Exhibit A

Rationale for Fixed 35 dB Notches for the Amateur Bands in Access and In-Premise Broadband over Power Line (BPL) Regulations

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Background

Title 47 C.F.R. Part 15

> *§ 15.611(c) Interference Mitigation and Avoidance.*
>
> *Access BPL systems shall incorporate adaptive interference mitigation techniques to remotely reduce power and adjust operating frequencies, in order to avoid site-specific, local use of the same spectrum by licensed services. These techniques may include adaptive or ''notch'' filtering,* ***or complete avoidance of frequencies, or bands of frequencies, locally used by licensed radio operation.***

It is a widely accepted principle of electromagnetic compatibility (EMC) engineering that to avoid causing harmful interference, radiating systems must either have emissions that are lower than the ambient noise level at a receiver's antenna if it is using the same spectrum as that receiver or the system must avoid locally used spectrum. This principle is clearly and correctly enunciated in the rule cited above.

This paper outlines the EMC practices and standards that industry has implemented generally to ensure that interference problems from some technologies are few enough that it is practical to address any remaining problems on a case-by-case basis. The entities developing these practices include some of the BPL industry manufacturers and their industry associations. Most BPL manufacturers and operators use these practices in current U.S. installations and all have demonstrated and confirmed that these practices are practical and possible in the deployment of their systems.

These practices have been developed over the past decades, with industry working closely, in many cases, with ARRL. They have been successful. With millions of devices deployed by those industries that have implemented permanent notch filtering or spectral masks to protect Amateur Radio, ARRL has not received complaints of harmful interference to Amateur Radio from permanently and effectively notched products. When this track record of success is compared to the interference problems involving BPL systems that have not used them, it is apparent that the proven, practical solution of non-use of the Amateur bands in the design specification of broadband emitters (i.e. BPL) with distributed radiating elements (i.e. house wiring, telephone, etc.) should be implemented in regulations.

Best EMC Practices

In general, with some exceptions, the electronics industry as a whole has attempted to design products that do not cause widespread interference problems. Attempting to resolve interference when it occurs post-deployment is costly and time-consuming, and in many cases, general industry has taken pro-active steps to design systems that avoid interference by avoiding locally used spectrum.

Some spectrum users operate on fixed frequencies, from fixed locations. In these cases, systems can be designed to avoid these fixed frequencies if those systems are deployed near those fixed locations. In some radio services, such as the Amateur Service, licensees are allocated blocks of spectrum and issued licenses that permit the use of that spectrum from any location, at any time. In these cases, the only way to avoid interference is to avoid using the spectrum, because for some types of licensed operation, it is generally not possible for the operator of an unlicensed system to know or predict where the licensed users will operate, or what frequency they will select for their operation. In most cases in this environment, it is not practical to attempt to resolve interference after the fact. As evidenced in the U.S. by attempts of BPL manufacturers to resolve interference reported in Briarcliff Manor, NY and Manassas, VA (to cite but two examples), the process of post-deployment resolution (if successful at all), can take many months to complete. Experience shows that such mobile or temporary operation would be consistently disrupted and that many attempted communications would have failed long before the interference could be resolved.

Where interference is created by unlicensed narrowband emitters (a spurious signal from a computer clock, for example) it is often possible for licensed users with frequency agility to select an operating frequency within a band by avoiding a few frequencies that may have interference. Although this is not required of licensed users (and should not be an expectation by spectrum planners) it could represent a practical solution to a local interference problem that might otherwise require regulatory intervention. In the case of broadband emitters, however, this technique is not possible because broadband signals (such as BPL) fully occupy the spectrum they use. In the case of BPL systems, the spectral occupancy of the BPL signal results in every possible voice or data communications channel within an entire band of frequencies having noise from carriers or modulation from the broadband system. In the case of access BPL systems, which operate over a large geographical area, the interference potential is extensive.

Notching and Spectral Masks of the Amateur Bands

The Amateur Radio Service operates on a number of different frequency bands, using a wide range of operating modes, antenna parameters, transmit power and receiver characteristics. Its licensees operate from fixed, mobile and portable locations which are unpredictable and variable. Use of the High Frequency (HF) bands is extremely intensive at all times. For broadband systems, the only way to protect the Amateur Radio Service from interference has proven to be the complete avoidance of the use of Amateur spectrum in the design and implementation of any broadband system that will be deployed in locations where Amateur operation is likely. This principle has been considered by a number of industries generating broadband signals conducted on phone lines and power lines and after testing and evaluation; many industries have implemented an industry practice to not use the Amateur bands in the design and specification of their broadband products. Unfortunately, because the practice is voluntary and not mandated by regulation, some companies do not follow these industry practices in the deployment of some broadband products.

Some of these technologies use telephone wiring to conduct broadband signals. This wiring generally is very well balanced at audio frequencies and at least reasonably well balanced at radio frequencies. Although this balance is not perfect, it is self evident that balanced, twisted pairs will be much better balanced than power-line wiring, where no attempt has ever been made to achieve balance, even at 60 Hz .[1] The spacing of the conductors on overhead wiring, the grounding of the neutral, often at multiple points, the addition of transformers, loads, side branches, and, for premise wiring, light switches that open only one of the two conductors all result in a much greater tendency to radiate from power lines than is seen in twisted-pair telephone wiring. In-premises, balance is equally poor because of grounded neutral wire, the presence of loads within the premises and the severe unbalance caused when a light switch is opened, leaving the neutral wire as an antenna connected to the otherwise poorly balanced transmission line formed by the 120V or 240V wiring.)

Even with this superior balance of telephone wiring, the industries using phone wiring to provide broadband signals, after considerable discussion and testing, concluded by consensus that it was necessary to implement notching and spectral masks to protect Amateur Radio. This practice is even more necessary and important to apply to power lines carrying broadband signals.

Home Phone Networking Alliance (HPNA)

HPNA equipment is similar to BPL, but using phone wiring within a building rather than the power lines to network computers within that building. The Home Phone Networking Alliance is an industry association created to help create a specification for HPNA equipment. In 1999, HPNA approached ARRL, asking for help in assessing the interference potential of HPNA equipment. HPNA also asked ARRL to help test solutions that could be implemented in the design of the HPNA specification.

As a result of the joint findings with ARRL, HPNA chose to implement a fixed and permanent spectral mask in the 7.0-7.3 MHz band, which was the only Amateur band that would have been used by HPNA products if they did not implement the mask.

[1] An ITU-R report, SM-2158, discussed later in this paper, describes this imbalance.

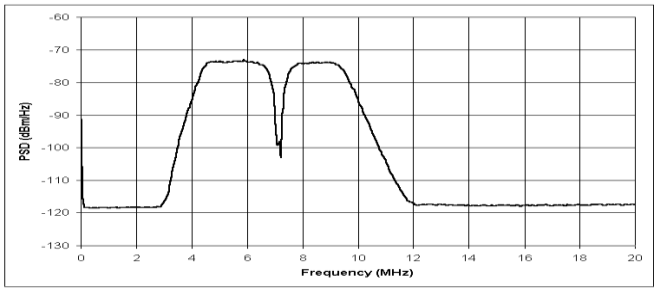


Figure 1 – This shows the typical performance of an HPNA product. This spectral mask for the 40-meter Amateur band has helped HPNA products achieve a good record of compatibility with licensed radio services. This was implemented by the HPNA after its testing demonstrated that without this spectral notch in its product, interference to Amateur Radio licensees was very likely.

VDSL

Telephone wiring is also used to deliver broadband services. Early versions of Digital Subscriber Lines (DSL) technology provided several hundred kb/s to end users. Its technology operated on spectrum up to 1.1 MHz. Newer DSL protocols extend to nearly 30 MHz, delivering a much higher data rate. There are several variants on these protocols, but collectively they are known as Very high Speed Digital Subscriber Lines (VDSL)[2].

Although VDSL standards are still under development, primarily through the Telecommunications Industry Association, the VDSL standards under development all include spectral masks for Amateur Radio. This was done through the consensus standards process, for essentially the same reasons that HPNA chose to implement a spectral mask for Amateur Radio – to prevent widespread interference problems involving Amateur Radio resulting from the emission of noise from broadband signals placed on telephone wiring. ARRL was a participant in this standards process, providing information and material to the industry, as a formal presentation at one of its standards-committee meetings.[3]

Figure 2 below shows the specifications that the VDSL industry has successfully implemented to protect Amateur Radio. Although twisted-pair telephone wiring is generally a reasonable transmission line compared to overhead power lines, good engineering and industry consensus determined that spectral masks were necessary to protect Amateur Radio.

[2] A tutorial on VDSL can be seen at http://www.hill2dot0.com/wiki/index.php?title=VDSL2.

[3] This presentation can be downloaded from http://p1k.arrl.org/~ehare/rfi/vdsl/VDSL-TIA.PPT (case sensitive). It is entitled "Possible Impact of VDSL on Stations Operating in the Amateur Radio Service." It was an invited presentation, at the request of the T1E1 VSDL standards committee.

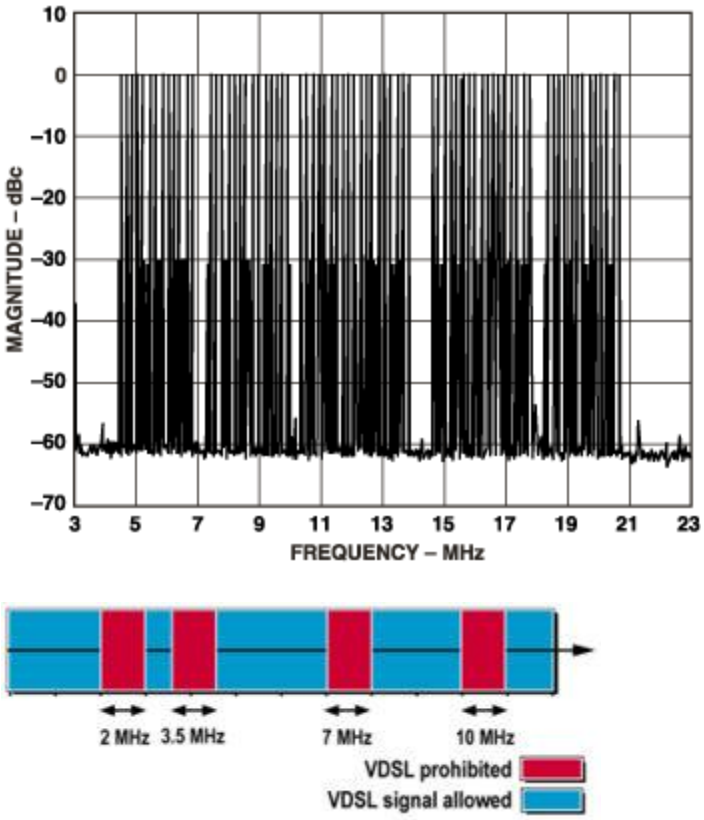


Figure 2 – These two graphics show the spectral masks for the Amateur bands used for two of the VDSL protocols, protecting Amateur Radio. The notch depth as shown in the measurement in the upper graphic is approximately 60 dB, representing good state-of-the art notching. These specifications have prevented major interference problems involving VDSL[4],[5].

HomePlug In-Premise BPL

Some of the earliest work by the BPL industry towards using spectral masks to protect Amateur Radio was done by HomePlug, an industry consortium of in-premise BPL manufacturers, and ARRL. In 2000, as the HomePlug specification was in its very early stages of development, HomePlug approached ARRL, asking for its help in conducting tests of the potential of its HomePlug protocol, both with and without spectral masks for Amateur Radio. This testing soon ensued, with HomePlug member representatives and ARRL staff working together to evaluate both the need for and effectiveness of the spectral mask HomePlug was considering using. When HomePlug considered the test results and ARRL's recommendation, it implemented permanent, fixed masks in the HomePlug specification. A copy of the joint test-result report is provided separately as Exhibit B.

[4] http://www.analog.com/library/analogDialogue/archives/36-02/ad9875/index.html
[5] http://www.hill2dot0.com/wiki/index.php?title=VDSL2

The levels of PSD specified for HomePlug products as used for the testing is shown below in Figure 3.

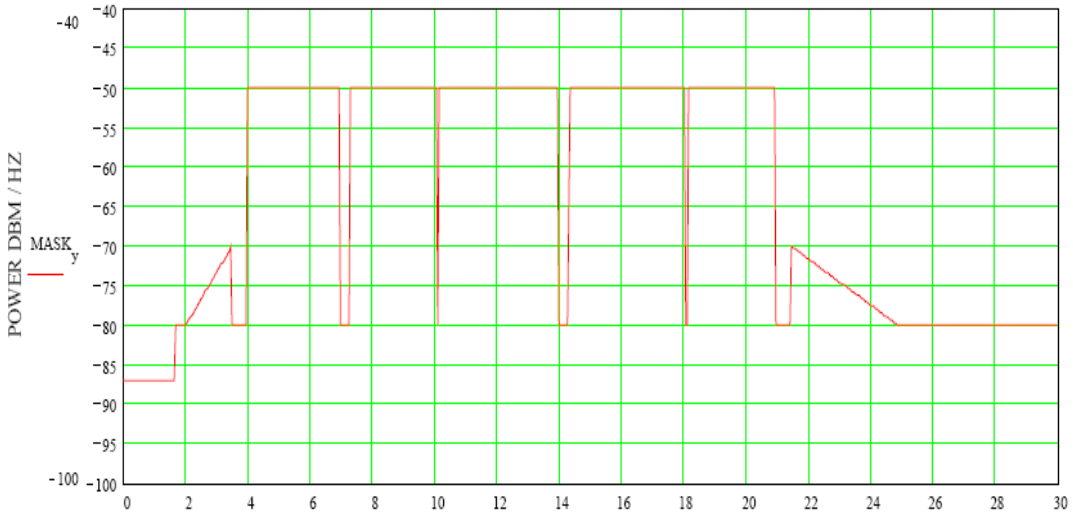


Figure 2. Test Signal PSD Mask

Figure 3 – This shows the levels of power-spectral density used for the joint testing done by ARRL and HomePlug. The notch depth of 30 dB was state of the art at the time. It has been consistently achieved in the production of millions of products. (To put the levels of this graph into perspective, a power-spectral density of -50 dBm/Hz equates approximately to a conducted voltage of approximately 93,000 uV (99.4 dBuV) quasi peak in a 9 kHz bandwidth across 100 ohms.

This technique of protecting the Amateur bands with spectral masks with sufficient filtering has proven successful for both HomePlug and Amateur Radio. With over 20 million HomePlug devices deployed in the United States, ARRL has not received a single report of harmful interference from HomePlug products involving Amateur Radio. This work has served as a model for other industries, such as DSL and HPNA. Spectral masking to protect specific radio services is a mature and proven technology that, if made part of regulations for broadband emitters, would serve to ensure that the rules that govern unlicensed devices have a strong foundation written into the rules on which other industries can build a similar success.

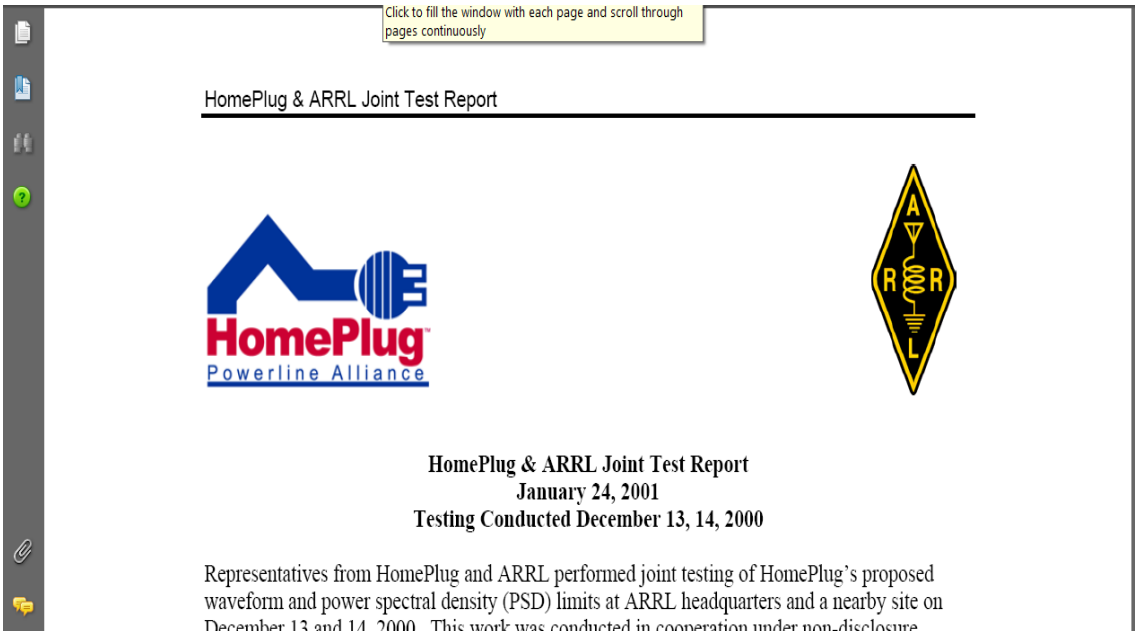


Figure 4 – This joint report by HomePlug and ARRL about their testing of proposed HomePlug protocols documents the results and the reasons that HomePlug felt it necessary to include permanent spectral masks for the protection of Amateur Radio in its product specification. The entire report is provided separately as Exhibit B.

HomePlug has consistently supported notching in its published papers and industry specifications. The following is quoted from a white paper available on the HomePlug web site, simply titled, "HomePlug AV White Paper [6]."

> ***Physical (PHY) Layer***
>
> *The Physical Layer (PHY) operates in the frequency range of 2 - 28 MHz and provides a 200 Mbps PHY channel rate and a 150 Mbps information rate. It uses windowed OFDM and a powerful Turbo Convolutional Code (TCC), which provides* ***robust performance within 0.5 dB of Shannon Capacity****. Windowed OFDM provides flexible spectrum notching capability* ***where the notches can exceed 30 dB in depth*** *without losing significant useful spectrum outside of the notch.*

DS2 (BPL Chipset Manufacturer)

The Access BPL industry has also, in part, followed the principle of developing protection for Amateur Radio. In 2006, after some time of informal discussions, ARRL and DS2, a major manufacturer of BPL-protocol chipsets, worked together at ARRL's Laboratory to document improvements that DS2 had made to its BPL technology. The changes DS2 had made to its products had significantly improved the notching capability of the generation-2 DS2 chipsets.

[6] This is available at http://www.homeplug.org/tech/whitepapers/HPAV-White-Paper_050818.pdf

This testing was documented by ARRL in an article that was featured prominently on ARRL's web site. [7] (DS2 was supportive of the content.) This article outlined the improved communication and cooperation, but more importantly, it showed that DS2's improvements resulted in a product that was capable of a notch depth of 40 dB. A copy of that article is provided separately in this proceeding as Exhibit C. A measurement made in the ARRL Laboratory by ARRL and DS2 staff is shown below in Figure 5.

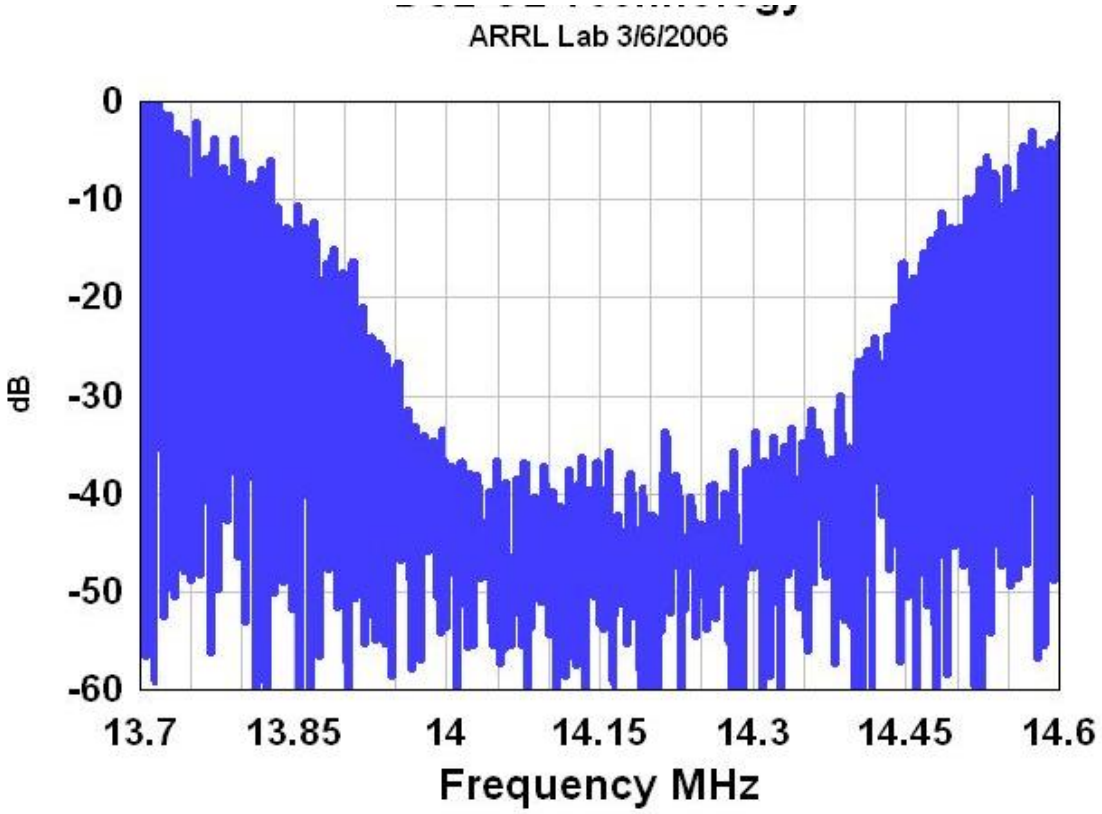


Figure 5 – This 40 dB notching capability was demonstrated to ARRL in the joint testing it did in 2006 with DS2.

DS2 and ARRL have both been supportive of the capability of DS2 chipset modems to achieve 40 dB of notching. The following quotes from DS2 staff appeared in various industry and trade journals:

[7] "League Views BPL Manufacturer's Interference Abatement Efforts with Interest," March 22, 2006, http://www.arrl.org/news/stories/2006/03/22/1/

***Computing Unplugged,* August, 2006, "A BPL Manufacturer Responds to All the Complaints [8]"**

> *"In 2003 (three years ago), DS2 introduced its second Generation powerline chipset, which was the first in the industry to provide speeds up to 200 Mbps, and 40dB programmable notches. These chips have been designed to allow BPL vendors to design equipment that meets FCC requirements, to adequately protect ham radio bands and to provide additional mitigation mechanism in case any isolated interference case is detected in a BPL network. The ARRL lab tested this technology in April this year and issued a favorable review."*

DS2 manufactures the BPL chipsets used by Ambient, Amperion, Corinex, IBEC and others.

Main.Net

Main.Net is the manufacturer of the BPL system formerly used in Manassas, VA. It was also deployed in a number of other areas. (At this time, most if not all of the US Main.net systems have been shut down, or practically so.) Although the resolution of BPL in interference in Manassas was an exceptionally long and difficult process and only partially effective at best while the system was active, Main.Net has learned from these experiences and has significantly improved the notching performance of its current generation product.

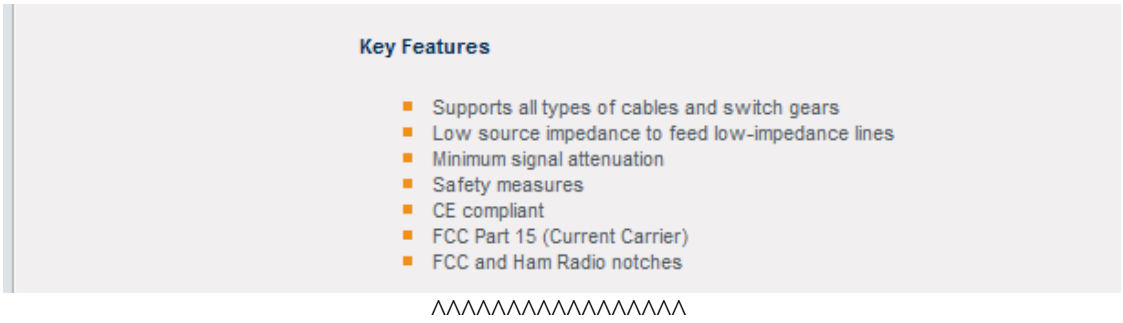


Figure 6 – This excerpt from the MainNet-PLC.com website outlines the technique that Main.Net advertises to its potential customers as an effective EMC solution. "FCC and ham radio notches" are touted by this BPL manufacturer as a key feature.

US FCC BPL Database

The FCC-mandated BPL database maintained by the United Power Line Council also provides evidence that existing BPL systems in the US are almost universally notching the entirety of the HF Amateur allocations.

[8] http://www.computingunplugged.com/issues/issue200608/00001836001.html

The following is a summary table of the present state of the industry BPL database. These data are representative of the state of the reporting problems found in the FCC-mandated database.

TABLE 1: SUMMARY BY ZIP CODE COUNT

Number of ZIP codes with notching in the BPL database	145
Number of ZIP codes for which notching is not specified	8
Number of ZIP codes where listed facilities do not appear to be in operation	25

TABLE 2: BPL SYSTEMS IN OPERATION FOR WHICH NOTCHING OF THE AMATEUR BANDS IS INCLUDED IN THE DATABASE ENTRY

BPL operator	ZIP Codes	Status of notching the Amateur bands or other status
CenterPoint Energy	23	"FOLLOWING FREQUENCIES NOTCHED: 3.5 MHz to 4.0 Mhz 5.3305 MHz to 5.405 MHz 7.0 MHz to 7.3 MHz 10.1 MHz to 10.15 MHz 14.0 MHz to 14.35 MHz 18.0 MHz to 18.168 MHz 21.0 MHz to 21.45 MHz 24.89 MHz to 24.990 MHz 28.0 MHz to 29.7 MHz." Reports from local Amateurs in contact with the BPL-system operator indicate that the system is no longer being used, but still powered up and radiating.
Current Communications Group	69	The database does not specifically note that Current notches the ham bands, but their system uses HomePlug products, which do not use Amateur spectrum.
Designed Telecommunications	2	"The Amateur frequencies have been notched since the network was turned up February 2006"
Habersham EMC	2	"All appropriate Amateur Radio and Public Safety Frequencies are Notched in Compliance with FCC Part 15 Requirements."
First Energy	3	"(P)ower mask used to prevent transmissions on amateur radio frequencies and exclusion frequencies"
Gridline Communications	2	System #1 uses Current Technologies equipment, with HomePlug Amateur notches. System #2 shows at least some Amateur bands are notched.
IBEC	33	"All appropriate Amateur Radio and Public Safety Frequencies are Notched in Compliance with FCC Part 15 Requirements."
Utility.net	11	"All appropriate Amateur Radio and Public Safety Frequencies are Notched in Compliance with FCC Part 15 Requirements." (Note: Utility.net systems are no longer in operation.)

TABLE 3: BPL SYSTEMS IN OPERATION FOR WHICH NOTCHING OF THE AMATEUR BANDS IS NOT INCLUDED IN THE DATABASE ENTRY

BPL Operator	ZIP Codes	Status of notching the Amateur bands or other status
City of Princeton	1	System is not notched, but the BPL operator has informed ARRL that one customer remains on the system, so it must still be included in the database.
French Broad Electric Cooperative	1	Notching status not listed, but the entry indicates that this is a trial for 8 customers
Lebanon Utilities	1	No notches listed, but this system is known to ARRL to have notched Amateur Radio
PowerGrid	3	Database indicates systems only used in Essen demo center and 4 units connected to irrigation pumps in rice paddies.

TABLE 4: BPL SYSTEMS IN THE DATABASE THAT ARE NOT IN OPERATION OR FOR WHICH NO INDICATION CAN BE FOUND THAT THE SYSTEM IS IN ACTUAL OPERATION

BPL Operator	ZIP Codes	Status of notching the Amateur bands or other status
Ameren UE	4	The contact email for the BPL operator results in a failed-mail error message. These systems do not appear to be in current operation.
Amperion	3	The contact email for the BPL operator results in a failed-mail error message. These systems do not appear to be in current operation. When last tested by ARRL, Amperion systems were notching the Amateur bands.
Chelan PUD	1	This system still appears in the BPL database, but the BPL operator has told ARRL by email that the system is not in operation.
City of Manassas	1	The database does not indicate that this generation-1/generation-2 hybrid Main.net system is

		notched, although Manassas Amateurs report that the G2 areas of the system are notched most of the time. Note: As of July 1, 2010, this BPL system is no longer in operation.
Concord Light	1	This system still appears in the BPL database, but the BPL operator has told ARRL by email that the system is not in operation.
Copper Road	7	The contact email for the BPL operator results in a failed-mail error message. These systems do not appear to be in current operation.
Freeport Electric	1	The contact information for the BPL operator is incorrect. Email sent to the address provided is returned as failed mail, unknown user.
Itron	1	The database entry contains no frequency information at all. Status of notching and system unknown. Note: This BPL system is no longer in operation.
Jacksonville Electric Authority	3	This system still appears in the BPL database, but the BPL operator has told ARRL by email that the system is not in operation.
New Visions	4	The contact email for New Visions does not result in a failed-mail error message, but New Visions has not responded to several ARRL email inquiries from information. Local amateurs report that they have never heard the BPL systems in operation on any frequency, Amateur or otherwise. It is

		probable that the majority, if not all, of these systems have never been placed in operation.
PPL Telecom	1	The last vestige of the PPL BPL system was shut down in 2009.
Shpigler Group	1	The BPL operator has informed ARRL that he has reported to UPLC that he is no longer operating this BPL system; however, the entry for this system was never removed by UPLC.

As can be seen in the above tables, there are a number of issues and errors in the BPL database. A complete report of the poor state of the database is separately provided as Exhibit D.

IEEE P1901 BPL standard

In addition to the HomePlug industry specification, the most compelling indication that the BPL industry recognizes the importance of not using the Amateur bands, and for the most part is implementing systems that do not do so, is found in the IEEE standard on BPL protocols and specifications: IEEE P1901, *Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications*. There are several clauses in this standard that are clear about the need to completely avoid the use of spectrum allocated to the Amateur Radio Service.

P1901 provides specifications for several of the BPL protocols in current use. All use variants of orthogonal frequency division multiplexing – essentially a multi-carrier technique that spreads data among multiple carriers, to allow more robust operation in a noisy, hostile environment[9].

Wavelet OFDM in P1901

Table 15.12 in P1901 describes the wavelet OFDM major specifications. The maximum PHY layer transmission rate is described only with "ham" notches implemented, with no forward error correction. As implemented with these non-optional notches for Amateur spectrum, the maximum transmission rate is 220 Mb/s, with 440 Mb/s optional; demonstrating clearly that notching the Amateur bands does *not* have a major deleterious effect on BPL-system performance.

[9] Annex G of P1901™ discusses the impact of noise on BPL system performance.

Clause 15.4.4 describes the transmission spectrum of wavelet OFDM BPL. This clause also states that:

> *"(I)n addition, masking should be applied for all carriers defined at for protection of amateur radio spectrums.* ***These masked carriers are not output at any time****. And other carriers may be masked.*[10]*"*

Notch Depth in P1901

Figure 15-29 and Table 15-14 in P1901 describe typical masking levels. In P1901, these are listed as examples, showing that the power spectral density in the un-notched spectrum is at a level of -50 dBm/Hz, and in the notches at a level of -80 dBm/Hz[11].

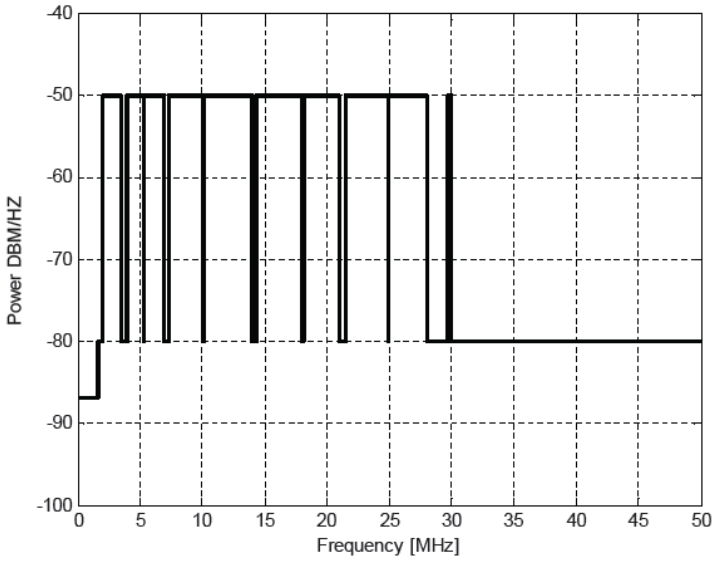


Figure 14-21—FFT Transmit Spectrum Mask for North America

The transmitted power spectral density must be below the limits specified. Measurements are made using equipment conforming to IEC CISPR 16-1 specifications with a resolution bandwidth of 9 kHz for frequencies below 30 MHz and 120 kHz for frequencies above 30 MHz and a quasi-peak detector. The transmitter must be configured to transmit continuously.

Figure 7 – This Figure from the P1901standard shows the implementation of spectral masks to protect the Amateur bands. These notches are specified at -35 dB in the language of the standard.

[10] Interestingly, the Amateur band notching is defined and discussed in this section, but not the notching mandated by 47 C.F.R. Section 15.615(f)(1).

[11] For comparison, across 100 ohms, the impedance specified for conducted measurements in the P1775 BPL EMC standard draft, -50 dBm/Hz corresponds to a conducted signal level of 1000 uV.

Specific Notch Depth in P1901

In addition to the levels shown in the examples, P1901TM has a clause that clearly shows that the technology is capable of 35 dB of notch depth and that such notching "significantly reduces interference to other systems":

15.4.5 Notch and power control

> *Controlling two or more carriers using the wavelet OFDM creates various power level bands of up to* ***-35 [dB]****,which significantly reduces interference to other systems (e.g. Short wave radio) using the same frequency bands.*

It would be reasonable to have FCC regulations harmonized with the requirements of the P1901 BPL-industry standard.

P1901 Documents Notch Depth Achieved in Practice

The notch depth that is achievable in practice is seen in Figure 8 below, an example of notch depth in BPL products included by the P1901 consensus committee as a measured example in the standard. This shows that BPL technology is capable of notch depth of at least 45 dB, at least in this measurement chosen by the P1901 consensus body to be representative of the performance of BPL systems.

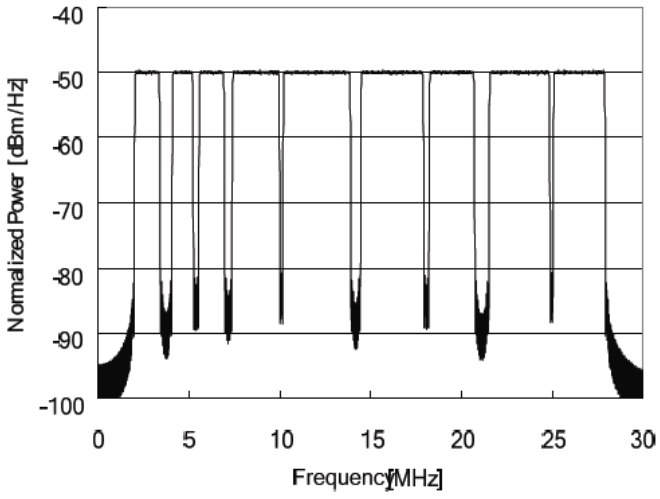


Figure 15-30—Example transmission spectrum of Wavet OFDM with notches (upto 30 [MHz])

Figure 8 – This Figure from the P1901 standard shows an actual and typical measurement of the notching implemented per the requirements of the standard.

Ofcom Report on PLT

On June 21, 2010, the UK Office of Communications (Ofcom), released a report it had commissioned, titled *The Likelihood and Extent of Radio Frequency Interference from In-Home PLT Devices.* [12] A copy of this report in its entirety is being provided as Exhibit G.

The conclusions reached in this report unambiguously confirm that BPL systems will result in widespread harmful interference to Amateur, international shortwave broadcast, FM narrowband and FM broadcast use unless existing practices of notching and adaptive power control are placed into formal regulations. To quote the report:

> *We have concluded that if uptake increases in line with our market forecasts, there will be **a high probability of interference** to some existing spectrum users at both HF and VHF by 2020 if PLT device features do not change from those currently implemented. (Emphasis added.)*

Excerpts from the Executive Summary explain this in more detail, as do relevant portions of the body of the report.

> *Executive summary (emphasis added)*
>
> * * * * *
>
> *Ofcom has received complaints of interference caused by PLT devices and has requested this study. The majority of PLT devices on the market today operate at HF frequencies and, while they are not intended to radiate, there is evidence of interference to other HF users which has resulted in a number of complaints to Ofcom. While most of these complaints have been resolved, Ofcom is concerned that the problem may grow as the number of PLT devices deployed increases over time. Higher data rate PLT devices operating up to 300MHz have also started to emerge in the UK market and so potential interference at VHF is also a concern.*
>
> *Ofcom has asked PA to assess the likelihood and impact of RF interference from in-home PLT devices over the next 5 to 10 years.*
>
> ***Our results show that users of sensitive radio systems may increasingly suffer interference from PLT devices***
>
> *In this study we have taken a statistical approach to quantifying the probability of interference occurring as PLT devices become more commonplace. We have concluded that if uptake increases in line with our market forecasts**, there will be a***

[12] The report is also available in its entirety at http://www.emcia.org/documents/pltreport.pdf.

high probability of interference to some existing spectrum users at both HF and VHF by 2020 if PLT device features do not change from those currently implemented.

However, within this timescale, ***in addition to the existing practice of notching International Amateur Radio Union (IARU) bands,*** *interference mitigation features such as power control and smart notching are expected to have been implemented in PLT devices. Our results indicate that the introduction of these features will be enough to reduce interference to negligible levels in the majority of these cases.*

From Page 3 of the Executive Summary:

It is important that mitigating features are implemented in future PLT devices.

* * * * *

While power control and smart notching are already part of the product roadmaps of the PLT vendors that we consulted as part of this study, ***we recommend that where possible the introduction of these features is formalised to ensure that their introduction can be relied upon.***

A table in the Executive Summary of the Ofcom report, shown below, summarizes the impact of BPL devices and systems operating under the existing un-notched paradigm used in the current BPL devices deployed in the UK against the much improved impact of devices operating under the notching (Amateur) and power-control parameters recommended in this report:

A summary of our results showing probability of interference is given in the table below:

		2010	2015	2020
Note: Interference effects are estimated at limit of wanted signal / range				
HF - Shortwave broadcast listener				
	Power control only	High	High	High
	With power control and notching	Negligible	Negligible	Negligible
HF - Amateur radio				
	Default IARU notches only	High	High	High
	With IARU notches and power control	Negligible	Negligible	Negligible
HF - Aeronautical groundstations				
	Power control only	High	High	High
	With power control and notching	Negligible	Negligible	Negligible
VHF - FM broadcast listener				
	No mitigation	-	High	High
	With notching	-	Low	Medium
VHF - Narrowband FM				
	No mitigation	-	High	High
	With notching	-	Medium	Medium
VHF - Aeronautical Navigation				
	No mitigation	-	High	High
	With notching	-	Low	Low

Probability of Interference for user working at limit of wanted signal range.

Table 5: This shows the Ofcom conclusions about the probability of BPL interference to Amateur Radio and other licensed spectrum users with and without notching and power-control.

Another table in the body of the report provides additional detail:

	2010	2015	2020
Note: Interference effects estimated at limit of wanted signal / range			
Shortwave broadcast listener	High probability of interference with power control alone Negligible probability of interference if smart notching is added.	High probability of interference with power control alone Negligible probability of interference if smart notching is added	High probability of interference with power control alone Negligible probability of interference if smart notching is added
Amateur radio	High probability of interference with default IARU notches alone Negligible probability of interference if power control is added	High probability of interference with default IARU notches alone Negligible probability of interference if power control is added	High probability of interference with default IARU notches alone Negligible probability of interference if power control is added
Aeronautical groundstations	High probability of interference with power control alone Negligible probability of interference provided notching and power control are applied	High probability of interference with power control alone Negligible probability of interference provided notching and power control are applied	High probability of interference with power control alone Negligible probability of interference provided notching and power control are applied

Table 6: This explains the EMC probability of BPL in more detail.

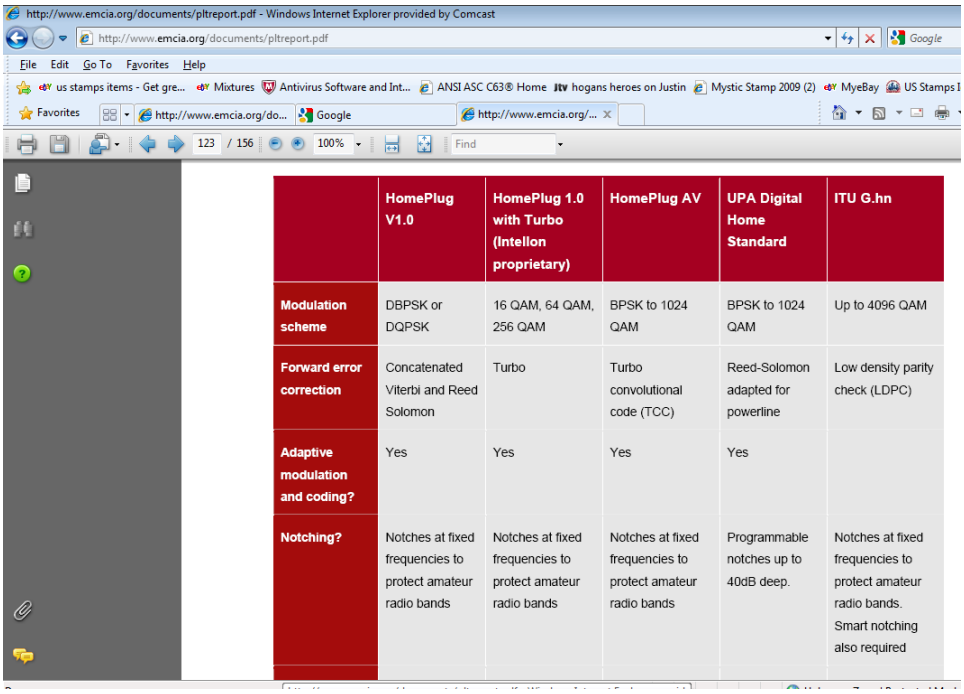
Notch Depth in the Ofcom Report

Notch depth is discussed in numerous places in the Ofcom report.

The latest generations of each of today's three main standards are very similar and have the following
features:

- An OFDM waveform
- Data rates around 200Mbps
- Frequency range from 2 to 30MHz +/- 2MHz
- Default notches applied in the IARU bands of 30 to 40dB in depth.

Table7: Ofcom has determined that notch depth of deployed devices in the Amateur bands is typically 30 to 40 dB.



	HomePlug V1.0	HomePlug 1.0 with Turbo (Intellon proprietary)	HomePlug AV	UPA Digital Home Standard	ITU G.hn
Modulation scheme	DBPSK or DQPSK	16 QAM, 64 QAM, 256 QAM	BPSK to 1024 QAM	BPSK to 1024 QAM	Up to 4096 QAM
Forward error correction	Concatenated Viterbi and Reed Solomon	Turbo	Turbo convolutional code (TCC)	Reed-Solomon adapted for powerline	Low density parity check (LDPC)
Adaptive modulation and coding?	Yes	Yes	Yes	Yes	
Notching?	Notches at fixed frequencies to protect amateur radio bands	Notches at fixed frequencies to protect amateur radio bands	Notches at fixed frequencies to protect amateur radio bands	Programmable notches up to 40dB deep.	Notches at fixed frequencies to protect amateur radio bands. Smart notching also required

Table 8: In the Ofcom report, the notch depth of the UPA specification, the BPL technology most common in the UK, is specified as 40 dB.

Measurements of Actual Device Notch Depth in the Ofcom Report

The following figures show the measured notch depth of various BPL modems tested to prepare the Ofcom report. (These Figure numbers and captions are as shown in the Ofcom report.)

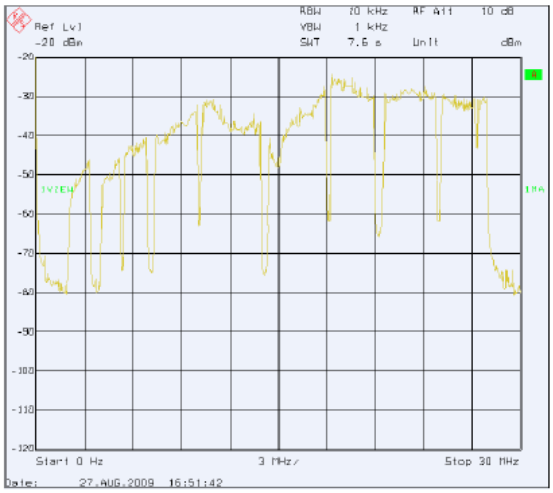


Figure 34 – Observed spectrum of a Belkin Homeplug AV PLT device

Figure 9 – This shows the notch depth that Ofcom measured of a typical HomePlug AV BPL modem.

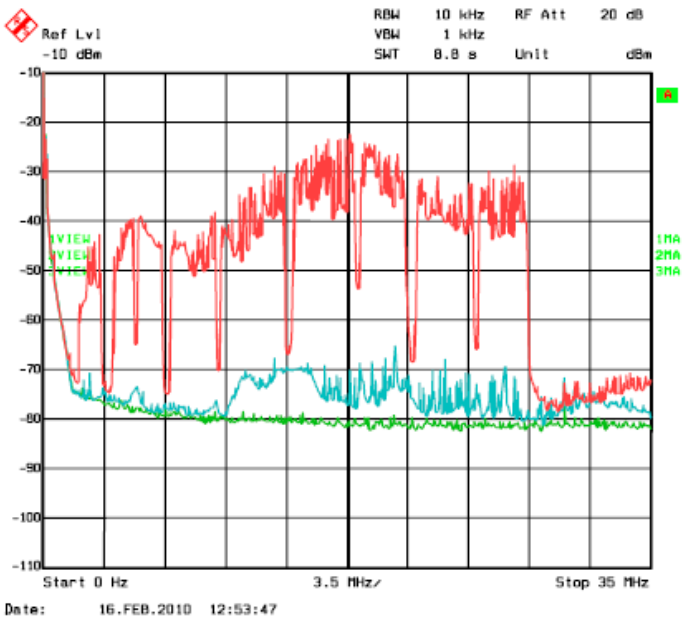


Figure 37 -Frequency response of Belkin Homeplug AV modem

Figure 10 – This shows another Ofcom measurement of a typical BPL modem.

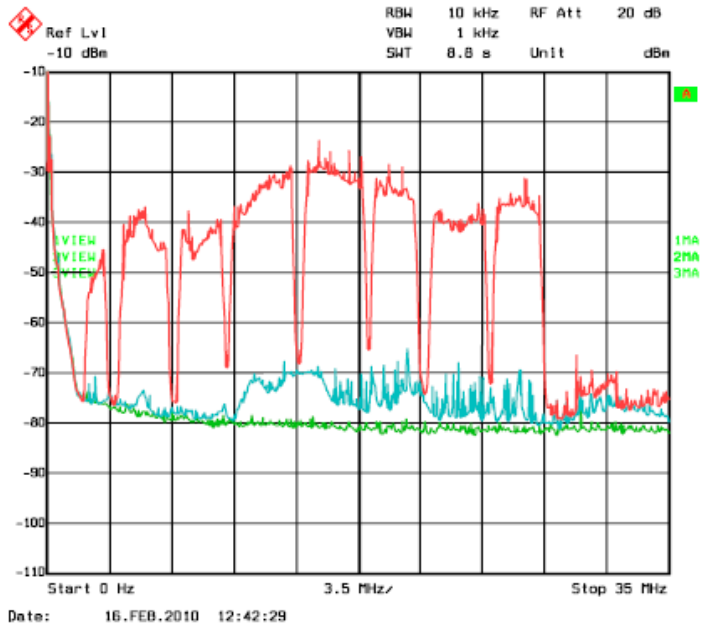


Figure 38 – Frequency response of the Comtrend 902 modem

Figure 11 – This is another modem that Ofcom measured.

The notch at 21MHz was examined more closely on both modems as shown in Figure 39 and Figure 40.

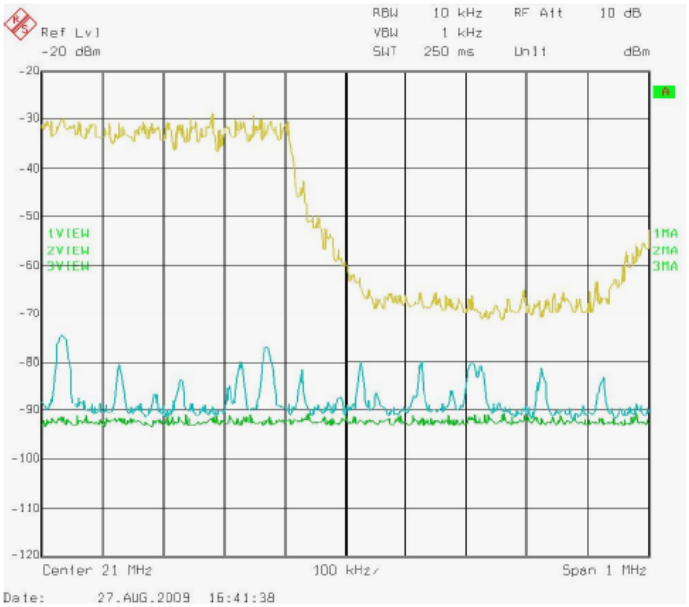


Figure 39. 21MHz notch on Belkin Homeplug AV modem

Figure 12 – This shows a view of the notch depth of a typical HomePlug modem over a portion of its frequency range.

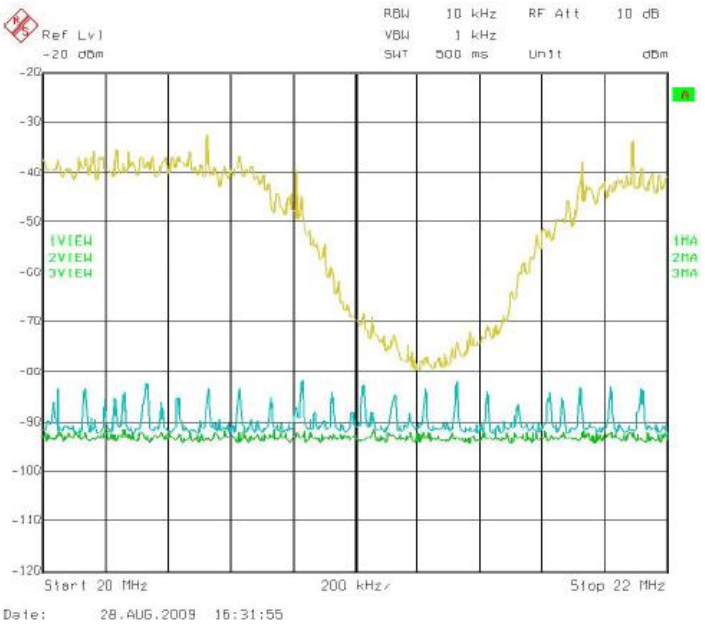


Figure 40. 21MHz notch on Comtrend 902 modem

Figure 13 – This shows a view of the notch depth of a second and typical HomePlug modem over a portion of its frequency range.

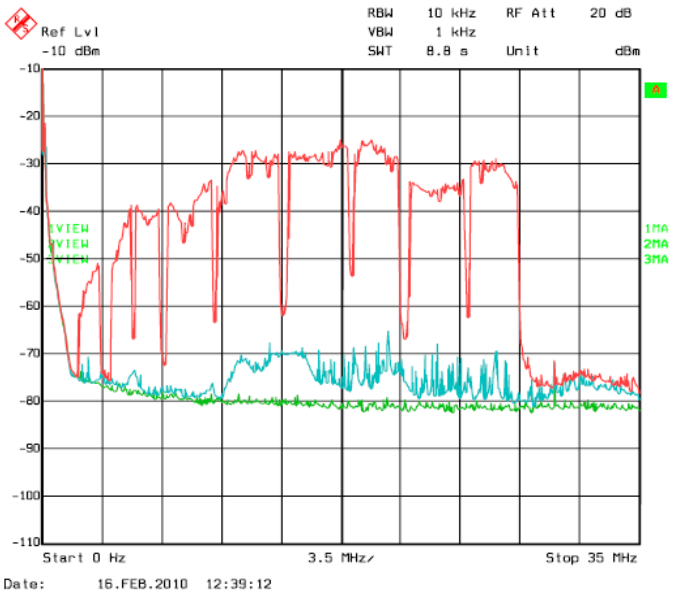


Figure 41 - HF spectrum from Belkin 1Gbps PLT adapters

Figure 14 – This shows a view of the notch depth of a high-speed 1 Gbps modem over the HF frequency part of its operating range.

FIGURE 2-11

Differential-mode and common-mode currents inside and outside a house

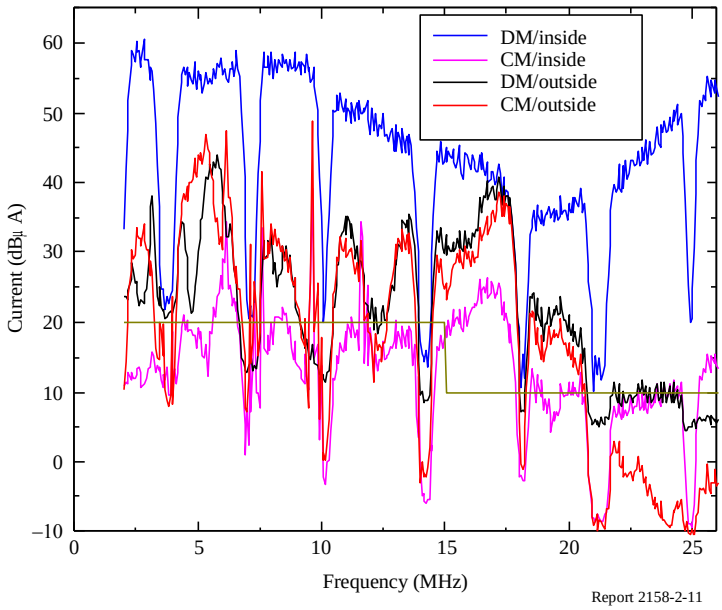


Figure 15 – This is a measurement provided to the ITU-R, included in its report on the impact of BPL on HF and VHF radiocommunications. See the section of this report that immediately follows.

Notch Depth in ITU-R Reports and Recommendations

In an ITU-R report from September 2009, Report ITU-R SM-2158 [13], *"Impact of power line telecommunications systems on radiocommunication systems operating in the LF, MF, HF and VHF bands below 80 MHz,"* in addition to concluding that "(b)ecause electrical power lines are not designed for the transmission of high data rate signals, PLT signals on electrical power lines have the potential of causing interference to radiocommunication services," the report also specifies a protection level of 0.5 dB as being necessary for stations in the Amateur Radio Service.

The report correctly notes that "Amateurs frequently operate at or near to the minimum signal-to-noise ratio for effective communication. Limits of communication are generally determined by the received signal strength in relation to the background noise. Amateurs manage to communicate effectively with a signal-to-noise ratio of some 6 dB for voice communications in a nominal 2.4 kHz bandwidth and as low as minus 6 dB (related to the same bandwidth) for Morse code or spectrum-efficient data modes."

Noise Levels

The ITU also has published a Recommendation, P.372 [14], which describes the median values of the levels of man-made noise in business, residential, rural and quiet rural environments. Stations operating in the Amateur Radio Service have frequency agility and, with the exception of established networks of a large number of stations, taking place on a particular frequency at a particular time, and Amateur systems such as repeaters, which are assigned a specific frequency by a coordination process, Amateurs typically select an operating frequency band, or a frequency within a band, based on propagation and the presence or absence of interfering signals.

The levels described in P.372 are *median* levels, with half of the measurements on which those reported levels were based being higher and half being lower. Amateur licensees typically choose a frequency within a band based on their assessment that the particular frequency has a minimum level of noise and/or other interference. The median levels of man-made noise in quiet rural areas are typically representative of the minimum noise levels to be encountered on Amateur bands, even in residential neighborhoods.

Some proponents of BPL have argued that noise levels are increasing over the levels of man-made noise that were used to prepare the ITU-R P.372 Recommendation, thus justifying increases in permitted noise levels. This premise is flawed on its face, because using each increase in noise level to justify the next increase in noise level would sooner rather than later, result in having spectrum that is unusable for any practical purpose. This is especially true for frequencies that have the unique characteristic of propagating for

[13] This report is available from the ITU from its web page, http://www.itu.int.
[14] The present version of this Recommendation is P-372.10. The reported noise levels over the frequency range of interest to analyze BPL have not changed from what is published in earlier versions of this document. The Recommendation is available from the ITU from its web page, http://www.itu.int.

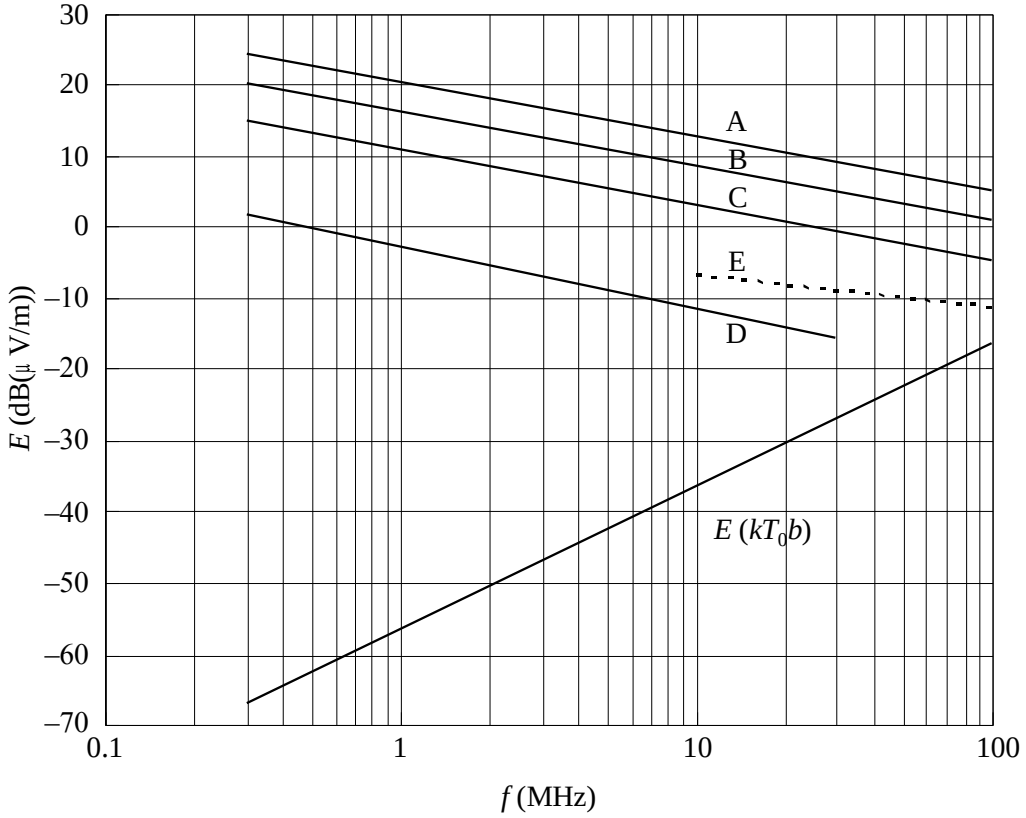
worldwide distances via refraction through the layers of the ionosphere returning signals radiated skyward back to the earth hundreds or thousands of miles away.

The ITU-R Report SM-2158 report disagrees with the suggestion that noise levels are increasing. The Report states (emphasis added):

> ***A1.1.3.2 Updated noise measurements for Europe***
>
> *Recent studies undertaken by MASS consultants in the United Kingdom used modern technology to obtain large data sets enabling good statistical analysis. Methods have been developed for obtaining the noise figure, producing data for the eventual modification of the information in the Recommendation. A method was also developed for determining the statistical characteristics of the impulsive component; see Report ITU-R P.2089. These results have been entered into the Radiocommunication Study Group 3 noise databank along with similar results from studies carried out in Germany.*
>
> *The levels of man-made noise found in both these studies are of the same order of level as those in the Recommendation,* ***leading to the view that there have not been major changes in the past 30 years*** *– perhaps increased electrical usage has been compensated by improved suppression techniques. However more results are needed before any revision to the Recommendation could be considered with confidence.*

It can therefore be concluded that the levels of man-made noise described in P.372-10 provide a reasonable estimate of the current levels of man-made noise and a reasonable basis to use in setting limits and protection levels.

FIGURE 3-1 EQUIVALENT FIELD STRENGTH OF MAN-MADE NOISE (B = 9 000 HZ)



Environmental categories:

Curve A: City — Curve D: Quiet rural

Curve B residential — Curve E: Cosmic noise

Report 2158-3-01

Figure 16 – This graph from the SM-2158 report shows the median values of the levels of man-made noise, as derived from P.372, expressed in electric field strength.

TABLE 3-4

Total protection requirements based on the 0.5 dB criterion – maximum field strength at 10m from a PLT installation

Frequency band (MHz)	dB(μV/m) in 6 kHz			
	Business	**Residential**	**Rural**	**Quiet rural**
1.8	18.5	13.5	8.5	–7.5
3.5	16.5	12.5	5.5	–8.5
7	14.5	9.5	4.5	–9.5
10	12.5	8.5	3.5	–5.5
14	11.5	7.5	2.5	–6.5
18	11	7	2	–7
21	10	6	0.5	–8.5
24	9.5	5.5	0	–9
28	9	5	–0.5	–9.5
50	8.5	4.5	–1.5	–10
70	8	4	–2	–10.5

Table 9 – This shows the total field-strength values (BPL plus ambient noise) at 10 meters distance that will meet the 0.5 dB protection value specified in the ITU-R SM-2158 report.

Table 9 above represents the total noise, including existing ambient man-made noise that could be present when measuring a BPL system *in-situ*. The SM-2158 report correctly notes that the actual emissions from BPL systems would need to be 9.14 dB lower than the existing ambient noise levels in order to meet the 0.5 dB protection criterion.

The following is quoted from the SM-2158 report:

3.2.3.1 Fade margin and the 0.5 dB protection criterion of HF amateur radio

For this reason, the maximum allowable increase in the total noise floor due to PLT emissions should be 0.5 dB. For the increase not to exceed 0.5 dB, the average noise field strength radiated by the power network at 10 m distance must be 9.14 dB below the pre-existing noise level.

3.2.3.3 Acceptable noise floor levels

From the criteria in § 3.2.3.1, the acceptable increase in noise floor generated by PLT is 0.5 dB greater than the figures derived from the graph in Fig. 3-3. It should be noted that the requirement is independent of the bandwidth of the received signal: to correlate with the usual measurement bandwidth of 9 kHz, the figures can be increased by 1.8 dB. Table 3-4 lists the field strength acceptable at 10 m from a PLT installation to meet. Figures for 70 MHz are obtained by extrapolation from Fig. 3-3.

Required notching and notch depth

The requirements of protection necessary to protect radio services from harmful interference that are described in the SM-2158 report would form an excellent basis on which to set limits. BPL emits at a fairly uniform level across a wide frequency range. Some BPL systems operate on a near-continuous basis and for access BPL deployed on overhead power lines, as demonstrated in other ARRL filings into this proceeding (describing FCC and other tests), BPL emits at or near the emissions limits for long distances down lines on which it is deployed. For all of these reasons, it is clear that the ubiquitous deployment of BPL, especially access BPL on medium-voltage distribution lines, would result in interference levels that exceed the protection criteria anywhere that BPL is deployed.

Stations operating in the Amateur Radio Service are common in residential environments. Those stations are licensed to operate from unspecified mobile and portable locations, and do on a regular basis. For these reasons, the only practical way to ensure that the required protection criterion is met is to have spectral masks applied to BPL for the spectrum allocated to the Amateur Radio Service.

The levels shown in Table 9 above (Table 3-4 in the SM-2158 report) 6 are specified for 10 meters distance. Current FCC regulations set limits at 30 meters distance. Over most of the frequency range used by BPL, a technically correct extrapolation has been shown to be 20 dB/distance decade[15]. This means that the levels shown in Table 9 would first have to be reduced by 9.1 dB to account for a 0.5 dB noise increase and then by 9.54 dB to account for the differences between 10 and 30 meters (20 dB/decade) to determine what field strength would meet the protection criterion. If applied to the FCC limits for BPL, assuming a 20 dB/decade extrapolation, this would require a 34 dB notch depth.

.

If the present FCC extrapolation were applied to BPL, the BPL emissions are higher, so to attain the the required protection criterion, a notch depth of for radiated-emissions testing of 43 dB would be necessary.

ITU-T G.9960

[15] See *Rationale for the Abandonment of the Use of a Single 40 dB/decade Extrapolation Factor for Radiated Emissions Measurements Made Below 30 MHz*, provided to the Commission on 11 January 2010.

Notch depth is also addressed in the ITU-T document, G.9960, "*Unified high-speed wire-line based home networking transceivers – Foundation."*

Table 7-38/G.9960 – Parameters of Limit PSD mask for the 100MHz-PB bandplan

Parameters	Frequency (MHz)	PSD (dBm/Hz)	Note/Description
f_{L1}	1.1	−90	Additional reduction below 1.1 MHz is to reduce crosstalk into ADSL
f_{L2}	1.8	−80	Coincides with the Amateur radio band
f_{L3}	2.0		
$f_{L3}+\Delta F$	2.0 + ΔF	−50	ΔF is an arbitrary small positive value
f_{HAM}	As defined in Table D-1	−80	Additional notches could be added based on regional regulations
$f_{H1}-\Delta F$	30 – ΔF	−50	ΔF is an arbitrary small positive value
f_{H1}	30	−80	ΔF is an arbitrary small positive value
$f_{H2}-\Delta F$	100 – ΔF		
f_{H2}	100	−100	
f_{H3}	110	−130	
f_{H4}	120	−140	
NOTE – All sub-carriers above $f_{H2}-\Delta F$ shall not be used for transmission (neither data nor any auxiliary information).			

Table 10: This table from G.9960 specifies a notch depth of 30 dB for BPL devices.

Additional Testing Showing Typical Notches in Deployed Systems

The BPL industry has generally implemented notching in its US deployments. Based on recent ARRL testing, the small BPL system previously deployed by Ambient in Briarcliff Manor, NY [16] in its final form was adequately notched in the Amateur bands and was operating at the FCC limits. Not surprisingly, this has effectively controlled harmful interference to Amateur Radio. Fixed and mobile Amateur stations can operate successfully from that area. (The depth of the notches was approximately 35 dB, consistent with the present state of the art of BPL notch filtering.)

In its earlier deployments, IBEC, a BPL manufacturer deploying BPL in rural areas, diligently followed the band plan it filed into the industry BPL database, notching all Amateur spectrum in its deployments. Attached as Exhibit E is a report commissioned by IBEC, whereupon it had implemented notches for the Amateur bands in an IBEC deployment in Cullman, AL. This report, performed by a licensed Amateur in Alabama, consulting for IBEC, concluded that the deployed system exhibited no significant increase in noise levels within the Amateur bands.

[16] In its latest 6-month report required by its Experimental license to operate that system, Ambient reported that "(t)he Company has continued its ongoing test program at its test site in Westchester County, New York since the grant of its original STA in June 2002. In December of 2009, testing of the second generation BPL equipment reported in prior progress reports at this location was completed and the equipment was removed from service. When the Company commences testing of new or modified BPL equipment, it will notify the Commission and file a report confirming compliance with Sections 15.109 and 15.209 of the Commission's rules, as applicable."

This is consistent with ARRL's staff findings in the deployments of BPL in a number of areas where the Amateur bands were universally notched in a deployment. [17] In those areas, with notch depth of approximately 35 dB, BPL noise could be heard *weakly* only in the *immediate* vicinity of some of the BPL injection points.

Demonstration by a BPL Manufacturer of the Effectiveness of Universally Implemented Notches for the Amateur Bands

IBEC also initially completely notched the ham bands in its deployment in the Central Virginia Electric Cooperative in and around Lovingston, VA, in preparation for testing done by local Amateurs in that area. The results of testing by local Amateurs, which did not include a measurement of notch depth, are included with this report as Exhibit F.

Although notch depth was not measured during that evaluation testing, the local Amateurs reported that the universal notch filtering implemented by IBEC system-wide at that time in preparation for this testing was effective in preventing widespread interference problems involving Amateur Radio.

On September 20, 2007 IBEC also demonstrated this universal notching to ARRL. Brent Zitting, an employee of IBEC met with the author of this paper at IBEC's BPL installation near Lovingston, VA to evaluate the BPL system in operation there. What was seen at the time was that (in areas where the BPL system did not exceed the FCC emissions limits), the notching as implemented was very effective at preventing widespread harmful interference problems involving Amateur Radio.

Zitting and the Author did find a number of areas where the emissions were measured significantly above the FCC emissions limits. In these areas, although the notch depth appeared to be approximately 35 dB, the noise levels in the protected spectrum were increased by 10 or more dB over the ambient noise levels. Zitting observed this and indicated that IBEC would look into this and correct any problems.

BPL Industry Not Consistently Following Industry Standards Practices

Unfortunately, contrary to the provisions in the IEEE P1901 standard, and its early assurances to ARRL and local Amateurs in its Virginia deployment area, IBEC has stopped following industry practice with respect to notching the Amateur bands, despite the positive EMC results it had in its Virginia system when universal notching was employed. This is a clear indication that, industry assurances notwithstanding, and even with IEEE standards in place that require that Amateur bands not be used for BPL, without a mandate in regulations that mirrors this industry-standard practice, some BPL operators will not follow industry standards and will deploy systems that cause interference to Amateur Radio operation.

[17] This includes the BPL systems operating in Briarcliff Manor, NY and Houston, TX. It also includes the systems that were operating in Little Rock, AR; Springfield, MA, now decommissioned.

As demonstrated by recent interference complaints and ARRL testing, IBEC has discontinued the practice that it had used to demonstrate that its notching resulted in systems did not cause harmful interference to Amateur Radio. After this demonstration, in contradiction to its entries in the BPL database, IBEC has chosen to use the Amateur spectrum its database entries indicate that it is not using. The result is predicable – in the BPL system deployed by IBEC in the Central Virginia Electric Cooperative, interference levels on the Amateur bands are strong over the entire service area.

IBEC has, to a degree, implemented notching in and around fixed Amateur stations that have filed formal complaints, but the local Amateurs note that the process of trying to implement notching on a case-by-case basis has been a difficult and iterative one, sometimes taking months to implement. Once notching is implemented, if a new customer signs on to the IBEC service near the licensed Amateur, based on a report of an Amateur in the Lovingston area, the process must be repeated again and again.

Local Amateurs have also complained to IBEC that HF mobile operation is no longer possible in the remainder of the system. IBEC's response has been to tell the Amateurs that there is nothing IBEC can do about interference to mobile operation. This is, of course, incorrect, as there is nothing in the FCC rules that specifies that protection from harmful interference must be provided only to fixed stations. In fact, the FCC rules specify a level of protection that is expected to be applied to mobile operations.

Figure below shows a measurement taken by ARRL Laboratory Manager Ed Hare, at the location of one of the complainants, W4BDR, in Afton, VA. Although this location was at least 30 meters from any overhead power line in the area, as can be seen, *the level of BPL noise outside the notches is greater than +50 dBuV/m, quasi peak, in a 9 kHz bandwidth*. The notch depth as seen in this test shows at least 35 dB notching is in place on two Amateur bands.

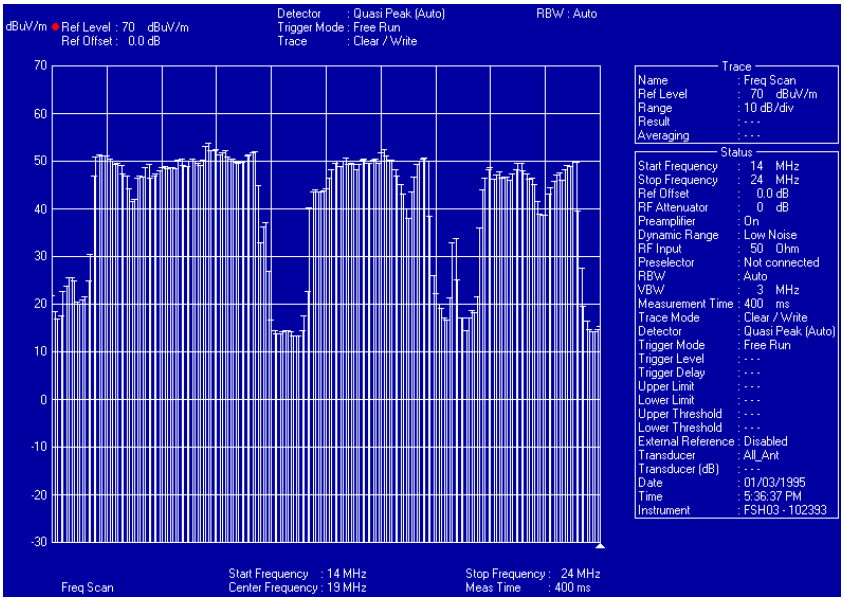


Figure17 -- This measurement of the spectrum from 14 to 24 MHz, made at the station location of W4BDR, in Afton, VA shows the very strong emissions from the BPL system installed near his station. The measurement point was approximately 30 meters from the nearest overhead line carrying BPL. Although a few of the strongest Amateur signals on two of the bands are seen, it is also evident that a notch depth of 35 dB was easily achieved by this system.

If this system were operated at a level that resulted in a field strength of 29.5 dBuV/m at 30 meters distance (and thus at the licensees station location), this 35 dB notching would be effective at preventing harmful interference.

This is all relevant to the principle that, as evidenced by industry standards and entries by diligent companies into the BPL database, notching in the Amateur bands in the U.S. and internationally is an achievable recognized and necessary practice that controls harmful interference. IBEC used this technique to obtain good publicity from ARRL and local Amateurs about the effectiveness of notching, and then subsequently stopped using the practice in the universal way it had demonstrated.

If this IBEC/CVEC system were operated in compliance with the emissions limits, using the technique demonstrated by IBEC to its own consultant, to ARRL staff and to local Amateurs in the area, it would operate like many other BPL systems in the U.S. and avoid major harmful interference problems involving Amateur Radio.

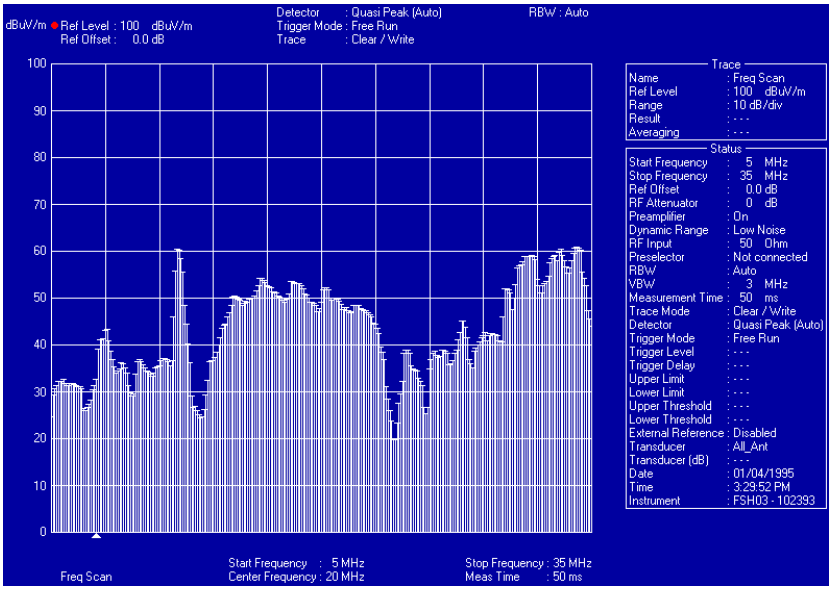


Figure 18 -- This measurement, taken near the CVEC corporate headquarters, shows the spectrum from 5 to 35 MHz. The measurement was made at a distance of 30 meters slant range from the overhead line, using an EMCO 6502 active loop and a Rhode and Schwarz handheld spectrum analyzer, using a quasi peak detector. The measurement

bandwidth of the instrument was set to automatic, with a measurement bandwidth of 9 kHz below 30 MHz and 120 kHz above 30 MHz.

In Figure 18 above, notches for the Amateur bands are not evident.

Solutions

The testing ARRL has done with the BPL industry, the testing done by independent entities, the statements by the BPL industry, the BPL-industry specifications such as HomePlug, the findings of FCC staff in its measurements and BPL consensus standards all lead to the same conclusion: It is both practical and necessary to avoid the use of the Amateur bands in the design and specification of BPL systems. Those systems that have followed the industry's own standards and done so have, from an EMC perspective, been successful. The Commission's Rules should be modified to incorporate this necessary regulatory restriction, in order to protect licensed services.

Across the board, testing done by ARRL, BPL manufacturers and independent entities show that notch depth in the neighborhood of 35 dB is easily achievable, with 40 or more dB being more typical of the most robust designs.

Based on the information in the BPL database and field experience, most of the present Access BPL deployments in the US are using the improved technology of 40 dB notching developed by DS2 or are using HomePlug technology, with fixed notches in the Amateur bands.
It is clear from looking at the measured field strength and notch depth from a number of authoritative studies of BPL devices and systems that a combination of a correct extrapolation factor based on 20 dB/decade in the region beyond wavelength/2pi from radiating BPL systems and a mandated notch depth of 35 to 40 dB provides the required protection criteria indicated by the ITU-R in its SM-2158 report.

This is no coincidence. When various scientific study and method converges on an answer when approached from widely different directions, it is good science that can be relied upon to create good regulations and standards that can facilitate coexistence between systems that, without such good science, are fundamentally incompatible. This has been confirmed by ARRL testing in a number of BPL areas. In those areas where notching of the Amateur bands has been employed, using the state-of-the-art notch depth shown in many measurements documented in this report, these notched BPL systems have not caused widespread harmful interference to stations in that area operating in the Amateur Radio Service.

Good regulations will provide good guidance to the BPL industry about how to more successfully design and deploy BPL systems. A level of 35 to 40 dB notch depth specified for future BPL designs is well within the capabilities of modern BPL equipment and is supported by industry standards and specifications and ongoing technical development. Incorporating this into the FCC rules would serve as a catalyst for continuing improvements, helping the BPL industry be more successful, protecting

licensed spectrum users and furthering FCC goals of making the maximum possible use of available spectrum.

Other Exhibits, provided as separate files

Exhibit B – Joint ARRL/HomePlug report
Exhibit C – DS2 visits ARRL article
Exhibit D – BPL database discrepancy report
Exhibit E – IBEC report on notching
Exhibit F -- Albemarle ARC testing of IBEC system near Lovington, VA
Exhibit G - Ofcom report