Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC. 20554

In the Matter of:	)	**ET Docket No. 03-104**
	)	
Inquiry Regarding Carrier Current Systems,	)	
including Power Line Broadband Systems	)	

REPLY COMMENTS OF MICHAEL KEANE

Michael Keane, on behalf of himself, respectively submits the following reply comments in the above captioned proceeding relative to the *Notice of Inquiry*, FCC 03-100.

SUMMARY

I am responding to comments made on three topics. First, I reply to comments made regarding protection for incumbent radio communications services from harmful interference. I note the preponderance of comments in this proceeding express concern over harmful interference coming from a ubiquitous source. A source that runs up and down the streets of their neighborhoods; a source that runs right up to the very front doors of their homes.

Let there be no prevarication, the field strengths of radiated emissions specified in Section 15.109[1] correspond to received signal strengths that are extremely high in comparison to signal levels routinely employed for HF communications. It is a physical impossibility for these strong signals *not* to cause harmful interference to every HF spectrum user in the general vicinity of a power line carrying BPL signals who uses the same frequencies that BPL employs.

Obviously, if BPL quickly fails in its market test, any interference it causes will be a short-lived problem effecting a limited number of unfortunate locales. On the other hand, if, as the Commissioners have publicly remarked, BPL indeed turns out to be the ubiquitous “third pipe” then its interference will likewise be ubiquitous and disruptive of all HF communications.

Two alternatives for dealing with interference have emerged from the comments in this proceeding: spectral masks and stricter radiated (and/or conducted) emission limits. Use of spectral masks could be mandated *de jure* by amending the rules or *de facto* by enforcing Section 15.5[2]. The specification of spectral masks by rule limits the flexibility of the Commission to manage the spectrum. Voluntary efforts are ultimately only as effective as the certainty of enforcement action by the Commission.

Secondly, I reply to comments on the subject of measurement practices used to verify compliance with radiated emission limits. The measurement standards specified in Section 15.31[3]

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[1] See 47 C.F.R. § 15.109.

[2] See 47 C.F.R. § 15.5(c).

[3] See 47 C.F.R. § 15.31(f)(2).

produce results that are systematically in error when applied to measurements taken in the reactive near field region. The result is an erroneous determination of compliance with the radiated limits specified in Section 15.209[4].

Finally, I reply to comments on the use of the marketplace to help resolve interference to authorized spectrum users. Interference is classical example of a market spillover. Left unregulated, market forces will not efficiently address interference. The additional economic incentives provided by enforcement of the Commission's operating rules[5] are crucial if the marketplace is to take proper account of interference issues.

INTRODUCTION

Upon review of the comments made in this proceeding, it is clear that there are two communities of interest. There has been scant input from consumers clamoring for Broadband over Power Lines (BPL) to bring broadband services to their doors or rather their wall plugs. Rather, there is a series of comments made by technology providers, electric power utilities and industry groups supporting the *status quo* or even a relaxation of the present Part 15 rules. The overwhelming majority of comments in this proceeding come from spectrum users who have no interest in BPL *per se,* only grave concerns over the harmful interference that will result from BPL operations.

My assessment of key points made in comments to this proceeding include:

- Access BPL equipment manufacturers have or soon will verify their products' compliance with Part 15 limits and begin marketing these products to electrical utilities.

- Operating at the compliance limit, Access BPL will generate widespread harmful interference to all HF spectrum users who are unfortunate enough to reside near power lines carrying BPL signals and who use frequencies on which BPL operates.

- Electrical utilities operating Access BPL equipment have sole responsible for resolving cases of interference caused by the hardware they have been sold. BPL operations may have to be suspended while interference problems are solved.

- Should Access BPL be widely deployed, the Enforcement Bureau and Office of Engineering and Technology can anticipate handling numerous legitimate interference complaints.

- Spectral masks may avoid some interference complaints at the expense of reduced bandwidth. Regulatory mandated spectral masks have undesirable policy consequences.

- Access BPL is strictly a "last mile" solution. Given the need for a means *other* than BPL to provide the necessary backhaul capacity, the infrastructure costs for providing broadband services to rural, isolated and other underserved areas via BPL will not necessarily be lower than competing last mile solutions.

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[4] See 47 C.F.R. § 15.209.

[5] See 47 C.F.R. § 15.5.

INTERFERENCE

I concur with the IEEE Power System Relaying Committee (PSRC) that: "avoiding interference is paramount."[6] As PSRC notes, in addition to amateur radio: "there are other radio services that need to be protected."[7] As a practical matter, if each authorized radio communications service having a primary or secondary allocation between 1.705 MHz and 80 MHz was to be adequately protected by "spectral masks," there would be few frequencies left on which BPL could operate.

Further, as the ARRL[8] and the North American Shortwave Association[9] have pointed out in their comments, specification of "spectral masks" in the rules is a short-sighted approach that needlessly restricts the Commission's flexibility in making future spectrum management decisions and in responding to changing external conditions such as modifications to the international table of allocations by the ITU.

Rather than relying on spectral masks proscribed by rule, it would be far better policy for the Commission to adopt radiated emission limits that provide protection to *all* spectrum users. Short of that, the incidence of real-world interference complaints can be expected to make the "voluntary" provision of spectral masks (or the functional equivalent) by manufacturers a *de facto* mandatory feature of Access BPL equipment. The Commission can assure this outcome without the need for it to adopt any *new* rules, if the Commission's actions in regard to BPL demonstrate that it intends to fully *enforce* Section 15.5[10].

In its comments, Progress Energy states that:

> Should such a situation ever arise, it can be addressed by the equipment's ability to shift frequencies in order to avoid interference.[11]

This is notionally correct for Access BPL systems that employ orthogonal frequency division multiplexing (OFDM)[12]. Specific OFDM carriers may be disabled in an effort to control interference. In practice, channel separation in OFDM relies upon an orthogonality relationship between carriers not frequency localization within a well-defined channel. A basic OFDM waveform employs a rectangular keying waveform, a waveform having notoriously poor frequency localization.

Consequently, the occupied bandwidth of an individual OFDM "channel" is quite large. Modulation products from OFDM carriers well displaced in frequency from any "masked" bands contribute significant signals to the protected bands. If spectral masks are to be defined by rule,

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[6] Comments of IEEE Power System Relaying Committee at p. 3.

[7] *Ibid*. at p.4.

[8] Comments of ARRL, National Association for Amateur Radio at ¶ 18 (see footnote 8) and ¶ 26.

[9] Comments of North American of Shortwave Association at p.3.

[10] See 47 C.F.R. § 15.5(c).

[11] Comments of Progress Energy, Inc. at ¶ 10.

[12] Comments of Ambient, Inc at p. 5; Comments of Amperion at p. 4; Comments Current Technologies, LLC at p. 5, footnote 3; Comments of HomePlug Powerline Alliance at p. 3; Comments of Main.net Communications Ltd. at p. 4.

they should be specified to set limits on the total power from all sources (carrier, modulation product and spurious emissions) falling within the protected bands.

PPL Telecom states in its comments under a section entitled "Low Risk from BPL Operations," that it believes:

> … BPL does not pose significant risks for unintended high frequency radiations that will impair the operation of consumer devices, amateur radio communications, or other forms of commercial communications (e.g. television, radio, mobile radio, etc.)[13]

Among the reasons PPL Telecom cites is:

> *Technology providers will FCC-certify their access and in-home BPL technologies.* The two technology providers presently supplying equipment to PPL Telecom (Main.net and Amperion) have completed extensive FCC testing for compliance certification and have attached FCC stickers on their BPL equipment. BPL technology providers have taken, through product design and independent testing, great efforts to ensure that their technology does not interfere with users of FCC regulated radio bands and will meet FCC Part 15 requirements.[14]

A substantially identical reason is echoed by the Florida Power & Light Company (FPL) [15], the Hawaiian Electric Company (HECO)[16] and PowerWAN[17] in their comments.

A manufacturer's legal responsibility ends upon verification (or certification) of their product's Part 15 compliance. In use, BPL operators such as PPL Telecom, Florida Power & Light and Hawaiian Electric (or their "tenants"[18]) have an affirmative duty to ensure that *their* equipment does not cause harmful interference to authorized spectrum users. An appeal to an attached FCC sticker will be completely inadequate in the event that harmful interference occurs. While a technology provider might assist by providing after sales support, ultimately the BPL operator has the sole legal responsibility for correcting any harmful interference that *its* equipment might cause. And, if notified by the Commission, a BPL operator must be prepared to immediately cease operations of all offending devices until the harmful interference is corrected.

Another reason that PPL Telecom gives to justify its belief that BPL does not pose significant risks for "unintended radiations" and interference is:

> *No detectable interference with other power line solutions.* PPL Electric has deployed a power line automated meter reading ("AMR") solution to over 600,000 customers in its central-eastern Pennsylvania service territory including the BPL trial locations of Emmaus and Whitehall. This AMR solution utilizes a narrow-band power line Two Way Automated Communication System ("TWACS") technology developed by Distribution

[13] Comments of PPL Telecom, LLC at p. 5.

[14] Comments of PPL Telecom, LLC at p. 6.

[15] Comments of Florida Power & Light Company at pp. 7-8.

[16] Comments of Hawaiian Electric Company, Inc. at pp. 3-4.

[17] Comments of PowerWAN, Inc at p. 8.

[18] Comments of Hawaiian Electric Company, Inc. at p.3.

> Control Systems Incorporated ("DCSI"). PPL Electric's testing and successful operation of both the BPL and AMR equipment in the trial locations indicate that there is no interference from the introduction of BPL technology.[19]

A reason also cited by FPL[20].

"TWACS" is a carrier current system that operates by signaling at the zero-crossings of the 60 Hz AC wave. With a maximum frequency of a several hundred hertz, TWACS is best described as a low frequency audio signal imposed on the power line. Why the successful (or conversely, the unsuccessful) operation of two carrier current systems, one RF (BPL) and one audio (TWACS), simultaneously on the same wire should have any bearing on the potential for interference to spectrum users caused by *radiated* emissions is mystifying.

PPL Telecom and FPL might be unaware of the technical details of systems they employ on their power lines and the physical mechanisms by which such equipment impacts on users of the radio spectrum. Alternatively, this could be an attempt at introducing irrelevant facts to obscure PPL Telecom's and FPL's inability to produce any real evidence in support of their assertion that BPL does not pose a significant interference risk.

I share the skepticism expressed by the National Association of Broadcasters that anecdotal evidence noting a lack of interference complaints equates to no interference[21]. Observations of the Potomac, MD field trial described in the comments of AMRAD[22] and Paul Alexander[23] suggest that some form of spectral masking was likely being used. If a similar practice has been employed preemptively in other field trials[24], the significance of "no interference reported"[25] is greatly diminished. Masked field trials are inherently biased and do not provide a full and fair assessment of either the adequacy of the present emission limits or the interference potential of BPL.

A published report describes the location of the Potomac, MD field trial as a "subdivision."[26] The location of the Cape Girardeau, MO field trial has been described as a subdivision as well[27]. A subdivision immediately calls to mind privately imposed deed restrictions and covenants, conditions and restrictions (CC&Rs). One of the things most commonly "restricted" by a subdivision's CC&Rs is the installation of outside antennas.

From the lengthy proceeding in RM 8763, the Commission is certainly well acquainted with the significant negative impacts CC&Rs have on amateur radio operations. CC&Rs discourage

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[19] Comments of PPL Telecom, LLC at p. 87.

[20] Comments of Florida Power & Light Company at p. 8.

[21] Comments of the Association for Maximum Service Television, Inc. and The National Association of Broadcasters at p.5.

[22] Comments of Amateur Radio Research and Development Corporation (AMRAD) at p. 2.

[23] Comments of Paul F. Alexander at ¶¶ 1 & 4.

[24] See Comments of PowerWAN, Inc. at p. 3: "Notching out of particular frequency areas in an OFDM signal is routinely done."

[25] Comments of United Power Line Council at p. 9.

[26] Joseph Swavy, "New outlet for fast Net access may shock you," *The Press of Atlantic City*, 27 July 2003. <http://www.pressofatlanticcity.com/news/business-casino/072703BROADBANDJUL27.html>

[27] George McCouch, "It's as bad as you think, a field trip to a BPL test site." 17 August 2003. <http://www.qrz.com/cgi-bin/ikonboard.cgi?s=3f43991761f5ffff;act=ST;f=7;t=42003>

active amateur radio operators from choosing to reside in subdivisions. When the holder of amateur radio license must live in an antenna-restricted development, the CC&Rs make it nearly impossible for the licensee to be active from his/her home on HF where an outside antenna is a virtual necessity for effective communications.

A subdivision makes an ideal setting for a BPL field trial if one were interested in minimizing the likelihood of receiving interference complaints. For the purposes of a full and fair assessment of the interference potential of BPL, a subdivision is inherently biased and thus a very poor choice. Given the limited extent of the nine field trials and their uncertain demographics, the reported absence of interference complaints from trial participants cannot be considered suggestive let alone definitive at this stage of the proceeding.

The absence of evidence is not satisfactory evidence for absence. Without detailed descriptions of each field test, the United Power Line Council's comment of "no interference reported" can only be viewed with great skepticism. It is quite clear that the public record in this proceeding so far lacks adequate technical data to objectively evaluate the claims of compatibility being made by manufacturers and utilities. Even so, one trial participant *has* submitted comments in this proceeding documenting his observations of harmful interference[28] to stations operating in the broadcast service and the standard frequency & time signals service.

Ameren Energy Communications Inc. (AEC) states in its comments:

> …considerable noise already is indigenous in the vicinity of the power lines existing independently of the BPL operation, and this noise does not cause harmful interference.[29]

The "considerable noise" in the vicinity of power lines, which AEC so cavalierly dismisses, represents the most frequently reported source of harmful interference to stations in the Amateur Service. That noise most definitely *does* cause harmful interference, AEC's assertion to the contrary notwithstanding. Interference so severe in some cases that it had to be referred to the Commission's Enforcement Bureau for resolution when cooperative efforts at resolving the problem failed. Power line interference continues to be a very substantial problem for the Amateur Service and an enforcement burden to the Commission. It would be totally unreasonable to accept the presence of noise that violates the Part 15 rules on incidental radiators[30] as proof that the present limits on radiated emissions from unintentional radiators are adequate.

An examination of the field strength measurements reported to the Commission by AEC[31] is illuminating in the light of what numerous comments in this proceeding have noted and observations have now begun to show regarding the interference potential of emissions with a field strength of 30 µV/m at 30 m (+29.5 dBµV/m)[32]. AEC's measurement of the background

[28] Comments of Paul F. Alexander at ¶¶ 1 & 4.

[29] Comments of Ampere Energy Communications Inc. at p. 10.

[30] See 47 C.F.R. §§ 15.5, 15.13 & 15.15.

[31] Ameren Energy Communications Inc., *Second Progress Report*, Experimental License WC2XXK, File No. 0093-EX-PL-2002, June 4, 2003.

[32] Quasi-peak in a 9 kHz bandwidth.

noise from one of the power lines[33] in its BPL field trial indicates a field strength +15 dB to +20 dB above the emission limits specified in Section 15.209[34], a level that we now know results in strong interference. This strongly suggests that the power line was itself a severe source of interference in the test area prior to commencement of any BPL trials[35].

It is therefore not surprising that no complaints were received in this field test. Potential complainants likely switched off their radios years ago in utter frustration over unremitting interference from the local power line. Had there been someone there to listen, a casual observer was unlikely to have taken note of an incremental increase in the interference level due to the BPL in the presence of the excessively high background level. A chronic disregard for the Commission rules should not be allowed to further the claim that inference does not present a problem.

Main.net Communications Ltd. (Main.net) states in its comments:

> Although there is some theoretical concern regarding interference to Amateur Radio operations below 30 MHz, Main.net's experience… has been that *there is no interference*.[36]

Independent monitoring of a Main.net field test in Linz, Austria by the Austrian Amateur Radio Society[37] resulted in at least fifteen formal complaints of interference being filed with both the Bundesministerium für Verkehr, Innovation and Technologie (the Austrian Federal Ministry for Transport, Innovation and Technology) and the Bundesministerium für Wirtschaft und Arbeit (the Austrian Federal Ministry for Economic Affairs and Labor) during the period November 2002 to January 2003[38,39].

In addition, at least one formal complaint of interference was filed with Agentschap Telecom, the Netherlands Radiocommunications Agency, in February 2002 during trials of a BPL system in Arhmem, Netherlands by the Dutch utility NUON using equipment supplied by Main.net[40].

Thus, it appears that Main.net's claim of "no interference" is directly contradicted. One hopes that the remainder of the nascent BPL industry is more forthright when we again hear: "*there is no interference."*

Despite limited access to the BPL test sites, in part due to the equipment manufacturers and utilities treating the locations of the field trials as proprietary information and in at least one case

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[33] Ameren Energy Communications Inc., *op. cit*., pp. 10-11, Fig. 3 & Fig 4 for Station A located 75 feet from the line.

[34] 47 C.F.R. 15.209(a).

[35] *See* George McCouch, "It's as bad as you think, A field trip to a BPL test site" 17 August 2003 at ¶ 6. <http://www.qrz.com/cgi-bin/ikonboard.cgi?s=3f43991761f5ffff;act=ST;f=7;t=42003>

[36] Comment of Main.net Communications Ltd. at p. 6.

[37] Austrian Amateur Radio Society, ÖVSV. <http://powerline-plc.info>. A video is available at <http://www.darc.de/referate/emv/plc/plc_video_linz.rm>

[38] International Amateur Radio Union - Region 1 EUROCOM WG, Newsletter January 2003. <http://www.darc.de/referate/ausland/iaru/eurocom/euronews0103.pdf>

[39] Comments of Mike Zwingl, Austrian Amateur Radio Society.

[40] *Ibid*.

even deliberate evasion[41], observations of BPL field trials are reported in the comments of AMRAD[42], Paul Alexander[43], Stephen Holton[44] and George McCouch[45]. Each of these commenters reports harmful interference to the radio communications services operating in the frequency bands employed by the BPL systems. These observations provide an initial glimpse at the inadequacies of the existing Part 15 radiated emission limits to, in the words of the NTIA, "preclude unacceptable interference."[46]

I join with Aura Communications Inc.[47] in calling the Commission's attention to ECC Report 24 of the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT) entitled *PLT, DSL, Cable Communications (including Cable TV), LANs and Their Effect on Radio Services.* This report addresses the compatibility between wireline communication systems including BPL (referred to as power line telecommunications (PLT) in the report) and radio services. Extremely relevant to the "controversy" in the current proceeding regarding the risk of interference from BPL, ECC Report 24 concludes in regards to amateur radio:

> For an antenna location as is common for most amateurs, close to or above the house, *the reception of interference radiating from the mains is very serious* for field strength levels equal to the example n°1 (NB 30) limit or the equivalent field strength level of the CISPR 22 Class B limit.[48]

And:

> Even the example n°4 (BBC) limit is *inadequate to avoid interference* in the above-mentioned situation, in particular on the higher amateur bands.[49]

The "NB 30" limits are the radiated emission limits of the Federal Republic of Germany's Regulatory Authority for Telecommunications and Posts (RegTP) specified in Usage Provision 30 of July 2001 ("Nutzungsbestimmung 30-07/01") of the Frequency Band Allocation Ordinance ("FreqBZPV")[50]. The NB 30 limits are from 31.6 dB to 42.5 dB *lower* than existing Part 15 radiated limits[51] from 1.705 MHz to 30 MHz. The "BBC" limits are radiated emission limits

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[41] Comments of ARRL, National Association for Amateur Radio at ¶ 20.

[42] Comments of Amateur Radio Research and Development Corporation (AMRAD) at p. 2.

[43] Comments of Paul F. Alexander at ¶¶ 1 & 4.

[44] Comments of Stephen M. Holton.

[45] Comments of George McCouch.

[46] Comments of the National Telecommunications and Information Administration.

[47] Comments of Aura Communications Inc. at p. 1.

[48] *PLT, DSL, Cable Communications (including Cable TV), LANs and Their Effect on Radio Services*, CEPT/ECC Report 24, May 2003, p. 107, emphasis added. <http://www.ero.dk/documentation/docs/doc98/official/pdf/ECCREP024.PDF>, Report; <http://www.ero.dk/documentation/docs/doc98/official/pdf/ECCREP024ANNEXES.PDF>, Annexes.

[49] *Ibid* at p. 107, emphasis added.

[50] Frequenzbereichszuweisungsplanverordnung (Frequency Band Allocation Ordinance) and Nutzungsbestimmung (Usage Provisions) are available at <http://www.bmwi.de/Navigation/Wirtschaft/Telekommunikation_20und_20Post/telekommunikationspolitik/rechtsgrundlagen.html>

[51] Part15 emission limits scaled to the NB30 compliance distance of 3 m using a 40 dB per decade extrapolation factor.

proposed by the British Broadcasting Corporation[52]. The BBC limits are from 68.7 dB to 78.9 dB *lower* than existing Part 15 radiated limits[53] from 1.705 MHz to 30 MHz.

CEPT/ECC concludes a field strength of even 1/5000 the existing Part 15 emission limits is *inadequate to avoid interference to amateur stations.* CEPT/ECC's assessment is based on the strength of the radiated fields and is independent of whether European or United States power lines or BPL technology produced those fields. Despite the implication of the IEEE Power System Relaying Committee's reply comments to the contrary[54], the laws of physics respect no national boundaries.

Perhaps most telling of all is CEPT/ECC's independent assessment that:

> The application of example n°5 limits or the CISPR radiated limits *would mask the level of amateur radio operation almost completely or even obliterate it*.[55]

The "example n°5 limits" referred to here are none other than the present Part 15 limits which the CEPT/ECC concludes would *obliterate* amateur radio operations.

ECC Report 24, incorporating input from forty-five European administrations, plus the reports from Japan's Ministry of Public Management, Home Affairs, Posts and Telecommunications[56], the United Kingdom's Radiocommunications Agency[57], the Federal Republic of Germany's Regulatory Authority for Telecommunications and Posts[58] and Switzerland's Federal Office of Communication[59] demonstrate that spectrum management agencies in other industrialized nations judge the evidence for harmful interference from BPL operations to be highly credible. This is profoundly different from what the Commission is being told by equipment manufacturers, power utilities and other industry representatives in this proceeding.

Comments from Current Technologies:

> We are starting with a noisy radio-frequency environment, and the Commission must take that into account in assessing the impact of BPL. No BPL regulation can "re-quiet" the environment back to the pristine state that some commenters prefer…We urge the

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[52] J.H. Stott, *Emission limits*, BBC R&D White Paper, WHP 013, November 2001. <http://www.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP013.pdf>

[53] Part15 emission limits scaled to the BBC compliance distance of 1 m using a 40 dB per decade extrapolation factor.

[54] Reply Comments of the IEEE Power System Relaying Committee.

[55] CEPT/ECC Report 24, *op. cit*. at p. 105, emphasis added.

[56] *Power Line Communication Study Group Report*, Ministry of Public Management, Home Affairs, Posts and Telecommunications, Tokyo, 9 August 2002. <http://www.soumu.go.jp/s-news/2002/020809_4.html>

[57] *Final Report of Technical Working Group*, UK Technical Working Group on Compatibility Between Radio Services and VDSL + PLT Systems Operating between 1.6 and 30 MHz, Radiocommunications Agency, London. April 2001. <http://www.radio.gov.uk/topics/interference/documents/twg-finalreport.pdf>

[58] *Abschlussbericht zur "Power-line" Studie* (Final Report of the "Power-Line" Study), Dr.-Ing. R Vick, Editor, EMV—Beratungs und Planungsbüro, Dresden, January 2000. <http://www.regtp.de/en/tech_reg_tele/start/in_06-03-02-03-00_m/index.html >

[59] *Appréciation du pouvoir perturbateur des installations PLC à Fribourg* (Assessment of the Interference Potential of PLC Installations in Fribourg), Federal Office of Communication, Biel-Bienne, June 2003. <http://www.bakom.ch/fr/funk/elektromagnetisch/plc_freiburg/index.html>

> Commission to carry out its analyses using models and parameters that accurately reflect both the likely emissions from BPL and the interference susceptibility of other services under actual operating conditions.[60]

I take exception to Current Technologies assertion regarding unidentified commenters desiring regulations to "re-quiet" the RF environment. There have been no comments seeking regulations to restore the environment to the state it was in some halcyon days of yore. Rather from a reading of the comments in this proceeding, commenters quite reasonably seek effective controls (regulatory or otherwise) to ensure that BPL emissions do not *pollute* their local RF environment, as that environment currently exists for them.

I otherwise agree with Current Technologies that the Office of Engineering and Technology should carry out analyses using models that accurately reflect the actual HF noise environment and interference susceptibility of radio communications services. I would commend to the Commission's attention ITU-R Recommendation P.372-8 (04/03)[61] as representing an internationally accepted standard for HF noise environments.

The American Public Power Association states:

> … the burden should be imposed on challengers to BPL to demonstrate interference in a factbased, empirical proof.[62]

The only *challenges* being offered by the majority of commenters are to the unsupported claims by its proponents that BPL poses little risk of interference to incumbent spectrum users and to the veracity of certain such claims. The majority of comments in this proceeding express no interest regarding BPL's possible entry into the marketplace or its eventual success or failure.

One wonders why the factual evidence from field tests in Japan and Europe were not sufficient indicators of a compatibility issue. There is no credible reason for doubting that devastating levels of interference to the frequency bands employed in the U.S. fields trials of BPL will be confirmed by non-advocate monitoring and measurements; just as such interference has been demonstrated elsewhere.

That quantitative data on EMC and interference has not been forthcoming from current field trials is troubling. Its absence has forced third parties to expend their own time and resources in order to provide the Commission with the "empirical proof" of interference. Yet, properly designed and objective field trials of BPL would have readily identified a basic EMC problem as serious as the interference resulting form BPL operations. Indeed, the Commission licensed BPL field tests on an experimental basis in part for:

> Development of radio technique, equipment, operational data or engineering data related to an existing or proposed radio service.[63]

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[60] Comments of Current Technologies, LLC at p. 12.

[61] International Telecommunications Union, Geneva. 2003. *Radio Noise*. ITU-R Recommendation P.372-8.

[62] Reply Comments of the American Public Power Association at ¶ 6.

[63] See 47 C.F.R. § 5.3(i)

The only way in which BPL, a wireline communications system that employs radio frequency devices operating as unintentional radiators on an unlicensed basis in accordance with Part 15, could be related to a *radio*[64] technique, equipment or service is via the harmful interference that BPL inflicts upon authorized radio communications services.

No authorization is required in order to perform testing of equipment to determine compliance with Part 15. Yet, compliance measurements were the only data that the Commission *required* experimental licensees provide in their progress reports. Despite explicitly referencing Section 5.3(i) in each experimental license grant[65], a section of the rules that concerns itself solely with radio, the Commission did not require licensees to report any EMC measurements from their field trials other than Part 15 compliance.

That no requirement to monitor and report on interference to radio communications services was imposed on these field trials is especially surprising. In addition to administering experimental licenses under Part 5, another function of the Office of Engineering and Technology is:

> *To evaluate evolving technology for interference potential* and to suggest ways to facilitate its introduction in response to Bureau initiatives, and advise the Commission and staff offices in such matters.[66]

Even without knowledge of the overseas field tests, the Office of Engineering and Technology clearly should have anticipated that BPL presents significant EMC issues and interference would be a central concern in a future proceeding on BPL. So now the same licensees whom the Office of Engineering and Technology did not require to collect data on interference in their field trials can argue in this proceeding that the absence of data should constitute proof there is no interference.

I concur with the National Telecommunications and Information Administration that the Commission should not waive or otherwise relax the existing Part 15 rules at this time:

> …because of the present lack of measurements and analyses showing that any resulting interference to allocated services would be at acceptable levels.[67]

The vast majority of commenters to this proceeding who operate HF and VHF communications systems share the NTIA's:

> … broad concerns with radiated emission limits and other measures that may be needed to protect these systems.[68]

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[64] See the definition of *Radio* & *Radio Waves* in 47 C.F.R. § 2.1. Radio refers to electromagnetic waves propagating through space, not to currents flowing in wires.

[65] License grant for WC2XXK, File Number 0093-EX-PL-2002; license grant for WD2XCN, File Number 0046-EX-PL-2003; license grant for WC2XUV, File Number 0046-EX-ML-2002; license grant for WD2XDT, File Number 0089-EX-PL-2003; license grant for WC2XZQ, File Number 0183-EX-PL-2002; license grant for WD2XCA, File Number 0011-EX-PL-2003; license grant for WC2XZG; File Number 0126-EX-PL-2002.

[66] 47 C.F.R. § 0.31(a), emphasis added

[67] Letter of July 1, 2003 from Fredrick R. Wentland, Associate Administrator, NTIA Office of Spectrum Management to Edmond J. Thomas, Chief, FCC Office of Engineering and Technology.

[68] Comments of the National Telecommunications and Information Administration.

In addition, I thoroughly applaud the initiatives NTIA describes in its comments:

> NTIA has initiated modeling and analyses that address the interfering potential of BPL technology and the radiated emission limits needed to preclude unacceptable interference to federal government systems. This effort includes research of relevant technical studies and measurement efforts that have been performed throughout the world as well as regulatory approaches taken for BPL (e.g., carrier current systems) by other countries. NTIA's Institute for Telecommunication Sciences (ITS) is also commencing extensive measurements of experimental BPL systems. The measurements are designed to define the local ambient noise environment and reveal the most important BPL radiated emission characteristics for use in NTIA's modeling and analysis efforts. Based on the results of this effort, NTIA will recommend radiated emission limits and other operational restrictions for BPL systems that are necessary to preclude unacceptable interference to federal government systems.[69]

It would appear that the NTIA does share the view expressed by many BPL proponents in this proceeding that the existing Part 15 limits adequately protect authorized spectrum users from harmful interference[70].

I would ask the Commission to consider why it should be necessary for NTIA's Spectrum Engineering and Analysis Division to perform modeling and analyses and NTIA's Institute for Telecommunication Sciences to make measurements that the Commission's Office of Engineering and Technology should have completed with respect to non-federal spectrum users prior to the opening of the present Inquiry.

TECHNICAL ISSUES

I note a number of comments in this docket filed by equipment manufacturers and electrical utilities. Most grossly understate the interference potential of BPL and dismiss the need for the Commission to consider any changes to the standards and operating requirements in Part 15 to minimize the likelihood of harmful interference to authorized users of the spectrum. Certain of these comments reflect little or no understanding or appreciation for the engineering and physics of their own technology. Amongst the most egregious comments are:

"Point-Source"

In its comments Current Technologies writes:

> *(a) POINT-SOURCE EMISSIONS*. Some parties to this proceeding assume the entire length of a BPL-equipped power line emits radio-frequency noise, and hence evoke the frightening image of a miles-long transmitting antenna. That is simply wrong. BPL emissions come almost entirely from a short segment of line immediately adjacent to

[69] *Ibid*.

[70] Comments of Amperion Corporation at p. 6; Comments of HomePlug Powerline Alliance at p. 6; Comments of United Power Line Council at p. 10.

> where the BPL device is attached. From a few meters away, the signal closely resembles that from a point source. [71]

One is left speechless by the sheer audacity. The proposition that the electric and magnetic fields due to signals of decametric wavelength on a conductor 100's of meters in length (not miles-long) originate "within a few meters" of the exciting source is so physically absurd and ludicrous that one is tempted to wonder if it is intentionally deceptive. At best, this appears to be a woefully inept attempt to apply the results of the infinitesimal radiator approximation to an entirely inappropriate situation.

For an electrically long wire, it is not until one is a several hundred meters to a few *kilometers* away (not a few meters) that the fields begin to closely resemble those from a point source, *i.e.* the far field. Despite Current Technologies' willingness to publicly challenge the Commission's understanding[72] of the problem, an understanding shared by the National Academy of Sciences[73], there is no controversy here. The theory underlying radio frequency radiation from wires, both long and infinitesimal, is well established[74,75]. Moreover, several participants to this proceeding have supplied as part of their comments the results from fully credible numerical models describing the radiative behavior of power lines that should lay to rest the preposterous claims made by Current Technologies.

A *conducted* transmission medium

In its comments Current Technologies writes:

> BPL uses the wires only as a *conducted* transmission medium, and has no more inherent propensity for causing interference than does any other unintentional digital emitter. [76]

Any other "digital device" that is also an unintentional radiator is restricted in the level of conducted signal it may inject into the power lines. BPL is able to function precisely because BPL is *exempted* from the conducted limits that apply to all other digital devices under the rules governing carrier current systems operated as unintentional radiators. There would be significantly less concern in regards to BPL's radiated emissions if BPL had to conform to the same *conducted* limits as "any other" digital device.

BPL's *special* propensity for causing interference is the result of BPL being a carrier current device, which can inject a conducted signal into the power line 40 dB[77] greater than other

[71] Comments of Current Technologies, LLC at p. 14.

[72] *Ibid*. footnote 23 at p. 14.

[73] Comments of the National Academy of Sciences at p. 4.

[74] C.H. Walter, *Traveling Wave Antennas*, New York: McGraw-Hill, 1965.

[75] R.W.P. King, *Theory of Linear Antennas*, Cambridge: Harvard University Press, 1956.

[76] Comments of Current Technologies, LLC at p. 14.

[77] The average PSD of the signal conducted on the power line is –60 dBm/Hz to –55 dBm/Hz for BPL; see comments of Ambient Corporation at pp.5 & 11. See also Appendix A. In contrast, the average PSD for a signal conducted onto the mains at the Class B limit would be □ -101 dBm/Hz over the frequency range of 1.705 MHz to 5 MHz and □ -96 dBm/Hz from 5 MHz to 30 MHz. The PSDs corresponding to Class B limits were computed for the nominal 50ohm impedance presented by the LISN used for compliance measurements.

unintentional radiators are permitted. The excess of BPL's conducted signal over the Class B limits is, not coincidentally, comparable to the factor by which BPL radiated emissions will typically exceed the local ambient noise level[78]. The conducted limits specified in Section 15.107[79] protect authorized spectrum users; the radiated emission limits specified in Section 15.209[80] result in widespread harmful interference.

Where participants to this proceeding have provided insight into their methods of coupling BPL signals to the power lines, both differential and common mode injection are used[81]. Where common mode injection is employed, more signal is lost due to radiation than arrives at the destination by conduction. It is fair to say that, under those circumstances, BPL uses the wires *very poorly* as a conducted transmission medium.

"Aggregation"

In its comments Current Technologies writes:

> An Access BPL system has one medium-voltage device at each transformer, but only one of those on a BPL distribution leg -- typically many blocks long -- can transmit at a time. Low-voltage devices, including user modems, may be closer together, but the HomePlug standard allows only one such device served by a given transformer to transmit at a time. The total emissions from all the houses served by one transformer add up to only one modem. And when the signals from devices at one transformer reach the next transformer, they are too attenuated to add significantly. There is no harmful aggregation.[25]
>
> [25] To evaluate aggregation, we compare the aggregated signal at a victim receiver from several emitters some distance away to the signal from a single emitter nearby. Suppose a BPL-equipped transformer is located on a pole 9 meters above the receiver. We compare its interference potential to that from 10 other BPL-equipped transformers, each 100 meters away. The total signal at the receiver *from all 10 distant BPL devices combined* is only 8% of the signal from the device overhead. Thus, only the nearest device produces significant signal at the receiver. There is no relevant aggregation.[82]

The attempt by Current Technologies at a quantitative example in the footnote is a variant of what is well know, at least among physicists, as Olber's Paradox[83]. Except in this case, Current Technologies has, by an arbitrary choice, created a strawman that leads to a totally misleading conclusion.

If BPL legs are uniformly distributed as one would expect, then within an area 100 times greater, as encompassed by a circle of 10 times larger radius, there should not arbitrarily be just 10

[78] Comments of ARRL, The National Association for Amateur Radio, Exhibit C, "*Calculated Levels from Broadband Over Power Line Systems and their Impact on Amateur Radio Communications Circuits.*"

[79] See 47 C.F.R. § 15.107(a).

[80] See 47 C.F.R. § 15.209(a).

[81] Comments of Amperion, Inc. at p. 5; Comments of Ambient Corporation at p. 5; Comments of Main.net Communications Ltd. at p. 5.

[82] Comments of Current Technologies, LLC at pp. 14-15.

[83] Often stated as: "Why is the night sky dark?" E. R. Harrison, *Darkness at Night — A Riddle of the Universe*, Cambridge: Harvard University Press, 1987.

additional BPL legs but rather *100* more legs. In this case, their contribution is not 8% but 81%. Rather than not adding significantly, the "aggregation" of signals from a uniform distribution of distant legs produces a signal level that is *comparable* to the nearest sources.

Taken to its logical extreme, as popularized by Olber in the 19th century, application of the inverse-square law[84] to a uniform distribution of point sources leads one to the conclusion that a large, perhaps infinitely large, signal should be present. The paradox is resolved in the case at hand because the Earth's curvature, local topography and other propagation factors result in signals strength falling off with distance more rapidly than an inverse square law predicts[85].

Carrier current systems have up until now been relatively rare and therefore isolated systems. The cumulative effect of radiated emissions from systems more distant than the nearest neighbor was not a consideration in formulating the present Part 15 rules. BPL represents something fundamentally different; as individual Commissioners have stated, BPL is envisioned to become ubiquitous. If this is the Commission's expectation, then cumulative effects *must* be considered when deciding how to protect authorized spectrum users.

"Bandwidth"

In its comments Current Technologies writes:

> *(c) MINIMAL EFFECT OF WIDE BANDWIDTH*. Some parties claim that BPL devices are more interfering than other unintentional emitters, such as computers or appliances, because they emit over a wide bandwidth. But emissions outside a victim receiver's passband have no significant effect on interference to that receiver. For example, a two-way radio with a 12.5 kHz receiver bandwidth is not affected by an interference source at frequencies outside that bandwidth. The overall bandwidth of a BPL system has no bearing on its propensity to interfere with any given receiver. In principle, perhaps, the higher bandwidth might be said to impact more receivers from a given BPL system. But it does not happen that way. Because BPL emissions are local to a point source and do not aggregate, even a wide bandwidth has little effect on a system's potential for interference to the overall population of receivers.[86]

Wideband signals from BPL devices are intrinsically no more or no less interfering than other wideband emissions having the same signal level. Other unintentional radiators such as computers, which might emit broadband noise, must comply with limits on their *conducted* emissions, limits from which carrier current systems are exempted.

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[84] It is fascinating to note that Current Technologies repeatedly tells us in its Comments that power lines do not act as antennas and do not *radiate*. Yet, the example they present is implicitly based on the use of the inverse square appropriate to the free space propagation of radiative fields.

[85] In reality BPL devices and their attached power lines antennas neither are point sources nor are uniformly distributed. Additional simulations with more accurate models are necessary to provide a more definitive answer to the question of significant aggregation versus no aggregation.

[86] Comments of Current Technologies, LLC at pp. 15-16.

The original, unattributed claim remains valid; carrier current systems such as BPL are *more* interfering than other unintentional radiators. Not because BPL devices emit over a wide bandwidth, that is merely Current Technologies' strawman. Rather BPL is more interfering because Access BPL devices inject signals at significantly greater power levels into significantly better antennas than do other unintentional radiators such as computers.

Its wide transmitted bandwidth does have an *enormous* effect on an Access BPL system's potential for causing interference to a population of frequency agile receivers. A highly successful mitigation strategy for a spectrum user is avoidance. When a Part 15 device happens to be using a single frequency or channel, a spectrum user (whose license grant permits) can choose to avoid the occupied frequency and use an alternate frequency or channel. When a Part 15 device occupies *all* available frequencies with a wideband signal, an authorized spectrum user's options for seeking refuge elsewhere are eliminated and the interfering signal cannot be avoided.

Conducted Limits

In its comments Current Technologies writes:

> Conducted emissions should not be regulated at all, outside the AM broadcast band, because they have no direct bearing on interference[26]. Even an implementation that results in high conducted emissions should be unobjectionable so long as the radiated emissions stay within limits.
>
> [26] Notice at para. 20. Today most plug-in receivers use switching power supplies and filters at the AC input that eliminate any realistic concerns about interference from conducted emissions introduced by way of the power cord.[87]

Clearly, the specification of conducted limits for digital devices not only serves to protect against the ingress of signals that reach an inadequately filtered power supply via conduction over the power line. Rather, conducted limits also provide one means of controlling the level of signal radiated by the mains that would propagate to the *antenna* of a receiver. The Commission summarized the intent of the Part 15 rules in the *NOI*:

> The Part 15 rules limit the amount of conducted RF energy that may be injected into a building's wiring by an RF device that receives power from the commercial power source…. This conducted energy can cause harmful interference to radio communications *via two possible paths*. First, the RF energy may be carried through the electrical wiring to other devices also connected to the electrical wiring. Second, at frequencies below 30 MHz, where wavelengths exceed 10 meters, long stretches of electrical wiring can act as an antenna, permitting the RF energy to be radiated over the airwaves. Due to the low propagation loss at these frequencies, such radiated energy can cause interference to other services at considerable distances.[88]

At present, *no* radiated limits exist for unintentional radiators below 30 MHz, except for the special case of carrier current devices. Control of radiated emission from unintentional radiators

[87] Comments of Current Technologies, LLC at p. 16.

[88] *NOI* at ¶ 5, emphasis added.

that are not carrier current systems is solely via the limits placed on the conducted signal. And these conducted limits have functioned moderately well in limiting instances of harmful interference. Section 15.107[89] conducted limits serve to protect authorized spectrum users; Section 15.109[90] radiated emission limits result in widespread harmful interference.

The radiated limits that *do* apply to carrier current devices are the radiated emission limits that are also the appropriate limits for an *intentional* radiator. It is difficult to see how the same limits would be appropriate for both intentional and unintentional radiators. The limits either are set too high for unintentional radiators resulting in unnecessary harmful interference or are overly restrictive for intentional radiators.

To summarize more than 4,000 comments and replies made in this proceeding by spectrum users: the radiated limits that apply to carrier current systems are *highly* objectionable to authorized spectrum users. These limits result in high levels of a continuously present wideband signal that makes a mockery out the concept of *sharing* spectrum.

Part 15

In its comments Current Technologies writes:

> … there is no basis for setting their limits below Class B, *which any receiver should be expected to tolerate.* [91]

This is a total misreading of the Part 15 rules, or perhaps an optimistically self-serving interpretation. The radiated and conducted emission limits specified in Part 15 obviously do *not* in any way define an operating environment that "any receiver `should be expected to tolerate`." The Class B limits readily result in harmful interference under the most general of circumstances, such as the presence of an authorized spectrum user's receiver. Authorized spectrum users are not required to *tolerate* harmful interference from an unlicensed Part 15 device whether the device in question happens to be operating at the Class B limits or substantially below those limits.

On the contrary, emission limits exist in part to assure a reasonable expectation of operability for the purchaser of an unlicensed Part 15 device. Even so, Part 15 compliance does not guarantee the owner of an unlicensed device absolute certainty that the device may be operated under all circumstances. The Part 15 limits attempt to minimize the possibility of harmful interference to authorized radio communications services. The intent is both to protect authorized services *and* to reduce the likelihood that the owner of a Part 15 device encounters the disappointing situation in which operation of an unlicensed device must be suspended because the device causes harmful interference. Setting emission limits too high is a disservice to the consumer, who expects compliance to mean that a device being marketed may also be operated should it be purchased.

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[89] See 47 C.F.R. § 15.107(a).

[90] See 47 C.F.R. § 15.109(e).

[91] Comments of Current Technologies, LLC at p. 17, emphasis added.

In its comments the American Public Power Association writes:

> Further, to the extent that interference is demonstrated, there should be an attempt to accommodate BPL, even if it means that existing communications providers may have to share or transfer bandwidth.[92]

The arrangement for "sharing bandwidth" between authorized radio communications services and unlicensed Part 15 devices such as BPL is clearly delineated in Section 15.5[93].

The ability to further "accommodate" BPL operation within Part 15 is limited. The Communications Act of 1934 as amended, requires individual licenses for use or operation of apparatus such as BPL when the device causes interference to radio signals or communications[94]. There are no exemptions from this licensing requirement[95].

Any further "sharing" more favorable to BPL or the "transfer" of bandwidth as APPA suggests could only be accomplished outside of the Part 15 rules. It might require the Commission licensing BPL devices and allocating substantial portions of the spectrum between 1.705 MHz and 80 MHz to BPL operation on at least a co-primary basis.

The APPA's suggestion to accommodate BPL, or rather accommodate the harmful interference resulting from BPL operation, fails to utilize the unique characteristics of the HF spectrum to provide unassisted long distance communications. Giving preference to unintentional BPL leakage over authorized services within the frequency range of 1.705 MHz and 30 MHz is clearly not the "highest and best use" for this portion of the radio spectrum.

In addition to being extremely poor spectrum management, what the APPA has suggested is highly non-competitive. BPL's competitors for bridging the last-mile, DSL and cable perhaps foremost amongst them but also free-space optical (laser), optical fiber, satellite, MMDS, LMDS, unlicensed wireless, 3G wireless mobile, *etc*., each relies upon the use of Part 15 compliant devices. These competitors seem to have encountered no fundamental difficulty in conforming to the non-interference basis of Part 15. We do not see BPL's competitors clamoring for the Commission to exempt *them* from compliance with Section 15.5. What APPA suggests is clearly not a technologically neutral change, benefiting as it does a single technology amongst many, a technology that is already notably late in coming to the table.

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[92] Reply Comments of the American Public Power Association at ¶ 6.

[93] See 47 C.F.R. 15.5.

[94] 47 U.S.C. § 301 states in part: "No person shall use or operate any apparatus for the transmission of energy… by radio… within any State... when interference is caused by such use or operation… with the transmission or reception of… communications, or signals from and/or to places beyond the borders of said State… except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act."

[95] 47 U.S.C. § 302(a) authorizes the Commission's regulation of devices *capable* of causing harmful interference and grants sufficiently broad authority for the Commission to promulgate rules that allow for unlicensed operation of radio frequency devices. The Commission authorizes exactly such unlicensed operation under Part 15 of its rules.

However, when interference *occurs* as a result of the unlicensed operation of such a device, the individual licensing provisions of 47 U.S.C. § 301 apply and the otherwise duly authorized operation of an unlicensed device that is causing interference must cease.

PowerWAN comments:

> As the bands from 2-50 MHz are used more by digital technologies such as BPL, better utilization of these important frequencies will result.[96]

BPL does not *utilize* the bands from 2-50 MHz. BPL is a wireline system that is intended to operate by conduction. BPL has no spectrum allocation; BPL is not even an unlicensed, intentional radiator. BPL is an incidental radiator that *pollutes* the radio spectrum from 2-50 MHz.

"Mitigation"

In its comments Electric Broadband writes:

> … third parties must be held responsible for taking steps to mitigate their vulnerability to interference.[97]

There is a new mantra making the rounds that holds interference should be considered a product of receivers; receivers that are too dumb, too sensitive or too cheap to reject unwanted signals. In the case of BPL, this is nothing more than blaming the victim. Interference that result from BPL operations being a result of the receiver is a bit like saying that air pollution is a result of the public's desire to breath clean air.

The view that inadequate receivers are a contributor to interference might have some validity for receivers having insufficient selectivity, poor adjacent channel rejection or limited dynamic range and suffer out-of-band or off-channel interference as a result. This is not the case for the typical HF communications receiver that already functions in a hostile mixed-signal environment. Moreover, out-of-band or off-channel interference are not at the core of the concerns over BPL. Rather, the real concern with BPL lays with its propensity for causing co-channel interference.

The suggestion that receivers must bear the burden of dealing with in-band BPL emissions is disingenuous. We must remember that BPL emissions are nothing more than the unintentional leakage from what is supposed to a wireline system, not a wireless system. Supposed to be a wireline system, as are its competitors: cable and DSL, if good engineering practices and not minimum cost were the driving requirement behind BPL.

Electric Broadband's comments on mitigation become very relevant when considering the EMC and strong-signal immunity of BPL equipment. To first order, Access BPL equipment will be as likely to find itself in the near field of a transmitter operating in the amateur service as a receiver employed in the amateur service is likely to suffer from BPL interference. As a Part 15 device, Access BPL equipment will receive *no protection* from interference caused by authorized spectrum users. EMC is a case where the entire burden of mitigation rightfully falls upon the "receiver," *i.e.* the BPL device.

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[96] Comments of PowerWAN, Inc. at p. 4.

[97] Comments of Electric Broadband at p. 6.

I join with the ARRL in expressing my concern over the strong-signal immunity of BPL or the lack thereof[98]. While the Part 15 rules are clear, the social engineering is not. Consumers purchasing services that depend upon operation of unlicensed Part 15 equipment are unlikely to understand who is at fault when the services for which they have contracted cannot be provided.

Consumer dissatisfaction with poor performance is an important element of how a market makes its decisions; and the marketplace can be expected to reward proper EMC decisions. Amateur radio operators, who are disinterested third parties to the market's ultimate decision, simply desire not to be cast in the role of scapegoats for the bad engineering and bad business decisions of those whom the market repudiates.

Class A vs. Class B

In its comments Current Technologies writes:

> Because Access BPL devices are either mounted high on a pole or enclosed within a metal curb-side housing, they should be permitted at least Class A emissions in both commercial and residential areas.[27]
>
> [27] Class A emissions high on a pole, 9 meters above a victim receiver, are lower than Class B at 3 meters (within 1 dB). *Compare* 47 C.F.R. Secs. 15.109(a) and (b) (distance conversions pursuant to 47 C.F.R. Sec. 15.31(f)(1)).[99]

The choice is not between an interfering device nearby versus one further away; the choice is between having more or less *unintended* and potentially interfering emissions from a device placed at a fixed distance. From 30 MHz to 88 MHz, Class B radiated emissions are 9.5 dB *lower* than Class A radiated emissions, when both are measured at the same distance. From 88 MHz to 216 MHz, Class B radiated emissions are 10.5 dB lower, 10.0 dB lower from 216 MHz to 960 MHz and finally above 960 MHz, Class B radiated emissions are 14.9 dB lower than Class A radiated emissions at the same distance.

In practice the difference made by 10 dB less signal is significant in protecting against co-channel interference from radiated emissions arriving via the antenna. Which makes the choice for a radiator, unintentional though it may be, that is "mounted high on a pole" in a residential area quite clear - Class B.

In its comments Electric Broadband writes:

> The term "residential environment" refers to the *inside of a dwelling*.[100]

While Southern writes:

> Overhead lines, by their very nature, are usually located at least ten meters away from homes and apartment buildings. Moreover, the buildings themselves would provide shielding to consumer devices that might be susceptible to interference.[101]

[98] Comments of ARRL, The National Association for Amateur Radio at ¶¶ 22-23.

[99] Comments of Current Technologies, LLC at p. 17.

[100] Comments of Electric Broadband at p. 8, emphasis added.

Suggesting that both Electric Broadband and Southern believe the Commission did not intend to protect receivers employing antennas mounted on roofs, chimneys, decks, patios, *etc.* on the *exteriors* of residential dwellings when it defined Class B.

The residential environment does not begin and end at a dwelling's walls. The Commission fully understands the necessity of external antennas in residential environments, having going so far as to preempt not just state and local governmental authority but private contracts as well in adopting the Over-The-Air Reception Devices (OTARDs) rule[102] regarding the placement of outside antennas.

Having helped to open the door to competition amongst the broadcast, cable and wireless cable industries by facilitating the installation of external antennas on residential dwellings, the Commission would logically also seek to protect these same OTARDs from interference caused by the radiated emissions of commercially owned equipment that will be located " high on a pole" and operated in the midst of residential areas.

500 µV/m at 300 meters!

Satius in its comments proposes a field strength limit for Access BPL of 500 µV/m at a distance of 300 m over the frequency range 1.705 MHz to 54 MHz[103]. A change to 500 µV/m at 300 m represents an increase of 44.4 dB over the present radiated field strength limits at frequencies below 30 MHz, and 54.0 dB above 30 MHz. Hardly what a neutral observer would classify as a "minimal change" as Satius contends. Rather this proposal is clearly a prescription for utter chaos.

PowerWAN suggests a more "modest" proposal to relax the limit on radiated emissions to a field strength of 100 µV/m at a distance of 30 m over the frequency range 1.705 MHz to 50 MHz[104].

Numerous comments filed in this proceeding have already noted the inevitability that widespread harmful interference will ensue following large-scale deployment of Access BPL using equipment that is compliant with the present Part 15 limits. Higher compliance limits only exacerbates the severity and rate occurrence of harmful interference.

Not only are the changes Satius and PowerWAN propose needlessly disruptive to authorized spectrum users, a relaxation of the radiated emission limits is ultimately counter-productive for the rapid development of this industry. The likely consequence of increasing the radiated field strength limits as suggested will be to have Access BPL rollouts stopped in their tracks even more rapidly by the plethora of legitimate complaints of harmful interference from authorized spectrum users.

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101 Comments of Southern LINC, Southern Telecom, Inc. and Southern Company Services, Inc. at p. 21.

102 See 47 C.F.R. § 1.4000

103 Comments of Satius, Inc. at p. 5.

104 Comments of PowerWAN Inc. at p. 3.

Relaxing the compliance limits for radiated emissions only makes the manufacturer's task of producing compliant equipment easier. For Access BPL, operators relaxed or flexible radiated emissions limits improve neither predictability nor stability. On the contrary, higher radiated emission limits only increases uncertainty, lowering an operator's confidence that a capital investment in building up infrastructure based upon Part 15 devices will not be money wasted.

Potential operators of BPL equipment must always keep one thing in mind:

> … limits specified in this Part will not prevent harmful interference *under all circumstances*[105].

Whenever a consumer, in this instance a utility or other BPL operator, acquires a Part 15 unlicensed device, the buyer assumes the risk that their latest acquisition, even though its has been verified to comply with radiated emission limits, may not be kept in service because harmful interference results from the operation of that fully compliant device. Overly permissive limits only make the risk of non-serviceability greater.

MEASUREMENT PROCEDURES

In its comments Electric Broadband admonishes:

> … the Commission should avoid exaggerating the difficulty of testing BPL systems under Part 15.[106]

Physics dictates that testing an Access BPL system for *compliance* with Part 15 limits cannot be an entirely trivial undertaking. In marked contrast to the typical Part 15 device, it is not valid to treat Access BPL equipment connected to overhead power lines as though it was an infinitesimal radiator. Testing of a carrier current system such as Access BPL will, as a matter of practicality, require measurements be taken within the reactive near field of the "equipment" under test.

Carrier Current Systems Are *Different*

The typical Part 15 unintentional radiator such as a computer, video game, *etc.* is physically "compact." Such devices satisfy the condition, $D < \lambda/50$ where D is the largest physical dimension of the "radiator," for using the infinitesimal dipole approximation[107] and the near field surrounding these radiators is "small"[108]: $r < \lambda/2\pi$.

An Access BPL system connected to an expanse of overhead electrical wires is *demonstrably* different: an Access BPL system may not be treated as an infinitesimal radiator.

One of the many ways in which BPL equipment differs from the typical Part 15 unintentional radiator is that the power line is an integral part of the equipment under test. Addition of these

[105] See 47 U.S.C. § 15.15(c), emphasis added.

[106] Comments of Electric Broadband at p. *i*.

[107] J. D. Kraus, *Antennas*, New York McGraw Hill, 1988.

[108] R. F. Harrington, *Time-Harmonic Electromagnetic Fields*. New York: McGraw-Hill, 1961.

wires as part of the unintentional radiator being tested for compliance violates the D < □/50 condition for use of the r < □/2□ criterion as the size of the reactive near field. For a physically large "antenna" the size of the reactive near field region is given by $r \le 0.62 \cdot \sqrt{\frac{D^3}{\lambda}}$; where, in the case of an Access BPL system, D is the length of the overhead wires[109].

The length of the overhead wires results in the reactive near-field region of any system incorporating the power lines being *enormous*. This is shown in the Table 1 below[110]. Measurements of an Access BPL system at the compliance distance of 30 m (or the even closer distances allowed by Section 15.35(f)(2)) are obviously going to be made from *deep* within the reactive near field.

Frequency (MHz)	**Infinitesimal Radiator** (D < □/50)	**Electrically Long Radiator** (D > □)		
	Reactive Near-Field r < □/2□	**Reactive Near-Field** $r \le 0.62 \cdot \sqrt{\frac{D^3}{\lambda}}$		
		D = 200 m	D = 400 m	D = 800 m
1.8	26.5 m	136 m	384 m	1087 m
3.5	13.6 m	189 m	535 m	1516 m
7.0	6.8 m	268 m	758 m	2144 m
10.1	4.7 m	322 m	910 m	2575 m
14.0	3.4 m	379 m	1072 m	3032 m
18.1	2.6 m	431 m	1219 m	3447 m
21.0	2.3 m	464 m	1313 m	3713 m
24.9	1.9 m	505 m	1429 m	4043 m
28.0	1.7 m	536 m	1516 m	4287 m
50.0	1.0 m	716 m	2026 m	5729 m

Table 1 – Size of Reactive Near Field Region
Infinitesimal versus Electrically Long Radiators

Measurements within the Reactive Near Field Region

In its comments Ameren Energy Communications suggests:

> First, measurements should be done at distances avoiding the reactive near field region around the line… Therefore, any procedures that will require close distance measurements are likely to be time consuming and unreliable.[111]

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[109] C.A. Balanis, *Antenna Theory — Analysis and Design*. New York: John Wiley & Sons, 1997.

[110] Line lengths of 400 m (1/4 mi) and 800 m (1/2 mi) are suggested by the Comments of Ambient Corporation:

[111] Comments of Ampere Energy Communications, Inc at pp. 15-16, emphasis added.

The NTIA has written:

> We also have concerns regarding compliance measurement techniques for BPL systems and the characterization of emissions from a BPL system for use in compatibility studies.[112]

The Part 15 rules are at present somewhat equivocal about the taking measurements in the reactive near field region:

> At frequencies below 30 MHz… an attempt should be made to *avoid making measurements in the near field…* [113]

But elsewhere:

> When measurement distances of 30 meters or less are specified in the regulations, the Commission will test the equipment at the distance specified *unless measurement at that distance results in measurements being performed in the near field*.[114]

As part of its Inquiry, the Commission should review the advisability of allowing field strength measurements to be made in the reactive near field region. I suggest the Commission consider requiring procedures for compliance testing employed by manufacturer's and independent testing laboratories be consistent with the Commission's own practices in regards to the near field as described in Section 15.31(f)(4)[115].

Unfounded Extrapolations

I concur with the comments of the ARRL raising concern over the significant systematic inaccuracy in extrapolating field strength measurements taken in the reactive near field of a *non*-infinitesimal radiator.[116]

An extrapolation of 40 dB per decade for measurements at frequencies below 30 MHz as currently permitted by Section 15.31(f)(2)[117] has an underlying physical basis under certain, very specific conditions. A factor of 40 dB per decade can be physically justified when it is applied to ***H***-field measurements taken within the reactive near field region of a radiator that is small enough to be treated as an infinitesimal radiator (*D* < □/50)[118].

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[112] Letter of July 1, 2003 from Fredrick R. Wentland, Associate Administrator, NTIA Office of Spectrum Management.

[113] 47 C.F.R. § 15.31(f)(3), emphasis added.

[114] 47 C.F.R. § 15.31(f)(4), emphasis added.

[115] 47 C.F.R. § 15.31(f)(4)

[116] Comments of ARRL, The National Association for Amateur Radio at ¶ 19.

[117] 47 C.F.R. § 15.31(f)(2)

[118] In the *far field,* a factor of 40 dB per decade is also physically justified for line-of-sight propagation when both source and receiver are located at very low heights above a reflective ground plane.

For an infinitesimal electric (Hertzian) dipole, $H \propto 1/r^2$ in the reactive near field[119]. The variation in H rather than E is in keeping with the Commission's long-standing practice of using loop antennas for "low frequency" (below 30 MHz) field strength measurements[120]; a small loop antenna being sensitive only to $\boldsymbol{H}$ and not to $\boldsymbol{E}$.

Specification of any single power law (a fixed number of dB per decade) to describe the variations of field strength within the reactive near field of a *non*-infinitesimal radiator is completely arbitrary and unsupported by any physics.

Although it may be appropriate for an infinitesimal radiator, scaling field strength by 40 dB per decade cannot be physically justified for the fields surrounding a *non*-infinitesimal radiator. Numerical experiments[121] clearly demonstrate just how inaccurate and misleading an extrapolation of 40 dB per decade is when applied to the fields surrounding typical overhead power lines.

The objective of compliance testing is not to just get *an* answer or even to get a *repeatable* answer. The objective must be to get an *accurate* answer, one that is `reasonably` free of systematic error, in order to provide confidence that compliance with specified limits has been demonstrated.

Comments in this proceeding have, in general, indicated broad support from industry for radiated emissions testing as the more *accurate* method for demonstrating compliance[122]. The NTIA comments:

> These procedures must correctly determine compliance without undermining the protective effects of the limits.[123]

Or, as Electric Broadband noted in its Comments:

> Test procedures are intended to be reasonably predictive of real world results…[124]

Ameren Energy Communications specifically calls attention to extrapolation factors:

> Second, extrapolation factors are necessary when the measurement distances required by standards cannot be practically achieved. The extrapolation factors used currently are

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[119] If the radiator were an infinitesimal *magnetic* dipole (a current loop) rather than an electric dipole then $H \propto 1/r^3$ in the reactive near field region. The factor of 40 dB per decade thus represents the more conservative of these two alternatives. See C.A. Balanis, *Antenna Theory — Analysis and Design*. New York: John Wiley & Sons, 1997.

[120] In the *Second Report and Order and Memorandum Opinion and Order* in Docket ET 01-278 (FCC 03-149), the Commission recently made changes to 47 C.F.R. § 15.31(a) to bring the rules into accord with the Commission's practice in this regard.

[121] See Appendix A.

[122] Comments of UPLC at p. 13; Comments of Amperion Inc. at p. 7; Comments of Main.net Communications Ltd. at p. 8; Comments of Current Technologies, Inc. at p. 16; Comments of Southern LINC, Southern Telecom, Inc. and Southern Company Services, Inc. at p. 23; Comments of PowerWAN, Inc. at p. 4; Comments of Ameren Energy Communications, Inc. at pp. 13-14; Comments of HomePlug Powerline Alliance at pp. 7-9;

[123] Comments of the National Telecommunications and Information Administration.

[124] Comments of Electric Broadband at p.11, emphasis added.

> based on the assumption of a point source. Given that the power lines do not act as point sources, *different factors must be applied*.[125]

I suggest the Commission, in the interest of accuracy, consider as part of this proceeding whether use of an arbitrary 40 dB per decade extrapolation factor in an un-physical situation (the reactive near field) should remain a part of permissible testing procedures when the application of that factor in the reactive near field is demonstrably inaccurate and results in an erroneous determination of compliance.

In its comments Southern writes:

> Southern also recommends that emissions testing of Access BPL be based on average peak measurements, not quasi-peak measurements. The quasi-peak measuring method was developed in the 1930s to measure interference to broadcast radio reception. Accordingly, although quasi-peak measuring has evolved over the years, it is not clear whether it is the best method for analyzing the interference potential of something as advanced as Access BPL. Southern believes that the Commission should closely investigate this issue and give strong consideration to allowing testing of Access BPL to based on average peak measurements.[126]

It is impossible to determine whether Southern's *non sequitur* of "average peak" measurements was recommending the measurement of average power or measurement of peak power. It does not matter, neither would be desirable.

The signal of an Access BPL system that employs orthogonal frequency division multiplexing (OFDM)[127] is "noise-like." An OFDM signal has an approximately flat, featureless power spectral density; in the time domain the amplitude distribution of an OFDM signal approximates Gaussian random noise with a high (~ 12 dB) peak to average power ratio.

A Gaussian amplitude distribution is a valid description of ODFM provided a large number of "sub-carriers" are simultaneously present. When limited to the bandwidth of a quasi-peak detector, or an HF communications system, the amplitude distribution of an OFDM signal becomes decidedly *non*-Gaussian.

A basic OFDM signal is composed of multiple subcarriers each on-off keyed by a nominally rectangular waveform. When passed through a narrow filter and viewed in the time domain this signal becomes a sequence of impulses, each impulse coincident with the on-off or off-on transition of a subcarrier *i.e.* key clicks.

Because of the high peak to average power ratios, quasi-peak remains the preferable method for testing "something as advanced as Access BPL," a signal that appears to a victim receiver as impulsive noise.

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[125] Comments of Ameren Energy Communications, Inc. at p. 16, emphasis added.

[126] Comments of Southern LINC, Southern Telecom, Inc. and Southern Company Services, Inc. at pp. 22-23.

[127] Comments of Ambient, Inc at p. 5; Comments of Amperion at p. 4; Comments Current Technologies, LLC at p. 5, footnote 3; Comments of HomePlug Powerline Alliance at p. 3; Comments of Main.net Communications Ltd. at p. 4.

With the modern modeling tools now at our disposal it is a straightforward exercise to simulate the effects of interference by BPL signals on the signals and demodulation schemes employed in HF communications systems. I concur with Southern that a review by the Office of Engineering and Technology of both the appropriate signal statistic (peak, quasi-peak, average or other) and the corresponding field strength limits would be fully appropriate as a part of this inquiry.

INTERNATIONAL CONSIDERATIONS

The radio spectrum is a unique national resource; moreover, the radio spectrum is also an *international* resource. The United States has clearly defined treaty obligations that constrain how it may permit the radio spectrum to be used. As a result, the Commission must consider the cross-border impacts of widespread BPL operations in this proceeding.

The frequency range below 30 MHz has extremely favorable propagation conditions that enable long-range communications. This part of the radio spectrum needs special protection. This fact has long been recognized in the Radio Regulations:

> Member states recognize that among frequencies which have long-distance propagation characteristics, those in the bands between 5 MHz and 30 MHz are particularly useful for long-distance communications; they agree to make every possible effort to reserve these bands for such communications . . .[128]

The disruption of authorized radio communications services operating at HF in favor of a telecommunications network intended for short-ranges communications (BPL is, we are told, a "last-mile" solution) would be contrary to the spirit of the radio regulations. Moreover, that would not be the "highest and best use" for this unique portion of the radio spectrum. While the Commission has authority to displace allocated services within the United States, it may not allow systems to operate that result in interference to radio communications services of other nations.

The cumulative effects of multiple BPL systems coupled with long distance skywave propagation via the ionosphere requires the Commission to assess the impact of widespread BPL operations on spectrum users across the border in Canada and Mexico, to ships on the high seas and to aircraft in international airspace.

The aforementioned CEPT/ECC report includes a study[129] of the cumulative effects of BPL emission that concludes:

> Whether cumulative interference is a significant issue is essentially determined by the *EIRP density* of the potentially interfering systems, together with the area within which they are deployed and its location with respect to the receiver.[130]

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[128] ITU Radio Regulations Article S4.11

[129] J.H. Stott, *Cumulative Effects of Distributed Interferes*, BBC R&D White Paper, WHP 004, August 2001. <http://www.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP004.pdf>

[130] *Cumulative Effect of Broadband PLT below 30 MHz*, CEPT/ECC Report 24, *op. cit.* 2003. Annex 7 at p. 56.

CEPT/ECC found that the cumulative effect of BPL systems to distant receivers varied from no interference to certain interference depending on the choice of parameters such as the radiated emission limits and the "ubiquity" of BPL systems. The Office of Engineering and Technology must therefore evaluate the interference potential to radio communications services of other nations using parameters that the Commission considers representative for BPL.

In addition, the Radio Regulations state:

> Administrations shall take *all practicable and necessary steps* to ensure that the operation of electrical apparatus or installations of any kind, including power and telecommunication distribution networks, but excluding equipment used for industrial, scientific and medical applications, *does not cause harmful interference to a radiocommunication service* and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations.[131]

The Commission is obliged to protect the reception of signals from foreign stations operating in the broadcast service from harmful interference from the power lines, when the international broadcaster's target audience includes the United States. I concur with the National Association of Shortwave Broadcasters:

> Since the clear intention of the international Radio Regulations is to avoid harmful interference, the U.S. has a responsibility to limit, or remove, any source of interference with such reception. The concern of NASB is that BPL, in fact, introduces such harmful interference.[132]

MARKET FORCES

The Commission takes an enlightened regulatory approach with respect to emerging technologies of "let the marketplace decide." If the Commission wishes the market to reach an unbiased decision, then the Commission must ensure that the market is able to fairly evaluate the technical and operational decisions made by equipment manufacturers and service providers.

As most college freshmen learn in Econ 101, not all markets work perfectly and there is an extensive theory of "market failure." One such "failure" that can arise from unrestricted use of property is a "spillover," in which one property owner's use creates costs to others. Radio interference is the spillover that is the entire rationale for government involvement in the management of the spectrum. It is the interference spillover that requires limitations on any market regime.

I concur with The HomePlug Powerline Alliance's view of the critical role the Commission must play in any successful market-based solution:

> In today's Part 15 regulations the Commission provides an incentive for responsible manufacturers to avoid interference to licensed services. Part 15.5 clearly states that

[131] ITU Radio Regulations Article S15.12, emphasis added.

[132] Comments of the National Association of Shortwave Broadcasters at p. 2.

> unintentional emitters such as carrier current systems must operate in a non-interference mode, and that upon Commission notification of resulting interference all operation must cease until the interference has been corrected. *This provides a powerful incentive for responsible manufacturers to avoid potential interference and thereby avoid the substantial cost and damage to business reputation of correcting an interfering system.* [133]

Only when the consumer must pay the full cost of each competing technology is the market's decision fair and unbiased. Allowing costs to be shifted onto third parties by failing to promptly take the actions described in Section 15.5(c)[134] when authorized spectrum users suffer harmful interference is exactly the sort of regulatory lapse that unfairly distorts and disrupts the efficient operation of the marketplace.

The unpredictability and customer dissatisfaction associated with interruptions in service and the additional costs and delays of mitigating interference in the operational phase rather than the design phase are important factors the market should be allowed to evaluate in deciding between competing technologies. The Commission must be prepared to couple its light regulatory hand with a firm fist of enforcement.

As the Commission's Spectrum Management Task Force has recommended:

> The Task Force believes that in order for the Commission to be able to meet the increasingly complex spectrum management demands being presented by the enormous growth in spectrum use, the Commission must devote sufficient resources to monitoring spectrum use and *enforcing the spectrum management rules*...[135]

For the present, the Commission need not be overly concerned with the verification and marketing of Access BPL equipment under the exiting Part 15 Rules. Those utilities and other broadband providers who might consider purchasing Access BPL equipment must realistically evaluate the likelihood they will be able to operate that equipment. The potential buyer must consider the equipment's demonstrated interference potential, the now heightened awareness of spectrum users as a result of this proceeding and the pendency of the NTIA's recommendations. Given the regulatory uncertainties the guiding principle for the near term would best be *caveat emptor.*

The Commission should clarify that there is one, fundamental regulatory certainty for equipment manufactures, utilities, BPL operators *and* spectrum users: harmful interference is unacceptable and shall not be tolerated.

From their comments in this proceeding, the nascent BPL industry has indicated that it is comfortable with the risk that their operations could cause harmful interference leading to

[133] Comments of HomePlug Powerline Alliance at pp. 6-7.

[134] See 47 C.F.R. § 15.5(c).

[135] Report of Spectrum Management Task Force, Docket 02-135

enforcement action and disruption of their business plans. The Commission should therefore consider allowing the market place to settle the outstanding technical issues and permit BPL development and operations to proceed under a minimum of regulation, the single *proviso*:

> Operation… is subject to the conditions that no harmful interference is caused.[136]

In conjunction with that minimal regulation, the Commission must also give the Enforcement Bureau and Office of Engineering and Technology a mandate to vigorously pursue enforcement of this lone operational rule as well as provide the Enforcement Bureau and Office of Engineering and Technology with sufficient resources to carry out that mandate. Such a policy would be in keeping with the Commission's strategic plan for the years 2003-2008 that includes an objective under the strategic goal for spectrum to "vigorously protect against harmful interference..." [137]

Respectively submitted,

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August 20, 2003

[136] 47 C.F.R. § 15.5(b)

[137] Federal Communications Commission Strategic Plan FY 2003 – FY 2008.

Appendix A

Near Field Behavior

To illustrate the behavior of ***E*** and ***H*** fields in the reactive near field of a physically large radiator such as an overhead power line, I provide the results from a numerical model for an overhead power line[138].

Model 1 Assumptions:

- Pair of #8 copper conductors
- Separation 1.5m (5 ft)
- Length 400m (1/4 mi)
- Height 9 m (30 ft) above ground
- Perfectly balanced with respect to ground
- "Average" ground parameters: conductivity □ = 0.01 S m^{-1}; relative dielectric constant □$_r$ = 13
- BPL signal applied differentially
- Terminated in load of 920 ohms

This is a very "conservative" model, representing the configuration least likely to radiate. Conversely, this set of assumptions represents the configuration that is most difficult to establish and maintain in the real world.

Solution of the boundary value problem employed the method of moments[139] as implemented in the Numerical Electromagnetics Code[140] (NEC-2). While numerical modeling is inherently highly accurate, an individual model represents both a simplification and an idealization, omitting many imperfections that will be present in a real system.

Results

In keeping with the Commission's standing practice of using a small loop antenna for "low frequency" (below 30 MHz) field strength measurements[141], only the ***H***-field is shown. Converting the compliance limit of 30 µV/m at 30 m for 1.705 MHz to 30 MHz as specified in Section 15.209 using the free-space impedance of 377 ohms yields an ***H***-field strength limit of 79.6 nA/m at 30m. Applying a 40 db per decade extrapolation factor gives an extrapolated "compliance" limit for *H* of 7.96 µA/m at 3 m.

Figure 1(a) shows the ***H***-field strength for the power line Model 1 described above at a frequency of 7 MHz. The amplitude of the exciting signal has been adjusted so the maximum field strength at a horizontal distance of 3 m satisfies the *extrapolated* compliance limit of 7.96 µA/m.

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[138] See G. Bingerman, "Transmission lines as antennas," *RF Design*, January 2001, pp. 74-82.

[139] R.F. Harrington, *Field Computations via Moment Methods*, New York: Macmillan, 1968.

[140] G.J. Burke & A.G. Poggio, *Numerical Electromagnetic Code (NEC) — Method of Moments*, UCID-18834, Lawrence Livermore National Laboratory, 1981.

[141] In the *Second Report and Order and Memorandum Opinion and Order* in Docket ET 01-278 (FCC 03-149), the Commission recently made changes to 47 C.F.R. § 15.31(a) to bring the rules into accord with the Commission's practice in this regard.

Shown in Figure 1(b) is the field strength at a horizontal distance of 30 m for the same model as Figure 1(a). The maximum field strength at a horizontal distance of 30 m is 632 nA/m, well in excess of the compliance value of 79.6 nA/m. The maximum field strength occurs at a vertical height of 39 m above ground level, a location not likely to be sampled in compliance testing. The maximum field strength at 30 m is only 22.0 dB less than the maximum field strength at 3 m, *not* 40 dB less.

Similarly, Figure 2(a) and Figure 2(b) show the *H* field strength at a frequency of 14 MHz. It was necessary to reduce the exciting signal by 1.9 dB from its level at 7 MHz in order to maintain "compliance" of the field strength at 3 m. The decrease in maximum field strength from 3 m to 30 m of 16.2 dB is again significantly less than the nominal 40 dB.

Finally, Figure 3(a) and Figure 3(b) show the *H* field strength at a frequency of 28 MHz. In this case, it was necessary to reduce the exciting signal by 12.2 dB from its level at 7 MHz in order to maintain "compliance" of the field strength at 3m. The decrease in maximum field strength from 3 m to 30 m of 16.6 dB is again significantly less than the nominal 40 dB.

This model is a simplification and an idealization. As an example, the impedance of the model power line is nearly constant with frequency at 920 ohms. The total loss is very low; almost all of the source power reaches the load. At 7 MHz the loss is 2.2 dB per km (0.07 dB per 100 feet) with less than 1% of the input power being lost to radiation. These are obviously unrealistically optimistic results. The loss is comparable to optical fiber at visible wavelengths. If overhead power lines actually performed as a transmission line for RF signals as well as this idealized model predicts then power line telecommunications would have been a reality long ago.

Even for this idealized model, which is highly sympathetic to BPL, the maximum conducted average PSD allowed for compliance with the radiated emission limits of Section 15.209 (field strength measured at the compliance distance of 30 m with no extrapolation) is –67 dBm/Hz[142]. This is 10 dB *less* power than what the reports from BPL fields trials indicate is being used[143].

In this proceeding, we have read of the large losses and wild impedance fluctuations with which BPL must contend. This is because a real power line is not perfectly balanced, is not driven differentially, is not terminated in a matched load, has impedance discontinuities along its length and standing waves are present. All factors that contribute to a real power line radiating significantly more radiation than this conservative model predicts. These factors lead to consideration of a second model.

Model 2 Assumptions:

- Pair of #8 copper conductor ("hot" & neutral)
- Length 400m (1/4 mi)
- Height 9 m (30 ft) above ground
- BPL signal applied as a "dipole" to the "hot" conductor at its mid-point
- Neutral "grounded" at four locations

[142] Assumes a quasi-peak to average power ratio of 10 dB.

[143] Comments of Ambient Corporation at pp.5 & 11

- "Average" ground parameters: conductivity σ = 0.01 S m^{-1}; relative dielectric constant ε_r = 13
- Line terminated at both ends in a load of 600 ohms placed between "hot" and neutral

This model represents a singe-ended (or common mode) configuration that is more likely to radiate. Despite being more pessimistic than Model 1 this model is still a simplification and an idealization.

Figure 4(a) shows the ***H***-field strength for power line Model 2 at a frequency of 14 MHz. The amplitude of the exciting signal has been adjusted so the maximum field strength at a horizontal distance of 3 m satisfies the *extrapolated* compliance limit of 7.96 µA/m.

Shown in Figure 4(b) is the field strength at a horizontal distance of 30 m for the same model as Figure 4(a). The maximum field strength at a horizontal distance of 30 m is 3.44 µA/m, well in excess of the compliance value of 79.6 nA/m. The maximum field strength occurs at a vertical height of 30 m above ground level, a location that again not likely to be sampled in compliance testing. The maximum field strength at 30 m is only 7.3 dB less than the maximum field strength at 3 m, *not* 40 dB less.

Conclusions

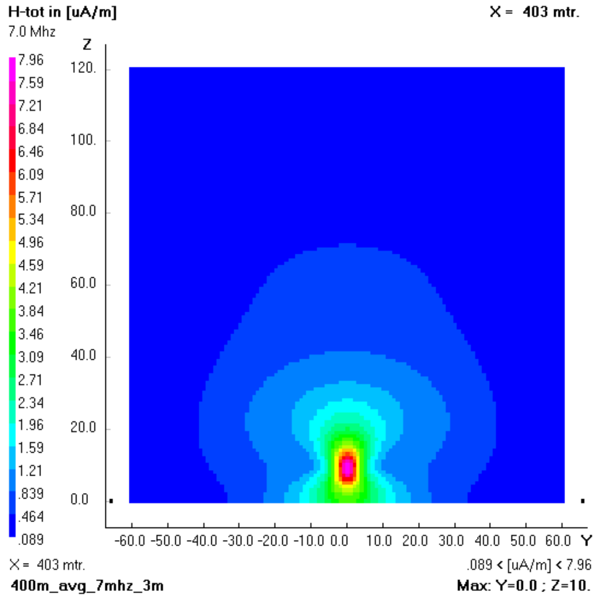
For both good radiators and poor radiators the decrease in maximum field strength from a horizontal distance of 3 m to a horizontal distance 30m is systematically far less than the 40 dB per decade allowed by Section 15.31[144] by quite significant amounts.

Within the reactive near field region of a electrically long radiator, the actual decrease in maximum field strength from a horizontal distance of 3 m to a horizontal distance 30m is likely to be less than the 20 dB per decade extrapolation for radiative fields in free-space ($H \propto 1/r$).

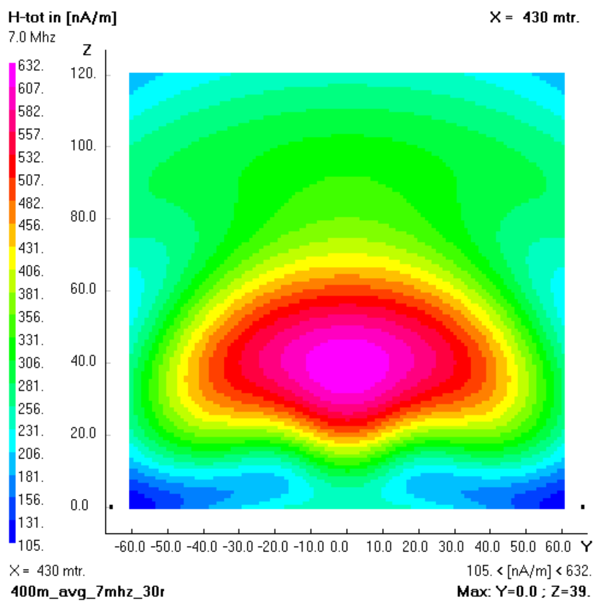
As the location of maximum field strength at a horizontal distance of 3 m is not coincident with the location of maximum field strength at a horizontal distance of 30 m and *vice versa*, an empirical extrapolation factor derived from measurements of two points will not be robust.

[144] See 47 C.F.R. § 15.31.

Figure 1. Field Strength in Near Field of Model 1 at a Frequency of 7 MHz.



(a) Total *H* field strength at a horizontal distance of 3 m from the terminated end of the line. Line runs from *X* = +0 m (source) to *X* = +400 m (termination). Input average[145] power spectral density is -49.3 dBm/Hz. Maximum field strength is 7.96 µA/m at a vertical height of 10 m.



(b) Total *H* field strength at a horizontal distance of 30 m from terminated end of the line. Peak field strength is 1.18 µA/m at a vertical height of 39 m. Maximum field stregth at a horizontal distance of 30 m is 22.0 dB less than peak field strength at a horizontal distance of 3 m .

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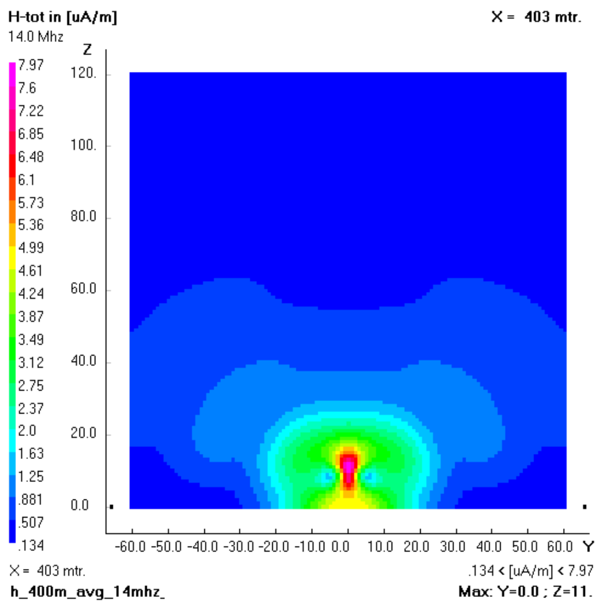
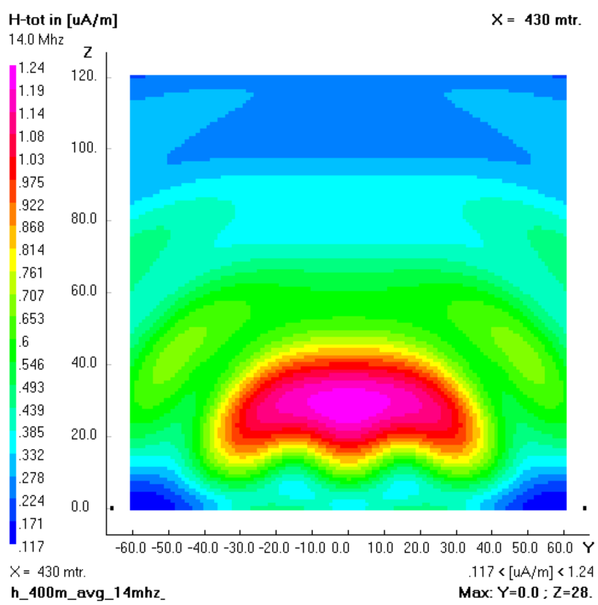
[145] Assumed quasi-peak to average power ratio of 10 dB.

Figure 2. Field Strength in Near Field of Model 1 at a Frequency of 14 MHz.

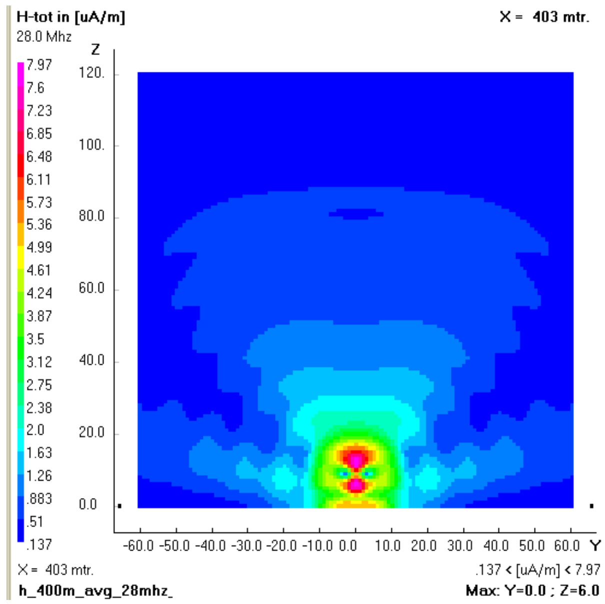


(a) Total *H* field strength at a horizontal distance of 3 m from the terminated end of the line. Line runs from *X* = +0 m (source) to *X* = +400 m (termination). Input average[145] power spectral density is –51.2 dBm/Hz. Maximum field strength is 7.97 µA/m at a vertical height of 11 m.

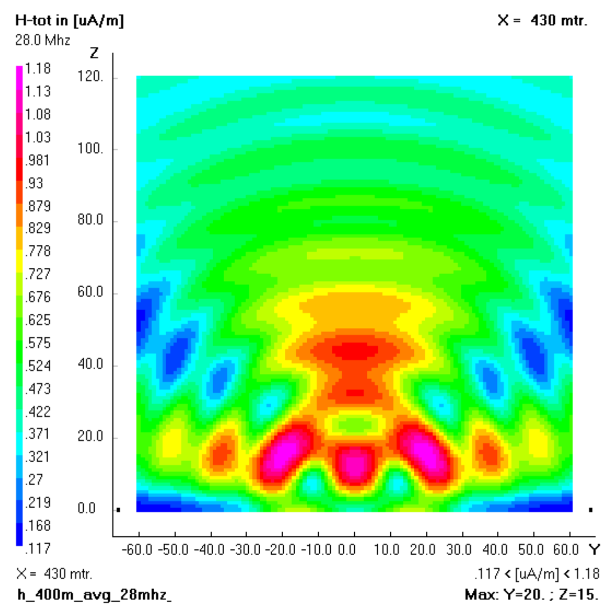


(b) Total *H* field strength at a horizontal distance of 30 m from terminated end of the line. Maximum field strength is 1.24 µA/m at a vertical height of 28 m. Peak field stregth at a horizontal distance of 30 m is 16.2dB below than maximum field strength at a horizontal distance of 3 m.

Figure 3. Field Strength in Near Field of Model 1 at a Frequency of 28 MHz.

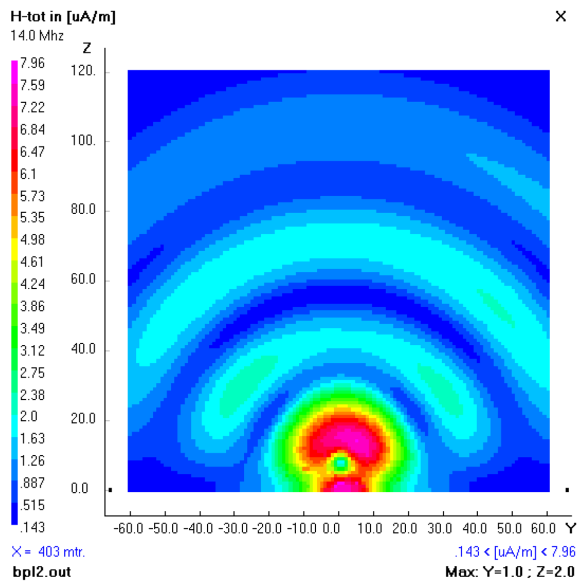


(a) Total *H* field at a horizontal distance of 3 m from the terminated end of the line. Line runs from *X* = +0 m (source) to X = +400 m (termination). Input average[145] power spectral density is –61.5 dBm/Hz. Maximum field strength is 7.97 µA/m at a vertical height of 15 m.

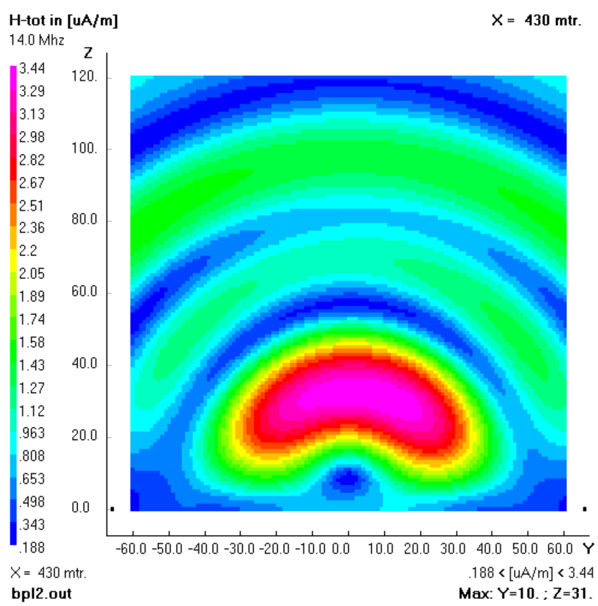


(b) Total *H* field at a horizontal distance of 30 m from terminated end of the line. Maximum field strength is 1.18 µA/m at a vertical height of 15 m. Maximum field strength at a horizontal distance of 30 m is 16.6 dB less than peak field strength at a horizontal distance of 3 m .

Figure 4. Field Strength in Near Field of Model 2 at a Frequency of 14 MHz.



(a) Total *H* field strength at a horizontal distance of 3 m from the terminated end of the line. Line runs from *X* = +0 m (source) to *X* = +400 m (termination). Input average[145] power spectral density is -58.0 dBm/Hz. Maximum field strength is 7.96 µA/m at a vertical height of 2 m.



(b) Total *H* field strength at a horizontal distance of 30 m from terminated end of the line. Maximum field strength is 3.44 µA/m at a vertical height of 31 m. Peak field stregth at a horizontal distance of 30 m is only 7.3 dB below than maximum field strength at a horizontal distance of 3 m.