In the Matter of ET Docket No. 03-104) 7 July 2003
Inquiry Regarding Carrier Current Systems)
Including Broadband over Power Line Systems)

Comments of Cortland E. Richmond (Jr.) KA5S

Introduction:

These comments are submitted on the Notice of Inquiry (NOI) in ET Docket No. 03-104. They are based on 20 years experience in Electromagnetic Compatibility engineering, 21 years working with military communications systems, and 45 years in Amateur Radio.

The NOI solicits technical information to ensure that Broadband over Power Line (BPL), will harmonize with existing services, and asks what changes would be necessary to Part 15 to make it possible to deploy BPL. This writer will show that BPL – if widely deployed - cannot coexist with existing service, and that nothing less than the repeal of prohibition of harmful interference would suffice to permit its deployment.

Responses (follow initial "R") to Inquiry questions (noted by initial "I)

I What spectrum and bandwidth would Access BPL use? The Commissions has granted experimental licenses to evaluate Access BPL equipment operating from 1.7 to 80 MHz. Would Access BPL devices operate in other portions of the spectrum and at what bandwidth?

R Frequencies used would have to be those which power lines propagate with sufficiently low losses as to allow service over economically deployable ranges. Generally, because the power distribution network is neither characterized nor controlled for RF frequencies, the HF spectrum is less suitable for this use than LF or even VLF frequencies.

I Is the spectrum used by Access BPL shared with In-house BPL? Are there any frequency sharing issues to be considered, i.e., should we designate spectrum for Access BPL and In-House BPL? Is spectrum sharing between Access BPL and In-House BPL feasible?

R Some means must be employed to separate In-House and Access BPL. While frequency division has traditionally been the method used, code, time and position multiplexing might allow use of the same frequency ranges for both types of BPL. However, coherent systems run the risk of enhancing radiation of signal current.

I "A number of high-speed In-House BPL devices have reached the market within the last few months, operating under our existing Part 15 rules for carrier current systems. "

R Existing Part 15 rules for carrier current systems do not protect radio spectrum users. Signals from a Part 15 compliant carrier current modem, for example, have been documented as causing harmful interference hundreds, if not thousands of meters from the installation. This writer has noted reception of a single such device at up to 8 km distance, and this, to an inefficient, loaded antenna mounted on an automobile. Under the circumstances, it is unreasonable to expect that Part 15 will offer sufficient protection to spectrum users from a deployed BPL technology.

I What data transmission speeds can Access BPL systems achieve? What speeds can be typically sustained under normal user environment conditions? What speeds are envisioned with deployed access shared among several users? Are the speeds symmetric in both the transmit and receive directions?

R Data speeds will be limited by
1. Spectrum usage constraints
2. The need to aggregate data
3. Modulation techniques and
4. Ambient noise and interference.

The experience of ADSl suggests that noise on power lines will be a limiting factor over economically achievable ranges. Certainly the presence of wideband and impulse noise on power lines will adversely affect speed possible.

It is unlikely that symmetrical speeds will be achieved. Customer Provided Equipment (CPE) such as BPL modems or computer cards, will necessarily be limited in the power it can produce, and this will lower achievable data rates from the user to the service provider. Again the experience of ADSL is replicated here.

It is reasonable to think that an Access provider with perhaps fifty households served from its local multiplexer/demultiplexer point will be unable to provide much more than a MBPS service to each household, and that in practical terms speed must fall considerably below this for a fully committed system.

I What are the modulation techniques? What techniques are used for ensuring the security of data? What schemes are used for contention resolution between Access and various In-House BPL devices, if more than one device needs to take control of the electric wire at the same time to communicate?

R Modulation techniques are legion. Which ones may be used depend entirely on service providers, Commission regulation, and the economics of manufacture, deployment and use. It is to be noted that Discrete Multi-Tone is currently used for ADSL, where Carrierless-Amplitude-Phase (CAP) modulation was used for the earlier ADSL services. This may be due to an increased sensitivity of wide-band techniques such as CAP to impulse noise, compared to modified narrow band techniques such as DMT. There are important implications for BPL in the experience of ADSL, which operates on rather more quiet conductors than power lines.

Security of data will, however, depend entirely on adequately secure encryption. The is no way to keep BPL physically secure on

existing power distribution systems, for its emitted fields are in essence uncontrolled. There are two needs:
1. Locally encrypted, user data protection and
2. Bulk encryption for access provider data signals.

It may be important to remember that encryption is separately regulated and that, for one reason or another, strong encryption may be compromised by those regulations.

Contention between Access and In-House devices is best mediated between devices. Experience with packet data systems suggests that where few devices share a resource, such as would the case at a subscriber's residence, collision detection could be adequate to the purpose. However, a more disciplined method might be needed at the Access provider's aggregation point.

I Would Access products work with In-House BPL products and services, without the need for additional equipment, such as converters and adaptors?

R It is unlikely that Access and In-house BPL products will communicate directly with each others networks. In-House systems will be designed for low-power, short-range, single or few user modes, and will almost certainly be incapable of directly ranging distant Access servers. Even if physically possible, the sharing of intellectual property necessary could make current software management problems look simple.

In addition, the need to mediate contention between hundreds or even thousands of users at a central Access server adds markedly to the problems of maintaining data transmission between users and service providers.

I What is the status of development and anticipated timeline for market deployment of Access BPL equipment?

R As the NOI states, systems are now in limited field trials domestically. However, trials elsewhere suggest that BPL suffers from problems considered intractable by those who have attempted to deploy it.

I Access BPL systems use high-pass filter circuits to bypass the transformer and its inherent low-bandwidth characteristics. What is the effect of these high-pass filters with respect to high-frequency signals used inside the house, e.g., from In-House BPL equipment or other in-premises technologies, that may rely on the low-voltage transformer as a natural barrier to avoid causing interference at higher frequencies?

R Filters which allow signals ingress also allow them egress. Presently local – and often intolerable – problems due to security lighting, RF-light bulbs, triac dimmers, high-current pulse power devices such as microwave ovens and Part 15 devices such as ITE cannot help but be aggravated by improved coupling to the more efficiently radiating conductors of the MV and HV power distribution system. It is not be unreasonable to predict that

Part 15 conducted emission requirements would have to be made more stringent if BPL systems are deployed.

I For Access BPL systems, several methods of RF signal injection onto the medium voltage lines can be envisioned:
An RF voltage could be applied between a power line and ground;
An RF voltage could be applied differentially between two phases of a power line; or
A single power line wire could be driven as if it were a dipole antenna—e.g., by inductively coupling RF energy to it.

R None of these provide a reasonable control over emissions, and none of them provide a predictable attenuation between injection point and destination. Applying RF between ground and a power line converts what is purported to be a carrier current system into a broadcast one. Applying it between two phases of a power line is only numerically an improvement, as the fields for long, wide-spaced parallel wires are not an unimportant source of radiated signal. The Commission already issues standards for “leaky” feedline security systems, and the aerial power lines are much more apt to radiate than systems the Commission already regulates. It is also worth while to note that traveling wave antennas based on the leaky feed line method are widely used because they DO radiate well.

I Other approaches may also be possible. What methods are being considered for signal injection onto the medium voltage lines? What are the implications on radiated emissions of various methods for injecting signals onto the medium voltage lines (e.g., differences in directional characteristics and magnitudes of the emitted fields)?

R There may indeed be differences in the directional patterns of emitted RF. However, electrical service providers who at present cannot (or will not) prevent harmful interference probably will also not control the directional characteristics of emitted RF BPL deliberately places on those conductors. Certainly, a higher degree of regulatory oversight will be necessary – if BPL is deployed – to ensure that service providers do control it.

An impact so far not mentioned is that of ingress to the efficient antennas for by HV and MV lines. Transmitting users of the radio spectrum will almost without doubt find it necessary to increase power to penetrate emissions from BPL, and current projections of immunity to nearby transmission should include allowances for this fact.

I Is there a need to define frequency bands that must be avoided in order to protect the licensed users on the same frequencies as those used by Access BPL systems? Are there mitigation techniques Access BPL systems can use to avoid possible interference with licensed users of the spectrum, such as mobile users or public safety and law enforcement users who may be traveling directly beneath the medium voltage lines?

R Individual services may be protected by exclusion in bands they are allotted. However, this approach suffers from an irremediable deficiency; it assumes that no new services will be developed, and no spectrum allocations will be changed. By sheer weight of investment, it makes it unlikely that the radio spectrum in the ranges it uses will be allotted, changed or protected.

I Since Access BPL equipment is installed on medium voltage lines that supply electricity to a residential neighborhood, should this equipment be treated as operating in a residential (Class B) or commercial (Class A) environment?1

R Experience with telecommunications equipment and ADSL suggests that Class B protection is more appropriate than Class A. Even if a class A device itself does not cause harmful interference, fields radiated by power lines would exceed those developed by any BPL device in isolation.

I How does the close proximity of Access BPL equipment to cable television and telecommunications equipment from third party service providers co-located on the same utility pole affect the operation of these services? On the other hand, what is the effect of this close proximity to Access BPL operations?

R One could reasonably expect rectification effects. Experience with telecomm equipment located near broadcast stations suggests that telecomm immunity requirements currently in use (see Telcordia GR-1089) may be insufficient to deal with the distributed coupling from parallel power lines. Telephone subscribers are not unresponsive to noise on the line, and dealing with this coupling will probably involve substantial expense to telephone service providers affected.

I High-speed In-House BPL systems are being deployed in residences with a telecommunications access connection from a DSL or cable modem service. What mitigation techniques are used by In-House BPL systems to avoid possible interference from DSL or cable modem within the same spectrum? On the other hand, what is the effect of DSL or cable modem on In-House BPL operations?

R Assuming that the relatively short-range In-House systems use a spread spectrum technique similarly to CAP, there may be minimal interaction between them and DSL or cable-modem operation. Additionally, cable-modem systems enjoy, by virtue of coaxial cable distribution, and so long as the integrity of that plant is maintained, a much reduced radiated coupling to and from other devices. However, there is at present no requirement for immunity of consumer devices to RF on the power line.

Additional note on the above sentence: Some consumer devices use RF in the spectrum discussed by the NOI internally. Video Tape players are perhaps the most prominent of these; they are extremely sensitive to RF in the HF spectrum. Who will be liable for problems caused by deliberately placing that RF on power lines?

I Are there test results from field trials of Access BPL that may assist in the analysis of harmful interference? Inasmuch as In-House BPL equipment is already on the market, are there any reports that may assist in the further analysis of harmful interference?

R Reports from deployment in Germany already suggest that initial predictions of no harmful interference were overly (and perhaps willfully) optimistic. It is noteworthy that residences using power line signal distribution are noticeable from a mobile station for some distance, and inescapable that a receiving installation located in a nearby residence would not be less affected.

I Are the existing Part 15 rules for low speed carrier current systems adequate to protect authorized users of the spectrum who may be affected by the new high speed BPL technology? What changes to these rules, if any, are necessary to protect authorized radio services?
How should the Part 15 rules be tailored both to ensure protection against harmful interference to radio services and to avoid adversely impacting the development and deployment of this nascent technology?

R The existing Part 15 rules, as demonstrated by the "Cable TV Modem" problem of a few years ago, are already inadequate; only the paucity of carrier current systems has rendered this lack tolerable.

To protect authorized radio services, it will be necessary for Part 15 Rules be "tailored" by making the limits for for unintentional and incidental radiators more stringent. It bears repeating that only wide-spread deployment of such radiators makes this necessary. This is similar to the 1980 proceeding on computers; as long as few sources were present, problems could be dealt with singly, but widespread use made regulation necessary.

At this time, it is probably impossible to avoid adversely impacting the proposed technology; it is a technology presently incompatible with over-the air use of radio frequencies. The admission by its proponents that authorized users are to be protected by restriction on frequencies used is sufficient evidence of this.

I Given their different operating environment, is it necessary to tailor the rules to differentiate equipment used specifically in Access BPL and In-House BPL applications, or should one set of general limits be applied to both? What should such limits be and what is the technical basis for them?

R Given the ubiquitous nature of the transmission means, it is probably unnecessary (and insufficient) to differentiate between Access and In-House applications. In most cases, the conductors concerned are long enough in terms of the wavelengths used, that size is less an issue than location. In-House systems would be either collocated or near the victim receiving installation, and Access systems would be higher-powered, wider spectrum-occupancy, with more efficient radiators making up for their greater distance.

Part 15 Class B radiated limits are (and always have been) insufficient to protect narrowband radio users. This is based on experience with interference to such users in the spectrum above 30 MHz. A limit adequate to prevent harmful interference to a television broadcast receiver with a desired signal of some 500 or 1000 microvolts is far from protecting a receiver whose input is often less than one microvolt, as is the case for low-power HF users, or even in the tens of microvolts, as with short wave broadcast listeners. Bearing in mind also the longer wavelengths involved, interference levels to a resonant antenna may be expected to be higher than at VHF.

Consequently, this writer believes the level given at 15.209 for 1.7 - 30 MHz, presently 30 microvolts per meter measured at 30 meters, would - if authorized users are to be protected - be usefully changed to 10 microvolts per meter measured at 10 meters. The lower level specified would be more realistically conform to signals being protected, while the closer distance would more realistically accommodate the location and nature of BPL radiating conductors.

I Would higher emissions for In-House systems result in any interference effects in other houses or apartments sharing the same local low voltage distribution by the RF signal being distributed on the low voltage side of the transformer? What limits should be specified, given the above considerations?

R Yes, setting higher limits for In-House systems would predictably result in higher interference levels for houses or apartments sharing the same local LV distribution. 15.107(c) does not in this situation prevent ingress to a dwelling of interference over which the occupant has no control. At a minimum, it appears that the levels of 15.107(a) should be applied. However, the Class B limits of 15.107(a) inexplicably increase at 5 MHz, which increase fails to take into account the greater efficiency of power wiring as a radiator with increasing frequency. Given that the primary coupler for BPL to radio receivers should be radiation from conductors, it would seem appropriate to decrease, rather than increase, allowable current above 5 MHz.

I Should the Part 15 rules specify both radiated emission limits and conducted emission limits for BPL systems, or would one type of limits be sufficient to control interference from both low speed and high speed BPL? Since all carrier current systems inject RF signals into the power line for communication purposes, would conducted emission limits be more appropriate to protect authorized radio services?

R The Part 15 Rules should continue to specify both conducted and radiated limits; some devices will be susceptible to conducted emissions (e.g.: video tape players, hi-fi audio equipment, telephone equipment) and others, mainly radio receiving installations, to radiated emissions.

I ... We seek comment on measurement methods for all types of carrier current systems, including new high-speed Access and In-House BPL devices. Because existing carrier current systems use the power line wiring inside a building to transfer information and data, the radiated emissions from RF energy conducted onto the power lines tend to vary from location to location, based on the installation’s AC wiring and the loading placed on that wiring. In effect, since the installation’s wiring functions as an antenna, that wiring becomes part of the system to be evaluated. As such, measurements to demonstrate compliance with the rules are not normally made at a standard open area test site, because the measurement of each system is unique to its location.

R This writer agrees that for design purposes, it is impractical to simulate the varied wiring configurations to be found in the field. This is one of the deficiencies inherent in BPL; a vendor cannot know, and cannot control, the wiring over which its equipment will operate, and yet must be held liable to prevent ill effects of that operation.

The standard Open Air Test Site (OATS) is not large enough to contain a radiating structure equivalent to a dwelling,let alone a HV power distribution system. This being the case, one must either abandon radiated emission testing, or accept an alternative method. Since BPL has potential victims to both radiated and conducted emissions, it seems appropriate to that suggest the latter choice is the most suitable for testing it.

The writer notes the Commission's comment ” Rather than requiring compliance measurements for each individual carrier current system installation, we have allowed measurements of radiated emissions at three installations that the operator deems as representative of typical installations.”

Based on the experience of doing Part 15 tests for more tan a few firms, allowing an operator wide discretion to design a set-up “representative of typical installations” is inviting a test designed to pass.

Therefore, and considering the above factors, this writer recommends adapting a standard radiator, perhaps a loop of known dimensions and turns, whose characteristics are known, and can be modeled and predicted, to serve instead of representative installations. Such a radiator could well allow use of the 10 meter OATS.

I For carrier current systems operating below 30 MHz, the radiated limits specify measurement distances ranging from 30 to 300 meters.2 The radiated limits for unintentional radiators operating above 30 MHz specify a measurement distance of 10 meters for Class A devices and 3 meters for devices other than Class A. Since measurements at large distances are not always practical, the rules provide for measurements at distances other than those specified, with the use of extrapolation factors. The actual extrapolation factor can be determined empirically. Alternatively, an extrapolation factor of 40 dB per decade can be used for frequencies below 30 MHz and an extrapolation factor of 20 dB per decade can be used when testing frequencies at or above 30 MHz.3 For measurements below 30 MHz, a loop antenna is required to be used to measure the emissions from the device.

R Distances in between source and victim will very often be closer that 30 meters in residential environments. For this reason, this writer suggests the Commission adopt (as noted earlier) the use of 10 meters for acceptance testing.

(The Commission has for long used factors for converting H-field [loop] measurements to an E-field equivalent with which many in the EMC professions have taken issue. This becomes particularly cogent here, as the distances involved and frequencies used place victim devices both in the near field, near to far field transition, far field and – in many cases – in the guided surface wave of the interfering sources. The probability of harmful interference will vary not only as 20 dB/decade but also with impedance of the field at the victim location. A remedy for this is to allow the use of both loop and rod pr other E-field antennas
for testing, and allowing extrapolation and conversion factors to be guided by the measurement results. This may be addressed in the NOI, but goes beyond it.)

I ... Currently, there are no specific test methods in our rules for carrier current systems, rather, measurement procedures have been left to the discretion of the party performing the tests, and thus measurements can be subjective and inconsistent. Furthermore, Access BPL equipment presents unique measurement challenges because it is typically installed on utility poles and operated over medium voltage lines. We therefore request comment and input on the following questions:

I The writer addresses the questions individually below.

How should measurement procedures for testing new BPL systems, both Access and In-House, be developed in order to promote consistency with measurements of existing carrier current systems and repeatability of test results?

I How should the measurement procedures for testing existing low-speed carrier current systems be developed in order to avoid the burden of selecting representative installations and to promote consistency and repeatability of test results? Is it possible to develop a standardized measurement method for testing in a laboratory or at an open area test site using some characterized wiring assembly or artificial impedance network? If so, how?

R As noted, a standard structure, perhaps a loop, or a set of loops, could be used for this purpose.

I Conducted emissions testing is usually performed using a line impedance stabilization network (LISN), which is an artificial power line network that provides a specified load impedance in a given frequency range. This device is also used to isolate the equipment from the AC supply and to facilitate measurements. If conducted emission limits alone are sufficient to control harmful interference from BPL systems, how should the measurement procedure be specified?

R The writer has commented already that conducted emissions alone would be insufficient. However, many of the devices being protected respond to the peak levels of emissions, and provision should be made for this effect.

I How should the characteristics of a line impedance stabilization network be specified for testing both In-House and Access BPL systems?

R The existing LISN should suffice; carrier current systems generate adequate power to allow use of a compensating network without undesirably reducing measurement sensitivity.

I Existing literature is inconclusive on the degree of difference in radiated emissions from houses and buildings when In-House PLC signals are injected in common mode (phase/neutral to an RF ground) versus differential mode (phase to neutral). Is there data available that shows radiated emission levels from houses and other buildings, located in the United States, for both types of signal injection? Is the difference sufficiently large as to justify separate conducted limits for common mode and differential mode signals? Alternatively, should a LISN be defined to simultaneously measure the total effect of the common-mode and differential-mode contributions in proportion to their expected respective contributions to radiated emissions? What should be the characteristics of that LISN?

R The types of wiring used in the United States do not admit of a single answer to Commissions query. State and in many cases, cities and counties, have adopted the National Electrical Code for various years, but buildings are not otherwise standardized, and the wiring to be found in may vary widely. This writer has lived in a dwelling (still standing) built in 1836, whose wiring was installed in 1921.

However, it may be assumed that wires are not spaced more widely from each other than in such construction, and that in more modern dwellings, common-mode signals and conversion of differential mode signals will be the primary culprit in In-House system interference with perhaps some few dwellings exhibiting greater conversion and differential coupling.

Of greater concern to this writer is the situation in buildings whose power is supplied from more than one phase. Large buildings are often supplied in this manner. In these cases, it is possible to have returns via other means than the power wiring, and for this case, one must assume the differential power is available over the return conductor loop to radiate interference.

For this reason, the writer believes that differential to common mode conversion must be taken into account, but what that conversion should be, is open to modeling and measurements the writer has not seen.

I   How should (In-House/Access) BPL systems be tested for compliance, given that they use (the building's wiring/ overhead medium voltage lines) as an antenna? ... Is it possible to develop a standardized measurement method for testing (In-House/Access) BPL in a laboratory or at an open area test site using a specialized LISN or some characterized wiring.

R See previous responses about use of a standard structure or loop (s) on an OATS. The writer believes both In-House and Access BPL could be usefully evaluated in such a manner.

I ... As indicated, supra, the low speed systems have not been a source of harmful interference to radio communications.

R As previously noted, this has been due to the scarcity of low speed systems sharing spectrum with radio users. As carrier current systems in the HF range become more widely used, and with deployment – should it occur – of BPL, will come realization that they pose more of a problem than has been recognized in the past.

It is a common idea that what has not caused problems before cannot do so in the future. This is not, as loss of two space shuttles has shown, a satisfactory approach to engineering.

I Would the new high speed Access and In-House BPL equipment pose a higher risk of interference to licensed radio services than the traditional carrier current systems?

R Yes, by greater numbers and wider use of spectrum.

I Unlike In-House BPL equipment, which usually involves multiple units of a standard module working together,11 Access BPL may involve two or more different types of components to form the complete system (e.g., Access BPL medium voltage coupler, Access BPL adaptor module, etc.)12 What components of an Access BPL system should be subject to equipment authorization?

R This writer believes that each component equipment able to cause harmful interference or the malfunction of victim devices (absent regulation of victim susceptibility) must be looked at. Certainly anything which could increase interference, and over which the vendor has control, is subject to regulation. For example, imbalance of a transmission line pair will raise differential to common-mode conversion; coupling networks must for this reason be included in the EUT tested.

I Should the new Access and In-House BPL equipment be required to comply with either the Certification procedure or the Declaration of Conformity under our equipment authorization program, which warrants additional oversight, or should they be covered under our Verification procedure like the traditional carrier current systems?

R This writer believes that the potential for harmful interference is high enough that additional oversight is justified. Certification is probably justified, at least to begin with, and the DoC procedure might be appropriate later.

I Will the power line carrier systems currently deployed by the utility companies to control and monitor the electrical system be replaced in the future with the new high speed BPL equipment?

R Probably not. PLC is currently protected by a Commission unwilling to allow radio spectrum users in the same frequency range as PLC. The rationale for r protecting that spectrum does not and cannot exist with regard to already-existing radio spectrum users at HF.

I How would the utility companies deploy these new control systems and how would these new systems coexist with the older control systems?

R One could expect that as they use different spectrum, they could coexist easily.

I Are any changes needed in the regulations governing power line carrier systems? Should power line carrier systems using BPL technology be subject to the general requirements for Access BPL systems, since the same system may now be carrying broadband signals as well as monitoring and control signals? How could, or should, these functions be separated?

R The deference currently shown to PLC cannot be provided BPL users of any stripe; whoever uses BPL technology should be subject to the same constraints as any other user.

I What interference issues, if any, besides the issues raised under the general BPL interference section, supra, must be addressed with the deployment of high-speed power line carrier systems?

R The RF power deployed overall may be sufficient, especially in large systems using phase-coherent coding, to cause harmful interference across national borders. Arguably, a national authority licensing and permitting interference with marine, aviation and Amateur communications, and with short wave broadcast reception is a matter for international concern.

Respectfully submitted

Cortland E. Richmond (Jr.)
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