germany

Table 3-3: German NB30 Limits

Frequency Range (MHz)	Limit of Peak Field Strength at 3 meters (dBµV/meter)	Measuring Bandwidth	Detector
>1 to 30	$40 - 8.8 * \log_{10}(f_{MHz})$	9 kHz	peak
>30 to 1000	27 (equivalent to radiated power of 20 dBpW)	not specified	peak

3.2.2.2 Proposed New Regulations

Several proposals have been presented on a regional basis for consideration to regulate emissions from cable and BPL equipment, and the parts of these proposals relevant to BPL systems operating in the frequency band of 1.7 – 80 MHz are listed below.[18] The first proposal, from Germany and taken from NB30, is shown in Table 3-4.

Table 3-4: German Regional Proposal

Frequency Range (MHz)	Limit of Peak Field Strength at 3 meters (dBµV/meter)	Measuring Bandwidth	Detector
>1 to 30	$40 - 8.8 * \log_{10}(f_{MHz})$	9 kHz	peak
The limit is given in terms of the electric field strength. Below 30 MHz the limit applies for the magnetic field strength, assuming an intrinsic impedance of 377 Ω. This proposal is supported by Austria, Finland, France, Germany, Romania and Switzerland.			

A second proposal, from Norway, is shown in Table 3-5.

Table 3-5: Norwegian Proposal

Frequency Range (MHz)	Limit of Peak Field Strength at 3 meters (dBµV/meter)	Measuring Bandwidth	Detector
>1 to 30	$20 - 7.7 * \log_{10}(f_{MHz})$	9 kHz	peak
Magnetic field data, in dBµA/meter, are measured with a loop antenna. The equivalent E-field data are converted from the H-field data by the factor of 51.5 dB which corresponds to the free space impedance of 120π Ω. This proposal is supported by Ireland.			

A third proposal, from BBC of U.K. and NATO, is shown in Table 3-6.

Table 3-6: Proposal from BBC and NATO

Frequency Range (MHz)	Limit of Peak Field Strength at 1 meter	Measuring Bandwidth	Detector
3 – 30	$H_{peak} = -29.7 - 8.15 \text{ Log}_{10}(f_{MHz})$,	9 kHz	peak

---

[18] European Conference of Postal and Telecommunications Administrations (CEPT) Electronic Communications Committee (ECC) Report 24, "PLT, DSL, Cable Communications (Including Cable TV), LANs and Their Effect on Radio Services," Section 7.

	(dBμA/meter, measured)		
3 – 30	$E_{peak} = 21.8 - 8.15 \text{ Log}_{10} (f_{\text{MHz}})$, (dBμV/meter, calculated from H_{peak})	9 kHz	peak
The H-field data are measured with a loop antenna, and the E-field data are converted from the H-field data by the factor of 51.5 dB. This limit is derived with the reference noise level from ITU-R Rec. P 372-7 and the protection distance of 10 meters where the sensitivity of a victim receiver degraded by less than 0.5 dB. It is supported by the radio users (military, broadcasting, civil aviation, amateur, etc.) of the LF, MF and HF bands.			

A fourth proposal, from BPL manufacturers and utility industries and taken from the FCC Part 15 limits, is shown in Table 3-7.

Table 3-7: Proposal by Certain BPL Proponents

Frequency (MHz)	Field Strength at 30 meters (μV/meter)	Measuring Bandwidth	Detector
1.705 - 30.0	30	9 kHz	quasi-peak

A comparison of these four proposals is shown in Figure 3-1. In this figure, the data are scaled to a 10 meter measurement distance according to §15.31 (f)(2) guidelines for measurement distance extrapolation under 30 MHz.

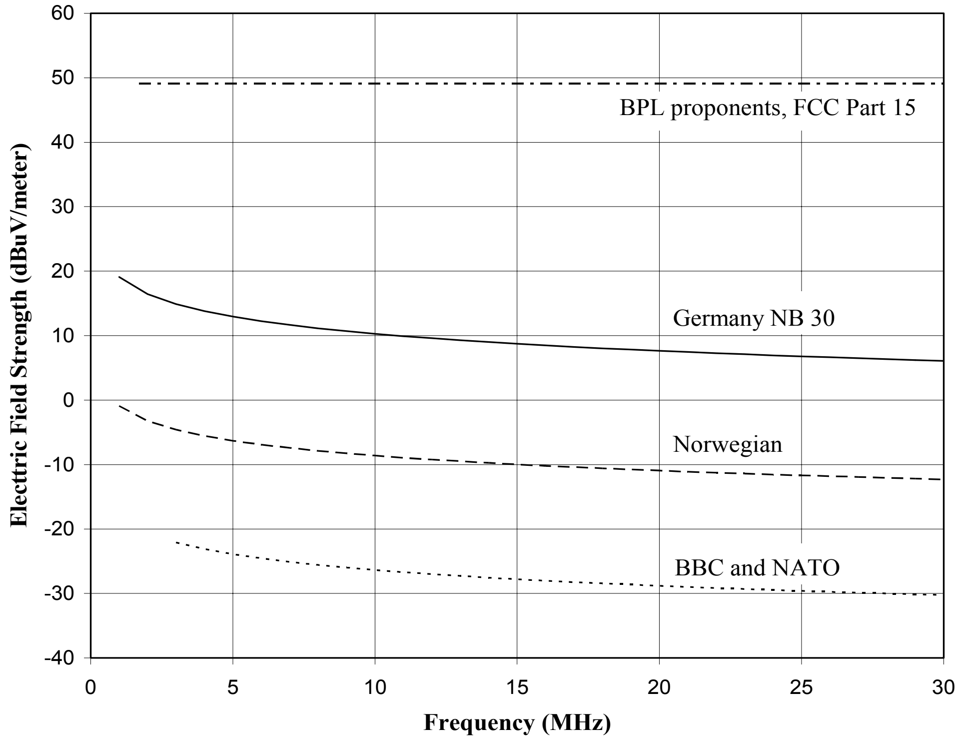

Figure 3-1: Comparison of Proposals for Regulating BPL Emissions

3.3 STUDIES

3.3.1 Analyses of Interference from BPL Filed Under the FCC NOI

Proponents and opponents of the Commission's NOI regarding Broadband over Power Lines submitted relevant technical information and analyses of the implications BPL will have on existing licensed services between 1.7 – 80 MHz. Some of their key points are summarized in the following paragraphs.[19]

3.3.1.1 Power Lines as Unintentional Radiators of BPL Signals

Ameren Energy Communications, Inc. (Ameren) analyzed the Medium Voltage (MV) power line with respect to its ability to act as an unintentional antenna for frequencies below 30 MHz.[20] In their analysis, Ameren stated that a two-conductor power line segment, driven differentially (*e.g.*, an "aerial" mode[21]), supports mostly transverse electromagnetic modes (TEM) of propagation and acts like a wave guide. This line radiates only at points of discontinuity, such as at line terminations, junctions with other lines, sharp line turns, and at power distribution equipment such as transformers and capacitors. They further state that reflections at the receiving end of the power line cause the formation of two opposite traveling waves, with radiation at both ends of the line.

Ameren noted that when calculating the radiation efficiency and gain of the power line, the source impedance at the BPL transmitter should be fixed and the load impedance should be allowed to vary. This contrasts with a line operating as a traveling wave antenna in that load impedance should be matched to the line's characteristic impedance (between 350 to 420 Ω for frequencies between 1 and 30 MHz). Their calculations show that as the line termination varies, not only does the line's radiation efficiency and gain change, the ability of the fixed source to couple power onto the power line decreases with the load mismatch. Ameren indicated that a single line is expected to be an inefficient radiator. Further, Ameren calculated the array factor for two conductors and show a 17% increase in radiation over the single conductor case. Ameren believes that transmission lines carrying TEM waves should not be compared with linear array elements as their radiation mechanisms are different.

---

[19] Inclusion or exclusion of any analysis in this section has no significance; NTIA reviewed all filings under the BPL Inquiry.

[20] *See* Reply Comments of Ameren Energy Communications Inc., BPL Inquiry, August 20, 2003, ("Ameren Reply Comments").

[21] As described in Ameren Reply Comments, "aerial modes" direct their peak radiation skyward.

Ameren also discussed the case of interconnected segments of MV power distribution line and pointed out that the radiation pattern is determined by the current distribution in the lines running in different directions, and the radiation is likely to be more isotropic. This, they believe, will result in lower gains and increased attenuation of signals as they divide amongst each interconnected segment and reflects at discontinuities. Ameren concludes that the strongest radiation will be at the source and that is the critical part of the system for determining radiation of BPL signals.

The ARRL submitted a paper presenting calculated antenna gains and patterns as a function of frequency for a simple power line model.[22] Their results indicated that as frequency increases, the power line acts more like an antenna, with a complex and highly directive radiation pattern.

In another paper, ARRL described their model of a MV distribution power line and compared the following three methods of injecting the BPL signal into the model[23]:

- Differential feed between two phases, with the feed at one end of the power line;
- One phase to Earth ground, with the feed in the center of the line;
- Single phase fed differentially; with one conductor grounded to a relatively poor RF ground and the ungrounded phase feed point was offset from center.

Based on their model, ARRL presented results for the antenna gain of the power line, with the single phase – differential feed with one conductor grounded as being the worst case. This case resulted in higher antenna gain for the modeled power line, and greater coupling to the simulated amateur radio antennas included in their model. ARRL noted that the calculated gain for this power line at 14 MHz rivaled many amateur HF antennas. A final observation was made that the radiated emission patterns for this model were very complex and that the peak radiation at 3.5 MHz is skyward.

3.3.1.2 Existing Part 15 Rules Regarding BPL Signals

Ameren questioned the validity of using a loop antenna to measure magnetic field strength.[24] Ameren pointed out that power lines act as "large radiators" and measurements close to power lines (e.g. 30 meters) are in the near field where the value of free space impedance typically used in the far field, 377 Ω (51.42 dB), is no longer valid. They presented graphs of electric (E) and Magnetic (H) fields, and H field + 51.42 dB to make the case that the far field value of free space impedance is incorrect in the near field.

---

[22] *See Power Lines as Antenna From 100 kHz to 50 MHz*, Ed Hare, Exhibit A to Comments of ARRL, BPL Inquiry, July 7, 2003, ("ARRL Comments").

[23] *See Methods of Feeding Overhead Electrical Power-Line Distribution Lines With BPL Signals and the Relationship of These Methods to the Radiated Emissions of the Conductors*, Ed Hare, Exhibit B to ARRL Comments.

[24] *See Use of Loop Antennae near Large Radiators*, Appendix to Ameren Reply Comments.

Ameren stated that the estimation error from the use of a loop antenna could be as high as 10 dBμV/m for measurements made along the power line, and as high as 20 dBμV/m moving away from the power line, even as far out as 700 meters. The model used for this analysis showed that the peak field strength is above the horizon, at an elevation angle of 12°. Ameren concluded that the loop introduces significant measurement errors near power lines and recommended use of a monopole antenna for BPL measurements.

In another paper, ARRL calculated the conducted emissions power levels based on several BPL manufacturers submissions to the Commission in response to the NOI.[25] ARRL stated that their calculations show a resultant level of conducted emissions exceeding 47 C.F.R. §15.107(a). ARRL further stated that, based on its understanding of how BPL couplers function, the typical losses for these couplers would lead to widespread radiated or conducted emissions.

ARRL addressed the possibility that inaccuracies may occur in measured results when following current Part 15 rules.[26] ARRL stated that from their model of power lines, BPL radiation patterns are complex and it would be difficult to predict where to make measurements to obtain the peak value of the electrical field. Another potential source of error may arise in arriving at an extrapolation factor, as they indicated that the HF electric field does not fall off at a 40 dB/decade inside 30 meters. Using the results from their power line model, ARRL noted that the power line field strength is greater above the power lines; therefore, measurements made near ground (1m) will typically underestimate the peak field strength.

To maximize the likelihood that measured results accurately characterize the BPL field strength, ARRL recommended in-situ testing at closely spaced distance intervals above, below, and to the sides of BPL system installations. The practice of using 3 "typical" installations to characterize emissions is considered by ARRL to be unrealistic and will result in measurements unrepresentative of the emissions in a real installation. Finally, ARRL noted that there are definitely standing waves in the simulation results for the power line modeled.

Using their power line model, ARRL calculated the received signal level from BPL emissions in the vicinity of an amateur radio antenna and the expected increase in noise floor. The BPL transmitted power spectral density was estimated and, from this, ARRL calculated that the radiated field strength will exceed Part 15 limits.[27] ARRL assumed ideal (high) coupling between the power line and the amateur radio antenna, and

---

[25] *See Broadband Over Power Line Devices and Conducted Emissions*, Ed Hare, Exhibit B to Reply Comments of ARRL, BPL Inquiry, August 20, 2003, ("ARRL Reply Comments").

[26] *See Electric and Magnetic Fields Near Physically Large Radiators*, Ed Hare, Exhibit D to ARRL Comments.

[27] *See Calculated Levels from Broadband Over Power Line Systems and their Impact on Amateur Radio Communications Circuits*, Ed Hare, Exhibit C to ARRL Comments.

that the antenna is located in a direction where the BPL signal's radiated emissions are at their peak. In addition, ARRL used the results of their model of the power lines to estimate power line "antenna gain." ARRL further described potential measurement errors that can mistakenly lead BPL vendors to believe that they are meeting Part 15 limits.

In a paper by the BBC, various proposals were considered for limits on emissions that are under review in CEPT SE35 (a European technical committee) and evaluated the amount of protection that these limits would provide to broadcast receivers near cabling carrying xDSL and PLT (BPL) signals.[28] The author concluded that none of the proposed limits adequately protect broadcast reception and that a proposal limiting the increase in noise floor appears to offer the most promise.

3.3.1.3 BPL Impact on Existing Licensed HF Communications Services

The ARRL modeled the reliability of HF communications for various noise floor levels.[29] Their modeling used noise floor levels for a quiet residential environment, the ITU-R Recommendation P.372.8 (2003) for median noise level in a residential environment, the ITR-R Recommendation level +10 dB, and the noise plus BPL signal level calculated by ARRL for a wide-scale BPL deployment where these devices operate at the maximum field strength allowed under Part 15. ARRL modeled these conditions at 5 MHz and 14 MHz using the VOACAP inverse-area coverage program.

A number of plots of HF link availability were provided in this ARRL report. The results indicated that the reliability of HF communications is already degraded when operating a receiver in the presence of the ITU-R median level noise, and if BPL use increased the noise floor by 10 dB, or to the level ARRL says will result from widespread BPL deployment at Part 15 limits, ARRL concludes that worldwide HF communications will be severely degraded.

In another paper, the BBC analyzed the cumulative effects of wide-scale deployment of xDSL and BPL. The BBC considered the skywave propagation effects on aircraft receivers and distant ground-based receivers due.[30] The author concluded from his analysis that the extent of skywave interference to aircraft and ground-based receivers from widespread xDSL/PLT system deployment may not be negligible. The author suggests that the relevant competent authorities should further investigate this interference potential.

---

[28] *See AM Broadcasting and Emissions from xDSL/PLT/etc.*, J. H. Stott, BBC R&D White Paper WHP-012, Attachment to Comments of David A. Lewis, BPL Inquiry, June 23, 2003, ("David Lewis Comments").

[29] *See Impact of Man-Made Noise From Broadband Over Power Line Systems Operating at the FCC Part-15 Radiated Emissions Limits on Worldwide HF Communications*, Ed Hare, Exhibit of ARRL, BPL Inquiry, August 20, 2003, ("ARRL Exhibit").

[30] *See Cumulative effects of distributed interferers*, J. H. Stott, BBC R&D White Paper WHP-004, Attachment to David Lewis Comments.

3.3.2 International Telecommunications Union (ITU) Activities

At least two of the three ITU Sectors have addressed BPL: the Telecommunications Standards Sector (ITU-T) and the Radiocommunications Sector (ITU-R). Working documents of the Study Groups in both of these sectors are not freely available to the public, so descriptions of current documentation and activities are presented in this section without comprehensive citations.[31]

3.3.2.1 ITU-T Study Group 5

In mid-2003, ITU-T Study Group 5 approved Recommendation K.60, which addresses "Emission Limits and Test Methods for Telecommunication Networks". Specifically, its intended application is for investigation of complaints of radio interference and its scope includes all telecommunications networks using LV AC electrical power lines and frequencies between 9 kHz and 400 GHz. The recommended "target" field strength limits for the 1.7-80 MHz frequency range are listed in Table 3-8. Associated measurement and administrative procedures are specified in the Recommendation. The procedures feature a number of interference mitigation steps that should be taken by the parties directly involved before consideration is given to filing an interference complaint with government authorities.

Table 3-8: Target Electric Field Strength Limits of ITU-T Rec. K.60

Frequency Range (MHz)	Field Strength (dBμV/m)		Measurement Distance	Measurement Bandwidth
	Peak	Quasi-Peak		
1 to 30	52 - 40 log (f)	40 - 20 log (f)	3 m	9 kHz
30 to 230	52 - 8.8 log (f)	40 - 8.8 log (f)	3 m	120 kHz
NOTES: f = frequency (MHz); below 30 MHz, 377 Ω impedance is assumed in estimating electric field strength from measured magnetic field strength; only the quasi-peak limit applies if background noise is too high for a peak measurement.				

3.3.2.2 ITU-R Study Group 1

Working Parties 1A (Spectrum Engineering) and 1C (Monitoring) met in November 2003 and examined BPL studies in response to Questions 221/1 and 218/1.[32] France presented an extensive, non-conclusory European study of potential interference from BPL and other wire-bound telecommunications systems. The United States (represented by ARRL) presented a paper outlining BPL interference measurement and

---

[31] Information on obtaining access to ITU documents, *e.g.*, via corporate membership, is provided at www.itu.int.

[32] The texts of Question 221/1, "Compatibility between radiocommunication systems and high data rate telecommunication systems using electricity power supply or telephone distribution wiring," and Question 218/1, "Techniques for measurement of radiation from high data rate telecommunication systems using electrical power supply or telephone distribution wiring," are freely available at www.itu.int.

analysis considerations consistent with the Commission's open BPL proceeding. Korea presented a paper describing an approach for measuring BPL emissions in a laboratory environment. A Liaison Statement presenting relevant Study Group 6 (broadcasting service) studies was reviewed. Insofar as Working Party 1A is the lead ITU-R group for development of recommendations regarding potential interference from BPL systems, it requested information from all other Working Parties responsible for signal propagation models and analysis and matters affecting specific radio services. Working Parties 1A and 1C both expect to complete their BPL studies in 2005.

3.3.2.3 ITU-R Study Group 3

The November 2003 meetings of Study Group 3, Working Parties 3J, 3K, 3L and 3M, generated extensive discussions on propagation aspects of Power Line Telecommunication (PLT) systems. The Study Group 3 Chairman declared this to be one of the three most important topics for these meetings. Subgroups 3K-1 and 3L-2 spent appreciable time discussing PLT systems and Subgroup 3J-C contributed relevant information regarding environmental noise. Working parties 3J, 3K and 3L jointly drafted a liaison statement to Working Party 1A, identifying concerns and suggesting methods of estimation of PLT signal radiation levels.

The concerns expressed included: the unbalanced nature and diverse characteristics of power lines; the possibility of both point and line sources of radiation; power aggregation of emissions from multiple sources; and the presence of both ground and sky waves. It was noted that in developing criteria for acceptable PLT use of radio frequencies, measurements of both electric and magnetic fields must be considered because of the unknown relationship between these fields in the near-field. It was suggested that: a model such as NEC be used for estimation of radiation; either ITU-R Rec. P. 368 or the software GRWAVE be used for evaluating ground wave propagation of PLT emissions; and ITU-R Rec. P. 533 be used for evaluating PLT propagation via sky wave. It was also suggested that ITU-R Rec. P. 372 be used for estimating levels of noise.

In addition to the Liaison Statement, Working Party 3L drafted a new question and formed a new Correspondence Group to work on the PLT Communications. The draft new question focused on prediction methods and models applicable to PLT systems. Defined studies were also given high priority. The defined studies address radiation mechanisms of PLT systems, modeling techniques, effects of local ground planes and conductors, methods of aggregation, propagation models for calculation of interference and measurement of radiated fields in the near field. The Correspondence Group will exchange ideas and communicate outputs of various studies under progress for review by the international group.

3.3.2.4 ITU-R Study Group 6

In ITU WP 6E, the European Broadcasting Union (EBU) submitted a document recommending revision of PLT field strength limits and measurement distance identified in an earlier study. This contribution suggested three shortcomings in the earlier study. First, digital broadcasting transmission, not Amplitude Modulation transmission, should be used to derive the allowable PLT signal strength. Second, the required signal-to-noise level should not support only a relatively interference-tolerant channel operating in a rugged mode with restricted capacity. Third, the 3-meter measurement distance specified in the NB30 limit (Table 3-3) is unrealistically large for indoor reception. Therefore EBU concluded that the NB30 limits were unacceptably lax by a large margin and proposed that: (1) the maximum allowable PLT interference should be at least 10-20 dB lower; and (2) reception at 1-meter and larger distances from the PLT emission source should be protected.

3.3.3 Other Technical Literature

Appendix B summarizes additional technical literature that was not filed in response to the BPL Inquiry.

3.4 SUMMARY

Studies performed by other parties and applicable FCC and foreign regulations were reviewed to ensure that NTIA's studies would address important interference mechanisms and factors as well as potential means for effectively accommodating BPL and radio systems. NTIA noted that BPL has been implemented with success in some countries, while other countries have postponed implementation of BPL systems until further interference studies are being conducted. Still others have withdrawn their approval for operation of BPL systems after experiencing interference problems. Several emission limits have been adopted or proposed for evaluation on international, national and regional bases. Most studies have been oriented to determine whether interference will occur at the variously proposed limits. In contrast, NTIA has oriented its study to find a solution that accommodates BPL systems while appropriately managing the risk of interference to radio systems.

Technical information and analyses submitted in response to the FCC NOI included several relevant observations. BPL signals unintentionally radiate from power lines, although there is substantial disagreement as to the strength of the emissions and their potential for causing interference to licensed radio services. Analyses indicate that the peak field strength due to unintentional BPL radiation occurs above the physical horizon of power lines. Current Part 15 measurement techniques may significantly underestimate the peak field strength generated by BPL systems as a result of using a loop antenna in the near field; performing measurements with an antenna situated near ground level (*e.g.*, 1 meter); and measuring emissions in the vicinity of BPL devices without also considering emissions from the power lines.