

BPL: The RFI Challenge

Gary Box

Aria Corporation

1350 Boone Ave., Golden Valley, MN, n0jcg@arrl.net

Abstract

Broadband over Power Lines presents all stakeholders with new RFI challenges. For the BPL vendors and utilities it is the challenge of meeting FCC Part 15 obligations limiting harmful interference to all licensed services that share the HF/VHF spectrum. To the licensed services using the frequencies BPL wishes to share, it is the challenge of identifying the impact of BPL and educating both the BPL industry and the public at large of the associated risks. The FCC in their Notice of Proposed Rulemaking on BPL noted "Operators would have a strong incentive to exercise the utmost caution in installing their systems to avoid harmful interference and ensure uninterrupted service to their customers". It is the purpose of this paper to bring into focus the scope of that obligation.

INTRODUCTION

All communication systems share the same building blocks; a transmitter, a channel or transmission medium, and a receiver. This is true for both intentional and unintentional paths. All communication systems are also subject to the same physical laws. Particularly, Claude Shannon and his information theory successors have taught us that reducing signal power or adding noise to a communication channel reduces the channel capacity. The channel's Bit Error Rate (BER) will increase as the signal power is decreased or the noise power is increased.

BPL signals lose power to two unavoidable physical mechanisms: path loss and radiation. Path loss is rather large because of the poor nature of the power lines as a transmission line in HF and low VHF frequencies and in particular, because of capacitive or inductive effects which further increase the BER. Likewise, any RF energy not conducted down a transmission line or absorbed by resistance will be radiated, improving the S/N ratio on the unintentional or interference paths.

Radiation should really be considered as a two-way path. It is a loss mechanism, to be sure, but it is also a path between the BPL system and a second "victim" system (and vice versa). It is the pathway for signals

to get into the BPL system as well as the way the BPL system affects external victims systems.

While BPL is a service that depends on the conduction of RF energy on the electric grid, the fact that the grid can and will radiate cannot be ignored. Similarly, the grid does not discriminate as to the source of the RF energy. Once it reaches the power line, it is irrelevant whether the RF energy was generated unintentionally by a bad insulator, or intentionally by a BPL injector. The power line will radiate just the same.

We can outline the RFI challenges for each of the elements of a BPL system.

BPL MODULATOR

Most BPL systems under consideration today use a form of OFDM, or Orthogonal Frequency Division Modulation. With OFDM, a large number of carriers, typically well over 1000, are generated [1]. Each of the carriers is then phase and amplitude modulated at a relatively slow, fixed frame rate. The result is a multitude of modulated carriers, each characterized by the $(\sin x)/x$ spectrum of a QAM signal. The carriers are spaced far enough apart to prevent interference with each other.

For data transmission purposes, each carrier acts independently at a relatively slow data rate. The fact that there are over 1000 carriers in parallel multiplies the throughput accordingly.

One of the advantages of OFDM is the ability to not use carriers at frequencies where there is conflict. This is the root of the BPL industry's approach of "notching" frequencies. However, there remain three main noise sources that generate noise in an otherwise "notched" channel:

- 1.) Quantization noise.
- 2.) The $(\sin x)/x$ tail from the summation of adjacent carriers.
- 3.) Lack of linearity resulting in intermodulation distortion.

Although “notching” can provide some protection, the depth of the notch may not be sufficient to protect sensitive services. A unique requirement of the OFDM waveform is that the summation of modulated carriers generates a severe peak-to-average power headroom requirement that in turn demands a very wide dynamic range in the signal path to preserve the phase and amplitude information and to limit intersymbol interference (ISI). Any non-linearity in the phase or amplitude response in the amplifier, coupler, and other unavoidable reactive components in the transmission path will cause intermodulation distortion, leading to additional RF energy in any notches as well as a higher BER. Additional hardware filters can be introduced into the system, but these are difficult and expensive to make sharp and remotely adjustable. Notching, filtering and distortion all reduce the channel capacity of the system and degrade BPL’s absolute maximum bandwidth of 39MHz, which is already only 1/10 to 1/20 that of wireless and cable.

THE POWER LINE

Once the RF energy from the BPL system is injected onto the power line, there are new challenges. If the energy is injected perfectly balanced on uniformly spaced conductors, at frequencies where the power line appears as a balanced structure, terminated in its characteristic impedance, far field radiation will be minimized. Even if the transmission line is balanced and uniform, its near-field (extending as far as 10 wavelengths) presents an interference source. It is the power line’s near and far-field behavior, and proximity to susceptible spectrum users that will dictate interference performance. It could be argued that the power line structure is actually the most critical component when considering unintended interference paths. Since this is a utility asset, it will fall upon the utility to manage this component of the system and comply with the obligations of FCC Part 15 Requirements.

Power line RFI has been with us for many years. While typically caused by failing insulators and other decaying grid components or from noisy electronic equipment (such as computers, motors, or industrial machinery), it does provide a benchmark of what to expect. Once the RF energy hits the power line, the source is irrelevant. The difference is that, to a degree, BPL is capable of controlling the frequency and amplitude of the RF energy it injects into the power line. Also, determining whether a particular BPL device is the source of interference is just a matter of shutting it off momentarily.

There are three components to the RF energy on the power line; the conducted component, near field component, and the radiated component. The conducted component is received by the BPL receiver. The near-field and radiated components will be received by any nearby victim receiver through its antenna. Near-field susceptibility will occur close to the power line (less than 10 wavelengths); radiated susceptibility will occur at distances greater than 10 wavelengths. Of the two, near-field susceptibility presents the greatest strength interference, and most problematic interference coupling mode. Although radiated energy can be reduced to good transmission line technique, the near-field component cannot be reduced except by shielding, such as the use of buried transmission lines

Since the early 1980’s, regulations have been in place to limit unintended RF energy from personal computers, chargers, motor controllers, etc. from being conducted onto the power line [14]. It could be argued that these regulations, in fact, created a power line that is friendlier to a concept like BPL, however the physics behind enacting those regulations in the first place still holds true. RF energy on the power line will radiate.

THE VICTIM ANTENNA

At far field distances (greater than 10 wavelengths) the behavior of the radiated BPL signal should approximate plane wave transmission, falling off as $1/r^2$. However, for a BPL center frequency of 14MHz, a wavelength is 20 meters and any antenna closer than 200 meters at that frequency will experience a more near field phenomena. This was verified by the NTIA in its study [2]. As the NTIA noted, most victim receiver systems will be within the near field, which is the worse case condition that should be considered.

The NTIA also found that the strongest radiation node might not be directly below the power line, or even in the immediate vicinity of the BPL device [2]. The strongest node may be some distance down the line and as high as or higher than the power line itself, and may repeat at fractional wavelength distances down the power line. This is consistent with transmission line theory for the near field of a mismatched parallel wire transmission line. For the BPL case, this is complicated by the fact that the carriers are spread over several MHz, creating different node patterns for the different frequencies.

The victim antenna would easily lie within this complicated near field. The antenna could range from a random length-telescoping whip on a consumer short wave radio, to a high gain antenna mounted on a tower at or above the height of the power line. Antenna gain can vary from a negative value up to 18dBi or greater.

Putting this together, we see that the gain of the unwanted communications path from the BPL modulator to the terminals of the victim antenna can vary over several orders of magnitude. It is this variability that makes it difficult to devise “one size fits all” solutions involving only the BPL components. At the very least, to guarantee true compliance to part 15 radiation levels and non interference, the installation of each device would have to be custom engineered; much like building construction depends on site-specific environmental impact studies.

However, unlike the building construction analogy, the BPL environment can change rapidly. All of the factors are subject to change over time, particularly the nature and location of the victim antenna, which is not under the control of the utility or BPL vendor. Currently, we are experiencing the declining side of the 11-year sunspot cycle. This means that the Maximum Usable Frequency, or MUF, is falling. The MUF is a measure of the RF reflectivity of the ionosphere and is found by transmitting RF energy vertically and measuring the maximum frequency that produces a reflection. During the minimum of the 11-year sunspot cycle, the MUF can fall as low as 10MHz. At the peak of the sunspot cycle, it can be as high as 50MHz. All licensed services using the HF frequencies adjust their operations in sync with the MUF and hence, the sunspot cycle. Any BPL systems deployed at frequencies between 10MHz and 50MHz during the current sunspot minimum will find a much higher level of activity from licensed services a few years down the road and will have to adjust accordingly. In some cases, this will involve re-engineering installations as victim receivers reappear in the higher HF spectrum.

There is one other victim antenna in a BPL system, and that is the power line itself. Like all antennas, the power line will receive RF energy as well as transmit it. This means that nearby RF sources can interfere with the BPL system. This has several implications. Most, if not all, unwanted external fields received by the BPL system will be from narrow band sources. They will cause the BPL system to lose a few discrete channels and slightly degrade BER or throughput—

unless they fall on critical synchronization or provisioning frequencies.

Strong interfering signals will be present near some BPL networks. These signals could originate from several North American licensed services, including amateur radio stations, CB and mobile VHF operators, low channel TV stations, international shortwave broadcasters, and critical infrastructure services such as aeronautical communications, military and law enforcement agencies, and emergency response networks. There are hundreds of thousands of powerful stations (up to 100 KW) that regularly transmit in the BPL spectrum.

The BPL receiver is necessarily wideband to receive the broadband BPL signals. Strong interference signals—anywhere within the BPL receiver’s bandwidth window—can lead to BPL receiver overload, desensitization, or distortion. The result could be degradation of BER and throughput or total path blocking. Strong signals could even cause damage to the BPL hardware.

Even if these powerful transmitters do not directly transmit on BPL frequencies, non-linear power grid components can lead to reciprocal mixing of the interference and BPL signals, or mixing of two interference signals. The mixing product can fall in the BPL receiver window leading to degradation of BER.

THE VICTIM RECEIVER

There appears to be much confusion in the ranks of BPL providers and utilities about the nature of licensed communication, particularly in the frequencies between 2MHz and 30 MHz [3]. Going forward, we would all be better served if both the BPL providers and the utilities had a better appreciation of current and future uses of the HF spectrum.

In general, all HF communication makes use of the most important property of the frequencies between 2MHz and 30MHz; the ability to establish and maintain communications over great distances without any intervening man made infrastructure whatsoever. For the past 100 years, the transmitter, antenna system and receiver engineering in this frequency range has concentrated on improving the sensitivity and selectivity of the HF data path. Modern transmitters are capable of transmitting RF energy in analog or digital modes with the suppression of out of band energy exceeding 50dB. Modern antenna engineering takes maximum advantage of computer aided design

techniques to optimize beam forming, take off angle and other important antenna characteristics. Modern receiver design concentrates on high accuracy reproduction of signals that are barely above the natural noise floor. The overriding design goal of modern HF communication systems has been to improve the S/N characteristics of the signal path, taking into account the variability of propagation influenced by the sunspot cycle and other natural and man made phenomena. In short, the goal is to maximize the throughput rate over the HF path as described by Shannon's law.

Far from being obsolete, modern HF communications use many of the same digital modulation schemes as cable modems, DSL and BPL, although at reduced bandwidths. The emerging short wave digital radio service, Digital Radio Mondiale, uses the same OFDM techniques as BPL to provide CD quality sound and data services over the international short wave bands [4]. The BBC estimates there are about 2.5 billion AM receivers in the world that would benefit from digital shortwave broadcasting [5]. Short wave broadcasting occupies 3.83 MHz between 2 and 30 MHz [6].

Another modern HF communication development is Automatic Link Establishment, or ALE [7]. ALE links computer controlled HF data transceivers in a highly robust network to maintain long distance, low speed data links with 99.99% up time, providing a no infrastructure, jam proof communication link for disaster management, commercial and government traffic. Although the data rate is too slow for most video services, in 1999 the NTIA reported that ALE is useful for providing e-mail, digital voice and graphics service to remote locations. ALE is also used to quickly establish temporary data links to facilitate establishment or repair of high speed links. ALE is commonly used over government and commercial land mobile and fixed services which occupy 12.17 MHz between 2 and 30 MHz [6].

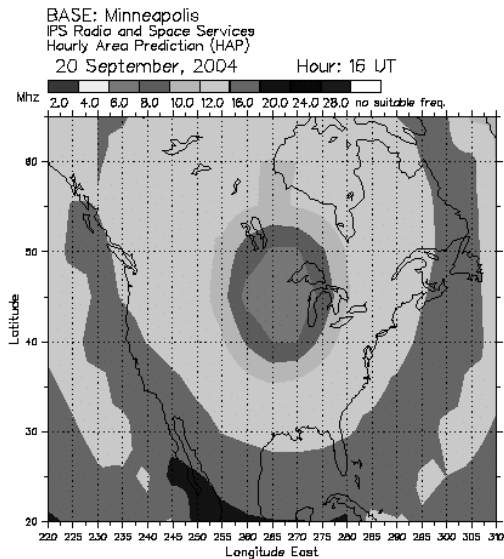
HF communications is still vital to the safe operation of air and marine transport. The Boeing Company, in comments filed on the FCC's Notice of Proposed Rulemaking on BPL, reports that critical communication with aircraft in flight may be carried out under conditions where transmissions are barely above a noise floor of -113Dbm [8]. Because of the difficulty of quickly detecting and eliminating interference from BPL devices, Boeing goes on to recommend that the aeronautical HF bands, which are spread in small segments over the entire 2 to 30 MHz

range, be off limits for BPL operation. Together, aeronautical and marine mobile occupy 7.28 MHz in this range [6].

The Amateur Radio Service also has allocations throughout the HF bands and is open to any US resident by taking a test. Jurisdiction for the service falls under the Public Safety & Critical Infrastructure Division of the Wireless Telecommunications Bureau of the FCC and is considered part of the nation's critical infrastructure by federal, state and local government bodies as well as several non government disaster services such as the Red Cross [9]. An example of the service provided by Amateur radio on HF is the Maritime Mobile Service Net [10]. This is a net operated by volunteers on 14.300 MHz providing a variety of emergency and non-emergency services to mariners, particularly those in off shore pleasure craft. While satellite based EPIRB beacons can locate mariners in distress, there is no regular service operated by the Coast Guard or private industry to maintain voice communication with them. The Maritime Mobile Net fills this gap using numerous land based fixed Amateur radio stations, many of which are located in urban settings and, as noted by the NTIA, may be affected by BPL. Amateur radio is dynamic. At the World Radio Conference in 2003, the requirement of Morse code proficiency for access to ARS frequencies below 30MHz was dropped from the international regulations and made the option of each country [11]. Since then, a number of countries have dropped the requirement and have experienced a corresponding increase in Amateur Radio HF operation. The United States has the second largest Amateur Radio population in the world, about half of which do not now have HF privileges. When, as is expected, the FCC follows the rest of the world, some 300,000 plus operators could suddenly appear on the HF bands. As an unlicensed part 15 user, BPL operators will have to respond accordingly. The Amateur Radio Service occupies 3.45 MHz between 2 and 30 MHz [6].

HF communications is undergoing the same digital revolution as the rest of society. An example of modern HF radio engineering is the Harris AN/PRC-150(C), which is a software defined radio capable of operation from 1.6 MHz to 60 MHz [12]. It is capable of voice and data operation and is particularly useful in establishing communication links up to 400 miles using a technique known as near vertical incident sky wave propagation, or NVIS. The following graph is an Hourly Area Prediction for Minneapolis showing the best frequency to use to maintain direct contact

between a mobile station and a fixed station [15]. This is not a computer model. It is derived from actual measurements and is updated hourly.



Clearly, HF is a viable medium to maintain communication links over a wide area. It is gaining ground as a critical communication component for defense, homeland security, and National Guard units nationwide. The AN/PRC-150(C) is a new radio. It was NSA certified and became generally available on September 11, 2001.

Both international ITU treaties and FCC Part 15 regulations hinge on the “harmful interference” clause with respect to unlicensed devices [13][14]. Since inception of those regulations, “harmful interference” has been defined in terms of the victim service. Furthermore, the regulations are clear that the responsibility for eliminating the interference rests solely with the operator of the part 15 device. Even after engineering and deploying a BPL system, the liability for interference elimination will pose a moving target as licensed services continue to evolve.

NTIA REPORT

In April 2004, the National Transportation and Information Authority issued the results of a study they made on the effects of BPL on government high frequency communications [2]. The study concluded, “Access BPL devices pose interference risks that are among the highest of the various kinds of authorized, unlicensed devices”. The NTIA study consists of both computer models and field measurements on a variety of BPL installations.

The NTIA computer studies revealed that while the highest horizontally polarized RF field would occur near the BPL device, the vertically polarized field tended to peak at locations under and adjacent to the line at impedance discontinuities substantial distances away. This was then verified by field measurements. Since part 15 RF level compliance requires the measurement to be taken at the strongest point, the NTIA concluded that compliance with part 15 should not focus on the device alone. In fact, the NTIA found that the current measurement procedure could lead to an underestimation of the actual peak field strength, further contributing to a high interference risk.

In order to quantify the interference potential, the NTIA used increased noise levels of 6 dB and 10dB to correspond to harmful interference to low to moderate and moderate to strong desired signals, respectively. They acknowledged that interference levels at or just above the noise floor are sufficient to be harmful to weak signals. They then modeled a power line radiating at the part 15 limit and determined the probability of interference to aircraft, fixed, marine, and vehicle mounted receivers as a function of distance.

For vehicle-mounted receivers, which tend to have inefficient antenna with negative gain, it was found that the 6dB interference contour extends out to 75 meters. This would be the interference level sufficient to be harmful to low to moderate signals. For fixed receivers, this 6dB contour extended out to 460 meters.

The NTIA results indicated that a good deal of the radiated energy is directed skyward. The results of the NTIA study with respect to aircraft showed that a density of 1BPL device/ square km, over a 10 square km area radiating at the part 15 limit would produce interference to moderate to strong signals to aircraft below 6km and out to a radius of 12km. The interference contour to aircraft for weak to moderate signals, extended to 40km.

The NTIA study provides a good assessment of the limits BPL must operate under if it is to meet the no interference obligation of part 15. The NTIA concludes the study with a list of suggestions for eliminating BPL interference.

1. Registration
2. Frequency agility

3. Power reduction
4. Avoidance of local frequencies
5. Operation with minimum power
6. Differential mode injection
7. Filters and terminations to extinguish the BPL signal
8. Careful choice of frequencies to decrease radiation.

BPL TESTS

To date, most operation of BPL systems in the United States have been in small, pilot and test operations ranging from a few blocks to a neighborhood [16]. None have been large enough to draw any conclusions of how interference issues will change as operations are scaled up. One obvious variable has been the proximity of BPL equipment or power lines to sensitive HF users. Strictly on a statistical basis, one would expect short wave broadcasting listeners and Amateur Radio operators to be the first to experience any interference from BPL operations, and this has in fact occurred. There have been over 40 formal interference complaints to the FCC about BPL operations [17]. I will highlight three specific cases that illustrate the range of the BPL RFI challenge.

Raleigh, NC

Progress Energy began deploying BPL test sites in late 2003 [18]. While no licensed high frequency users were located in the test area, it wasn't long before local ham radio operators, operating from their vehicles, noticed BPL related interference, beginning around January 2004. Following informal, established protocol, Progress Energy was contacted and efforts commenced to eliminate the interference. The principal tools available to Progress Energy were power reduction, some ability to mask out frequencies and the ability to shift the BPL spectrum. Progress Energy also acquired a mobile ham radio transceiver and antenna system to measure their progress. Through trial and error over a period of 5 months, Progress energy was able to reduce the interference present on most of the eight high frequency ham bands, although not all. Formal complaints were filed with the FCC with regard to the remaining interference. At this point, Progress Energy chose to abandon any additional effort at interference elimination and claimed that the remaining interference was 'not harmful'. Eventually, the FCC Office of Engineering and Technology sent out an investigation team. The team determined that one of the disputed sites was 25dB below the level of part 15 and sufficient to protect the nearest HF

operations. They also found that another site was producing harmful interference in the 10-meter amateur radio band and instructed Progress Energy to correct the condition. A couple of weeks later, Progress Energy announced they were terminating the test and concluded that they were not going to pursue further BPL deployment at this time.

The Progress Energy test site covered only a few blocks and included a significant underground section. Interference elimination efforts were found necessary but were carried out only on the 10 percent of the HF spectrum that comprises the amateur radio allocations. The efforts were focused on eliminating interference to mobile HF operations; the least susceptible of the operations studied by the NTIA, and were not completely successful. There is no indication that there was any evaluation of interference to the shortwave broadcast, aeronautical, marine, or NTIA frequencies in this test.

Cedar Rapids, IA

Alliant Energy began BPL tests in Cedar Rapids, IA in March 2004 [19]. The test involved overhead power lines in an area already known to be a source of radio frequency interference from the power lines. Amateur radio station WOSR, operating at a fixed location 183 meters from the closest line carrying BPL, immediately noticed increased interference. Unlike the situation in Raleigh, the Cedar Rapids case involved a fixed HF location using tuned dipole and high gain Yagi antennas, just the type of station noted by the NTIA study as the most susceptible to interference. Again, the utility had the same tools available to it to try to achieve interference elimination; power reduction, spectral masking (notching), and frequency shifting. Working with the amateur radio operator involved over a period of 2 months, some improvement was achieved, but not complete success.

In April and May 2004, calibrated spectrum analyzer measurements were taken at WOSR using the actual station antennas by the Cedar Rapids BPL Steering Committee. The spectrum analyzers used were calibrated to standards traceable to the National Institute of Standards and Technology. All other possible sources of interference, such as computers, radios etc were turned off for the testing. With the cooperation of Alliant Energy, data was collected with the BPL system on and off. The data documented intercepted BPL signals significantly above the sensitivity of amateur radio receivers. Notching of the BPL signal near amateur radio allocations was apparent, but it was neither accurate with respect to the

amateur frequencies, nor was it adequate to prevent harmful interference. The BPL Steering Committee further concluded that an additional 20dB of attenuation would be necessary just to maintain the same interference level if WOSR was located at a distance of 60 feet from the BPL line rather than 600 feet. They also concluded that practical receiver filtering and audio processing are not adequate to distinguish between desired signals and the injected BPL tones. They further noted that by choosing just one wire to conduct the BPL signal between points, Allient Energy and the BPL vendor have created an antenna that does radiate along its full length and that this configuration could give rise to nodes with directional gain from the ends of the unbalanced segments.

The report of the Cedar Rapids BPL Steering Committee was entered as comments to FCC NPRM 04-37 as well as forwarded to the American Radio Relay League, which then filed a formal complaint with the FCC. A short time later, Allient energy terminated the Cedar Rapids BPL test earlier than they had expected to and issued a notice that they would not be pursuing BPL at this time. The ARRL complaint was cited as a factor in the utility's decision to end the test prematurely.

The Cedar Rapids case focused on Amateur Radio frequency allocations, but it is clear from the collected data, that the BPL installation would also interfere with shortwave broadcasting and other HF users.

Penn Yan, NY

With much fanfare, the Village of Penn Yan, NY announced an agreement with Data Ventures to deploy a BPL system in November 2003 [20]. By March 2004, a BPL system had been installed over several blocks in downtown Penn Yan. Almost immediately, local ham radio operators detected interference. The first formal complaint to the FCC, in late March 2004, documented interference over the range from 18MHz to 30MHz as far out as ¾ mile from the BPL installation, using a mobile HF transceiver. The second complaint, in April 2004, documented interference between 27MHz and 30.7MHz, again using a mobile transceiver. In late May 2004, a third complaint detailed the changes the BPL vendor had affected. They were successful at clearing the BPL signal from the 10-meter band, but were only partially successful on 15 and 12 meters. The 17-meter band was still covered by the BPL interference. Significant interference levels were also noted between 30MHz and 40 MHz. While not covering any Amateur Radio

bands, there are public service agencies operating in this frequency range. BPL signals were also detected within short wave bands at levels sufficient to cause harmful interference.

On July 28 the Village of Penn Yan decided that BPL was not commercially viable and terminated operation of the BPL system. Data Ventures has since begun deploying a wireless network in Penn Yan.

CONCLUSIONS

In its Phase One report, the NTIA presents a good framework for dealing with the RFI challenges of BPL, even if not required by the FCC

Registration

This would need to go beyond simple notification of some central, closed database and would require notification and active involvement of all local HF users. Only with active testing using real HF equipment can a utility be assured that it is meeting the non-interference obligations of part 15. Anything less would only result in an endless cat and mouse game with all parties chasing interference, real or otherwise. The NTIA also left open the option of requiring some sort of on the air identification for BPL, something required of all licensed services.

Frequency Agility and Avoidance of Local Frequencies

The only way to guarantee non-interference on any frequency is to not have RF energy at that frequency on the power line. Accurately knowing the operating frequencies of the BPL signal, perhaps by direct, active measurement is the only way to verify this. Even if initial studies show no interference, any operation on locally used frequencies, including receive only frequencies like shortwave, leaves open the possibility of interference at some time in the future as the nature of HF communication undergoes natural changes and man made evolution.

Power Reduction and Operation with Minimum Power

The NTIA points out that power reduction is the most useful approach for eliminating interference. Many licensed services operate under the approach of using the minimum power level necessary to maintain communication. Whatever the point of view, BPL would be a user of the HF spectrum and would be well served by following the same principal.

Utility interest in BPL for load management, real-time pricing, equipment monitoring & control and other

uses is keen, but these functions do not require Mb/s performance. It may be possible to reduce radiated power to a point just at the noise floor and still get adequate utility performance.

Differential Mode Injection, Filters and Terminations to Extinguish the BPL Signal, and Careful Choice of Frequencies to Decrease Radiation

The electrical grid was not deployed with any thought of its high frequency characteristics. The fact that it can conduct HF at all is almost an accident. Just as site preparation is important to road construction, so too will the conditioning of the power line to accept any RF signals be important to BPL. This must be done in a way to maximize conducted energy and minimize radiation at the frequencies of interest while also making the result invariant under changing line conditions. Done correctly, this is a site-by-site operation. Perhaps guidelines will evolve, but there are too many variables to expect that to happen quickly.

Clearly, deploying BPL systems that use the HF spectrum put the utility or other responsible entity in the business of being an HF user. That will include monitoring HF conditions and being aware of other users at all times. As a part 15 HF user, this also means rapidly deferring to the needs of the licensed services. The practice to date has been to install the BPL equipment with some testing to verify compliance with part 15 radiation requirements. When local HF users detect interference, the utility or BPL vendor then attempt to resolve the issue on a case-by-case basis, typically by 'notching'. Successful mitigation has been slow, inaccurate and limited to the relatively small amateur radio bands. Little or no effort has gone into eliminating interference to short wave, marine, air or NTIA frequencies when found during these tests. Even if utilities and vendors get good at this 'Swiss cheese' approach, there is no guarantee that any given solution remains a solution. The changing propagation conditions, changing technology and a changing population of HF users guarantees that continuous adjustment and even re engineering will be required as long as Broadband over Power Lines uses the same spectrum as weak signal licensed services. Exercising "utmost caution in installing their systems to avoid harmful interference", as stipulated by the FCC will be a continuous task for utility and BPL vendors alike.

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