Before the
Federal Communications Commission
Washington, D.C. 20554

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

COMMENTS OF AMBIENT CORPORATION

Pursuant to Section 1.415 of the Federal Communications Commission ("FCC") Rules, Ambient Corporation ("Ambient") hereby submits its comments in response to the *Notice of Inquiry* in the above referenced proceeding.[1]

Ambient fully supports the goals the Commission seeks to achieve through this *NOI* regarding Broadband over Power Line ("BPL") systems. Rather than comment on a broad range of areas, Ambient's comments focus on those key policy and technical issues, where it believes its expertise will aid the Commission.

- BPL, even at this early stage, has shown it can provide broadband access at speeds comparable to DSL and cable.

  The Commission should support the earliest possible deployment of BPL technologies under current Part 15 requirements by providing assistance to companies developing BPL equipment during the pendency of these proceedings. Any lengthy delays in establishing workable procedures for confirming compliance with current Part 15 requirements could have severe adverse imp[act on the ability of BPL companies to fund their continuing development and deployment efforts.

- The Commission should also explore possible modifications to its existing Part 15 rules to foster deployment of advanced versions of BPL technologies in ways which will avoid harmful interference to licensed uses while providing BPL with conditions conducive to major exploitation of power lines for Broadband over Powerline.

I. INTRODUCTION

Ambient is the developer of proprietary technology to provide broadband Internet access for business and residential customers. The primary author of this response is the

[1] *Inquiry Regarding Carrier Current Systems, including Broadband over Power Line Systems*, Notice of Inquiry, *ET Docket No. 03-104* (April 28, 2003) (*"NOI"*).

inventor of a PLC Inductive Coupler for medium and low voltage access, and also a veteran amateur radio operator (details in Appendix A).

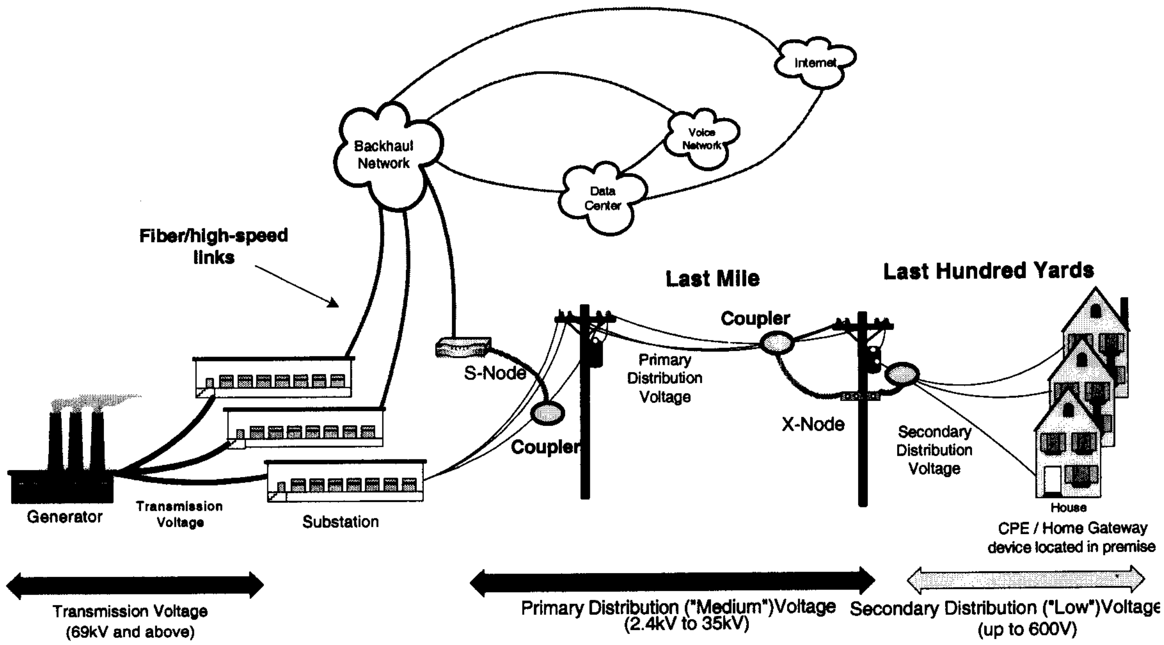
Ambient is developing this service using a carrier current system that uses conduction directly from connection to electric power lines. This technology is termed "Power Line Communications ("PLC") Network"[2] and uses Primary Distribution ("medium") voltage between 2.4kV and 35kV and Secondary ("low") voltage of up to 600V distribution lines to facilitate high-speed data communications.

Ambient's proposed PLC Network (see system architecture below) consists of modem-router boxes that are mounted on power utility poles and located at electric power substations, inductive couplers placed on medium voltage and low voltage distribution lines, set-top modem gate way boxes placed in customers' premises, and a backbone data feed connected through a router. It is a bi-directional full duplex network from the head-end side in which data arrive over the backbone feed. In the subsystem marked "S-node," the data packets are filtered by a router to pass only those packets meant for nodes on the network, modulated by a modem using spread spectrum technology onto a segment of the high frequency band, and then connected to a medium voltage distribution line using an inductive coupler.

At remote points on the network, a second coupler receives the signal off the power distribution grid and connects it to a modem-router box, marked "X-node." This box contains a modem card, which converts the signal back into a bit stream, onto a small router that passes those data packets meant for nodes serviced by that coupler. This data subset is then modulated by a second modem card into a high frequency signal. This signal is coupled onto the low voltage lines by means of an inductive coupler, travels along the low voltage drop into the customer premises, and is finally received by a CPE/Home Gateway, consisting of a modem inside a set-top box plugged into a electric wall outlet.

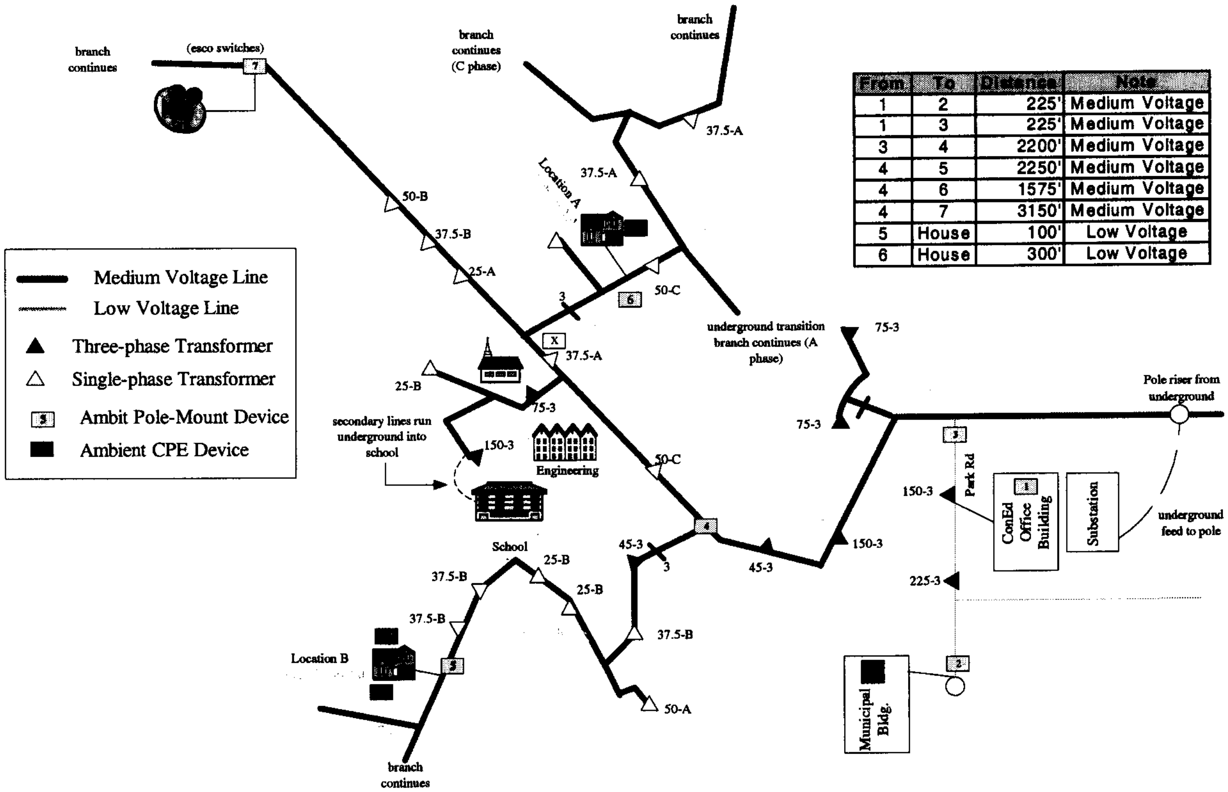
[2] Ambient refers to its system as a PLC system rather than BPL. See Ambient's comments regarding the definition of BPL, *infra* Section IV.a.

Figure 2: Ambient PLC System Architecture



Ambient has been operating a demonstration network under Special Temporary Authorization ("STA"), and has a pending application for an experimental license. The demonstration network has been in operation for nearly one year, providing service to the homes of two Consolidated Edison employees and to two officers at the nearby Police Department. EarthLink provides a high speed backbone data feed at the power substation feeding. The PLC system can provide data rates of over 3 Mbps to the power outlets of the homes being serviced, and data rates on the Medium Voltage ("MV") backbone of up to 16 Mbps. See graphic depiction below. Earthlink provides the backbone connection to the Internet at the substation headend via a T1 line.

Figure 1: Demonstration PLC Network



From	To	Distance	Note
1	2	225'	Medium Voltage
1	3	225'	Medium Voltage
3	4	2200'	Medium Voltage
4	5	2250'	Medium Voltage
4	6	1575'	Medium Voltage
4	7	3150'	Medium Voltage
5	House	100'	Low Voltage
6	House	300'	Low Voltage

II. SHORT AND LONG TERM COMPLIANCE OBJECTIVES FOR BPL

Ambient shares the Commission's "great interest and anticipation" of developments in the area of high-speed communication over power lines. We agree that the Commission should encourage present deployment of BPL technologies which comply with the Commission's current Part 15 rules. The Commission is also correct in its assessment that the introduction of new advanced high-speed BPL technologies warrants a systematic review of its Part 15 rules to consider proposed changes to facilitate development and deployment of BPL.

A. Short Term – Encourage BPL Deployment Under Existing Rules

To promote BPL in the time period before modified rules can be proposed and adopted, the Commission should encourage BPL (i) to continue experimentation and (ii) to deploy initial systems that comply with the current regulations in Part 15 governing carrier current systems (considering any request for limited waiver of particular requirements on a case-by-case basis). As part of this process, Ambient is encouraged by the continuing efforts of the FCC staff to provide guidance regarding test procedures for emissions testing.

B. Long Term – Maximizing BPL's Utility While Minimizing Risk of Interference to Licensed Services

Power lines are, by their nature, a noisy environment, and therefore there will be a direct correlation between data-rate over BPL and system power. The FCC should be cognizant that unless BPL can match or exceed speed achievable via cable and DSL, the basic objective of this NOI, and an important opportunity will be squandered. While Ambient, and other BPL's are exploring mitigation methods and technical fixes that would allow them to operate with minimum power, the FCC should consider to what extent it could modify existing emissions limits in Part 15, consistent with the need to protect other spectrum users. This section discusses the factors affecting the architecture and capacity of BPL operations

1. <u>How much power does BPL need to be effective</u>?

Ambient has considerable experience in Access BPL over the last three years using its proprietary inductive couplers and purchased OFDM modems. We have evaluated different modem chip sets and technologies, and are using a chip set which we believe to be the state of the art, in terms of data rate and reliability. We have found modem average transmitter power spectral density level needs to be set as high as –50 dBm/Hz to achieve best exploitation of overhead distribution power lines.

In some locations, a further power increase of 5 to 10 dB would be useful to overcome attenuation on lines suffering an unusually high path loss. Since the MV Access path represents a neighborhood backbone, it is desirable to maximize its performance.

For spectrum between 1.7 to 30 MHz, such a power increase might be accomplished by increasing permissible power levels above the 30 uV/m (29.5 dBuV/m) at 30 meters, which extrapolates to 48.6 dBuV/m at 10 meters Permitted under the Commission's current Part 15 rules. Above 30 MHz, current Part 15 limits decrease significantly, even for devices considered Class A (industrial). The establishment of a continuity of field intensity limits, measured at 10 meters, between frequencies below-30 MHz and above-30 MHz, for a frequency range reaching at least 40 MHz, would permit significantly greater data rates on typical overhead MV lines.

With the modem chip set Ambient currently utilizes and inductive coupling, the above power level allows transmission without repeaters along line distances of 1/4 to1/2½ mile in residential areas. By installing an additional repeater modem card in PLC nodes that already service customers, these distances may be extended. Rural transmission distances are likely to exceed 1 to 2 miles based on path loss measurements made in 2001 on long MV overhead power feeder lines with few branches. Again, repeating may extend those distances.

Overhead power lines have a "choppy" path loss frequency characteristic, due to the topology of the lines. Over a given frequency band, typically only 30% to 70% percent of the band is usable, in multiple narrow band segments. In these usable sub-bands, a signal to noise ratio (SNR) of 25 to 30 dB is required to exploit the full data rate potential. Modem technology is still developing, and these numbers should not be taken as final.

A lower SNR results in lower data rate. For example, measurements at our trial site in NY showed that reducing power by 12 dB reduced the data rates by a factor of approximately 4. Some bandwidth is attainable at much lower SNRs, and could support low data rate traffic, but such data rates could not be considered "broadband" rates.

Appendix B discusses various factors affecting the actual power coupled to the power line. It shows that–50 dBm/Hz corresponds to only –60 to –55 dBm/Hz average power coupled to the power line.

In conclusion, there is no excess "headroom" on moderately noisy power lines. Lowering power decreases data rate and does not exploit powerline data capacity, while raising power, bringing EMI levels to 10 meter Part 15 limits or above, allows greater data capacity.

2. <u>Overhead versus Underground MV Feeder Lines</u>

Overhead three phase lines are not shielded and a neutral wire may or may not be present. A portion of the signal injected on these lines will be radiated. This radiation will increase at impedance discontinuities, such as line branches and locations where powerline devices are attached. Single phase overhead cables have an important propagation mode between the phase wire and neutral, with separation typically exceeding two feet (60 cm).

Single phase underground cables can be viewed as coaxial cables, with neutral wires or a copper tape spirally wound around the insulation surrounding a phase conductor. The shielding is only partially effective at high frequencies, and is interrupted at the connection to pad-mounted distribution transformers. Burial depth is typically much less than one wavelength, at hf frequencies.

Underground cables with cross linked polyethylene (XLPE) insulation are similar to smaller rf coaxial cables and have low attenuation per unit distance, in the range of 1-6 dB per hundred meters. Cables with ethylene-propylene rubber (EPR) insulation have a low pass characteristic, having loss which increases rapidly above a few MHz. EPR cables can carry PLC signals at distances up to about 100 meters, at frequencies up to 15 MHz.

In conclusion, underground lines will radiate much weaker signals for a given PLC power level.

3. <u>Automatic Power Reduction</u>

Modem chip sets permit transmitter power levels and receiver gains to be set and optimized for varying line noise conditions. As is specified by the FCC's rules, emitted power is reduced to approximately the minimum level needed.

Considering PLC operating conditions may change at any given moment, if the power line noise is relatively low, then reduced PLC modem power would be used. In this case, the receiving antenna of a nearby radio receiver would likely also be subject to low power line noise, and the incremental additional noise due to PLC would be minimized (see Figure 1a).

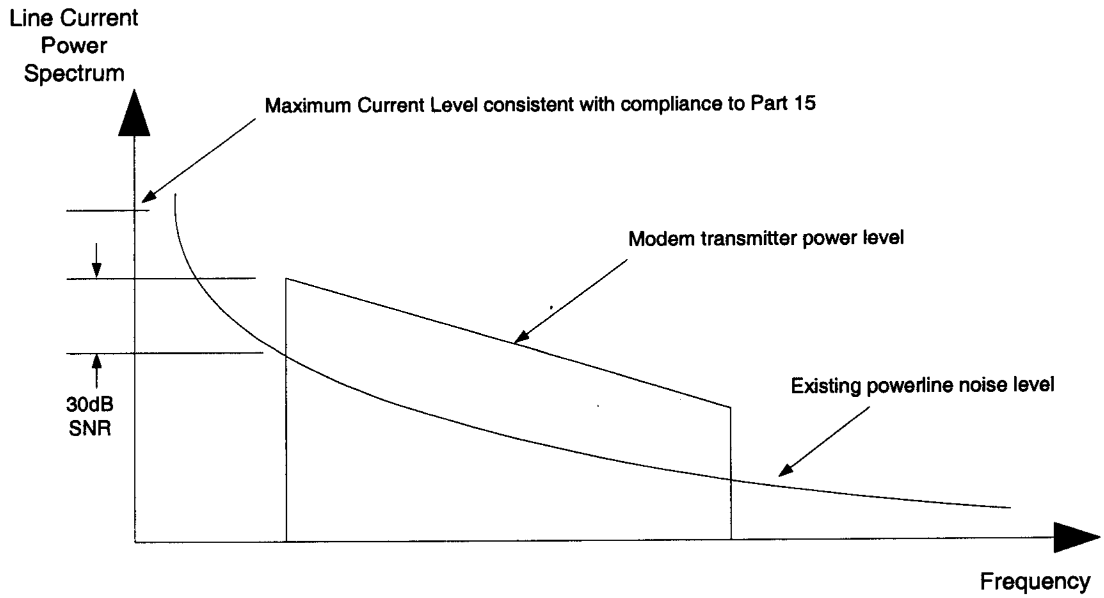


Figure 3. Modem transmitter power spectrum, with level set to maintain 30 dB SNR, and sloping power mask to maintain that SNR over wide band with minimum power.

Conversely, if the power line noise was high, the PLC modem should be automatically programmed to increase the emitted power, and the licensed station would suffer a moderate increase in noise level, but still limited to the pre-existing Part 15 limits (Figure 1b).

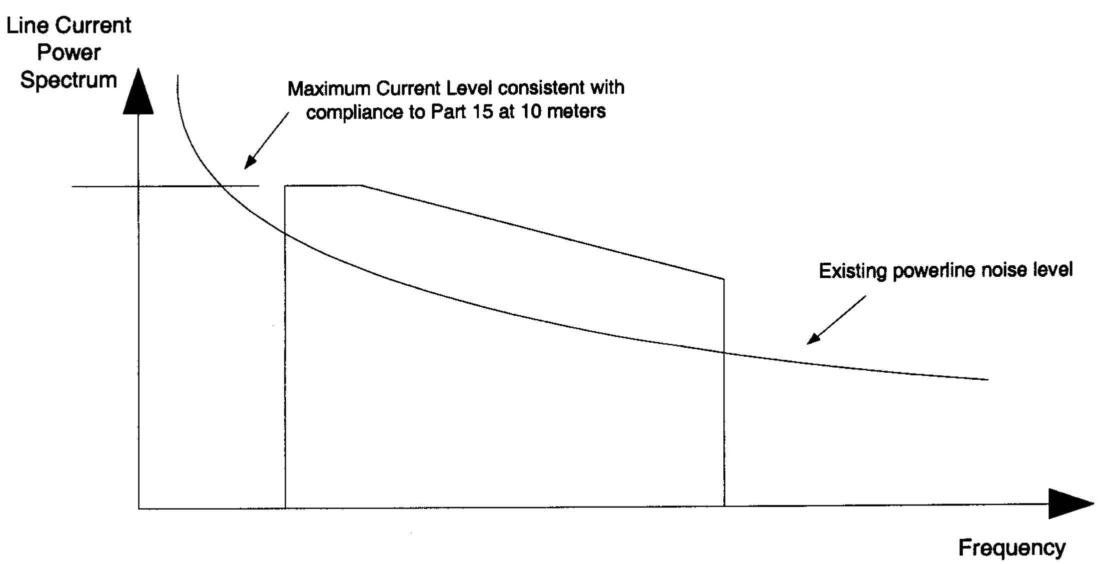


Figure 4. Modem power mask is minimized to realize SNR, but also limited to comply with Part 15

III. INTERFERENCE ISSUES AND POSSIBLE MITIGATION TECHNIQUES

Depending on the performance parameters of new modem technology currently under development, it may still be desirable to increase field intensity limits, so as to increase the data rates on MV overhead lines, which serve as neighborhood backbones.

The Commission should consider whether this might be feasible, in combination with various mitigation strategies that Ambient is now studying.

A. Use of OFDM and Agile Notching to Prevent Interference

It may be possible to implement a method of avoiding interference to nearby transceivers, utilizing the inherent characteristics of advanced OFDM technology. Orthogonal Frequency Division Multiplex (OFDM) modulation uses hundreds of narrow frequency sub-bands, optimizing the number of bits per symbol in each sub-band according to channel conditions there. For example, if a sub-band is in a frequency range of particularly high attenuation between a particular PLC transmitter-receiver pair, or power line noise or ingress noise make the SNR so low as to be unusable, then the modem transmitter can be programmed to avoid transmitting on that sub-band. The implication is that strong transmitters (*e.g.*, a remote shortwave broadcast station or local licensed communications station) would automatically create a notch for themselves in the PLC spectrum (Figure 1c). We term this "Agile Notching."

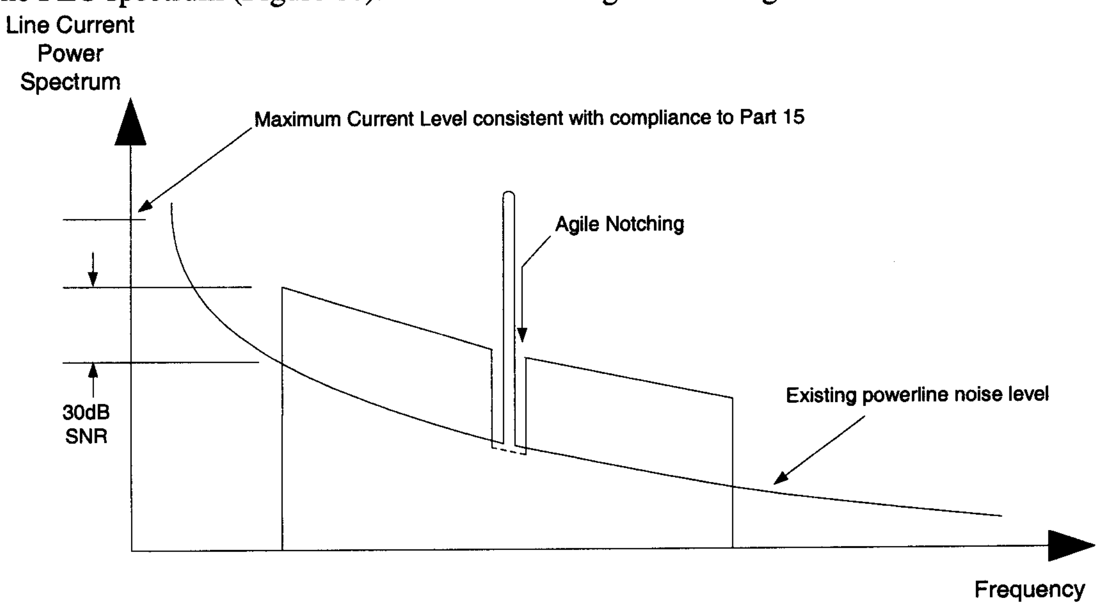


Figure 5. An illustration of Agile Notching, in which the modem avoids transmitting at or near frequencies that it can hear as strong signals, and thus does not interfere with communications on these frequencies

Should a communications station be transmitting a periodic invitation to transmit on one frequency and listening on another, the receive frequency is known and rarely changes. When the PLC modem hears strong ingress on the transmit frequency, it could create an agile notch on the receive frequency. It would also be programmed to have fast onset and very slow release, so that the frequency would remain quiet between transmissions.

In conclusion, PLC modems already have some of the adaptive functionality and agility built in, and we are studying techniques for mitigating interference to others.

B. Widespread Deployment of BPL May Help Reduce RF Noise Generated by Power Lines and Help in Identification of Failing Equipment

In the absence of BPL noisy power lines may create interference with existing spectrum uses. In fact, this interference has been identified as the number one interference problem for amateur radio operators.[3]

In Ambient's field experience, excessive noise over portions of the power lines is often caused by faulty insulators, surge arrestors or other devices associated with the power lines. When a BPL system is installed over a segment of power lines, the BPL installer can often pinpoint the source and will have every incentive to reduce this excess noise by identifying and replacing faulty devices.

This ancillary process will benefit amateur radio and other spectrum users in removing noise sources that might be the dominant noise source under certain conditions. This process will also benefits power utilities and their customers, for often noise from a power line device presages a device failure and power outage, requiring emergency service in good and bad weather.

In summary, adoption of BPL would not necessarily increase overall background emissions, as significant reductions in ambient EMI levels from cumulative radiation of power lines may be achieved during the installation process of such systems.

IV. RESPONSE TO KEY QUESTIONS POSED IN NOI

A. Definition of BPL

The NOI divides BPL between "Access BPL" and "In-House BPL." *NOI*, ¶¶ 14,16. Ambient believes that "Access PLC" service should be defined to include the "last mile" starting at the utility substation or other convenient point of connection to a data fiber or other high speed data backbone. This MV Access segment traverses overhead and/or underground medium voltage power cables, reaching distribution transformers installed near loads such as homes and businesses. From there, cables bring low voltage from the distribution transformer to the home, comprising the LV Access segment. This "Access" part of the BPL network, especially overhead wires, are more likely to radiate electromagnetic interference (EMI), due to the separation and height of the power conductors.

Ambient notes that the services it contemplates over its Power Line Communications Network includes not only BPL to the home or office, as set forth in the NOI, but also Utility Services including distribution feeder monitoring, control, load shedding and fault location. Since some utilities will begin operations using PLC for Utility Service only, and may need approval from utility regulators, lumping all PLC under the term BPL may create confusion and possible objections from such utility regulators.

V. CONCLUSION

[3] The ARRL EMC Committee Semi-Annual Report of January 2003 states "Power-line interference has continued to be the number one interference problem reported to ARRL HQ."

The Commission is correct that high-speed transmission capabilities could enable BPL technologies to provide an alternative platform for broadband deployment to the home and office. Our research confirms that neighborhood PLC Access over overhead Medium Voltage power distribution lines can provide a fast data trunk, currently in excess of 10 Mbps and projected to reach data rates many times that level. However, this development is contingent upon allowing vendors freedom to deploy in a seamless frequency range reaching at least 40 MHz, while new modem technology is developed and interference mitigation techniques are explored. Ambient plans to work closely with the FCC staff to maximize the capabilities of BPL technologies under current part 15 rules and to propose new or modified Part 15 rules that facilitate full bandwidth PLC while protecting incumbent users.

Respectfully submitted,

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Appendix A: Background of the author, Dr. Yehuda Cern

The author is the inventor of an inductive powerline data coupler, as disclosed in US Patent 6,452,482. This coupler provides a relatively low cost solution for coupling data signals onto power distribution lines. The coupler allows utilizing these lines over frequency bands in excess of 40 MHz, and bypassing distribution transformers. He is also the founder of the PLC business of Ambient Corporation.

The author has held amateur radio licenses for nearly 50 years, and an FCC First Class Commercial Radiotelephone License, and served as Chief Engineer of WQRS, a precursor to listener supported Public Radio.

Appendix B: Modem Transmitter Power Calculations

a) Only a portion of a Modem's output power is coupled to Power Lines.

Modem transmitter power levels are typically measured with the modem connected to a spectrum analyzer, which represents an ideal load resistor. Since the power lines were not designed for communications, their characteristic impedances are generally quite different than the ideal, and a "mismatch" results. Over the vast majority of a broad frequency band, a PLC transmitter actually couples to the line 5 to 10 dB less power than the modem is capable of, at best. Thus, typical modems couple only –60 to –55 dBm/Hz average power density, at their maximum power setting.

b) Power in a Voice Bandwidth.

A power density level such as –60 dBm/Hz average represents only 1 milliWatt per MHz, or 25 nanoWatts over a 2.5 kHz voice channel, and this at a maximum output power setting.

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