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November 28, 2005

Dr. Robert McCaughern
Director General Spectrum Engineering
Industry Canada
300 Slater Street
Ottawa, ON
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Subject: Radio Amateurs of Canada Response to Canada Gazette Notice SMSE-005-05 dated 2005-07-30 Consultation Paper of Broadband over Power Line (BPL) Communication Systems

Dear Dr. McCaughern;

Radio Amateurs of Canadian (RAC), the national organization representing some 50,000 licensed Canadian amateur radio operators, appreciates the opportunity to comment on this important document.

RAC was an active participant in the Radio Advisory Board of Canada (RABC) Joint Working Group responsible for replying to this Gazette notice. Although RAC generally concurs with and supports the RABC's comments that have been submitted for your consideration, RAC has added comments on it's RABC ballot for Industry Canada's attention.

GENERAL COMMENTS

RAC appreciates that BPL is a developing data transmission and telecommunications technology that may benefit both the Canadian public and Canadian power utilities. RAC is concerned that BPL developments and trials have shown that BPL has great potential to interfere with radiocommunication services in the LF, MF, HF and Low VHF bands. Of particular importance to RAC is the MF/HF band from 1.7 to 30 Mhz. These frequencies are unique; they are the only part of the spectrum which supports world-wide communications without intermediate infrastructure; they ~~and~~ must be preserved. Amateur radio operators use ~~uses~~ these frequencies for long distance weak signal communications on a daily basis.

RAC observes that the demarcation between telecommunication and radiocommunication systems is becoming blurred as technological advances increasingly enable their merger. RAC sees Access BPL as a data and telecommunications technology whose distribution system (over power lines) has demonstrated severe and continuous interference to radio services in the spectrum 2 to 80 MHz. While the Department is approaching the development of interference-reducing measures and equipment/system standards from the perspective of the Radiocommunication Act, RAC is unclear on the exact Canadian regulatory framework governing BPL deployment and operations and the impact that this framework should have for both Canadian radio spectrum users and BPL Access service providers.

Access BPL is competing with other Internet Access service providers. These other providers must provide, at their own cost, the infrastructure for Internet access by means such as wireless, cable or satellite. These services are non-interfering; that is, they co-exist with other radio services without creating noticeable interference. Most BPL systems are invasive, and capable of disrupting other radio services.

Further, the electrical power distribution system is part of a public utility, and in some provinces is subsidized by the public. If the maintenance of BPL systems is supported by hydro ratepayers, RAC considers that BPL access providers would have an unfair advantage in providing a service in a competitive environment.

RAC recommends that while preparing the standards for BPL equipment and systems, the Department clarify the regulatory framework governing BPL deployment and operations.

Relationship of Amateur Radio with Radio Spectrum

Amateur Radio was born in the early part of the 20th century and has been in the forefront of radio communications since, continuously developing and implementing new technologies such as the recently developed digital mode PSK31 that uses only 31 Hz of spectrum for keyboard-to-keyboard communications, part of a continuous search for spectrum efficiency by Radio amateurs. In Canada, a west coast amateur Radio operator developed the Internet-Radio-Linking-Protocol (IRLP), a system of linking Radio transmissions to the Internet using VoIP to communicate around the world.

From Radio's early beginnings the use of radio to provide a public service grew to the 1000+ Amateurs who provided emergency communications in the aftermath of hurricane Katrina. In Canada, amateurs supported emergency communications in recent disasters such as the eastern Canada ice storms, the Winnipeg floods, and the Okanagan fires in B.C. In most communities in Canada, Radio Amateurs are deeply integrated into their communities' disaster plans. Amateurs do this because they value their access to this unique resource, and that they have an obligation to use their skills for the good of our society.

SPECIFIC ISSUES

RAC will comment on the specific issues in the consultation paper with which it has concerns. The paragraph numbers are those used in the Industry Canada paper on BPL.

6.1 Equipment Standards and Approval Process

Due to the potential of BPL systems to interfere with HF/VHF spectrum users, RAC considers that the Department has an extraordinarily high "duty-of-care" with respect to guarding against harmful interference produced by any Access BPL operations it may authorize. RAC supports the Department in proposing a certification process that requires measurement test reports for BPL equipment and systems, demonstrating compliance with established performance standards.

RAC therefore recommends that the Department develop a new "Interference-Causing Equipment Standard" (ICES) to deal with BPL systems. This ICES, and any related radio regulations, should aim to protect radiocommunication services from interference generated by BPL systems. It should be consistent with similar standards and procedures, e.g. BPR-8 or RSS-210.

Moreover, the RAC also believes that it is important that each Access BPL operator be required to ensure that its overall system will comply, in all places and at all times, with established unwanted radiation limits through, for example, a continuous monitoring programme.

6.2(a) Emission Limits

RAC does not support the harmonization of emission limits with the FCC limits as published.

1. Measurement of Field Strength

There is controversy with the FCC method of measuring radiated emissions. In particular, the requirement to measure field strength at some distance less than the specified distance and then extrapolating for comparison to the specified limits raises questions of near field/far field scaling and the correct dB/decade to use. The current 40 dB/decade scaling required below 30 MHz has been shown in measurement trials to be too large[1]. [1]To overcome these scaling problems RAC recommends that Industry Canada develop BPL emissions level requirements at 10 metres instead of the FCC's 30 metres. Annex A is a paper "Low Frequency Radiated fields: Equipment And Issues" describing some of these measurement issues.

2. Effects of BPL Interference on HF Receivers

The majority of Amateur Radio Stations in urban areas are located on residential lots approximately 30 metres by 15 metres in size. In addition there can be medium voltage (MV) power lines running across both the front and back of these lots. Most antennas would be less than 15 m from the power lines, making the antenna well within the 30 uV/m @ 30 metres coverage of the emission limits as proposed by IC.

These emission limits are 26.2 and 29.2 dB above the man-made noise as measured by Industry Canada's Communications Research Center (CRC) in Montreal and Ottawa respectively. The median man made noise levels reported by CRC are:

Frequency MHz	***Measured results in Montreal urban areas***	***Measured results in Ottawa urban areas***
10	3.3(dBuV/m) or 1.46 uV/m	0.3(dBuV/m) or 1.04 uV/m
25	2.3(dBuV/m) or 1.3 uV/m	-3.7(dBuV/m) or 0.65 uV/m

HF is used by Amateur operators for weak-signal communications in which signals frequently vary from "strong" to barely above "atmospheric/galactic noise" or receiver noise. Although atmospheric/galactic noise varies in strength from hour to hour and season to season, Amateur operators can avoid this noise by changing operating times and/or frequencies. BPL noise, on the other hand, is continuous in time and frequency, and cannot be avoided by the operator. In general, man-made noise is the limiting factor in HF weak signal communications, especially in urban areas. For these reasons, 1 uV/m measured at 30 metres should be the maximum BPL emissions allowed on HF frequencies. Even so, many technically competent amateur radio operators recommend that the limit be reduced to 0.3 uV/m which will permit communications at typical weak signal levels. Annex B is a paper "A Review of the Proposed Industry Canada BPL allowable Emission Levels from the Perspective of Amateur Radio" for your information.

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[1] Ofcom PLT Measurements in Crief Section 3 Summary of Findings

6.2 (b) Interference Mitigation Requirements

[2]and

6.3 (a) Prohibited Frequency Bands

RAC requests that all amateur radio bands listed in RIC-2 be prohibited from use by BPL operators. However, RAC is concerned that notching frequencies or bands may not prevent harmful interference on the HF bands. 20 dB reduction may reduce the interference to the level of medium-strong signals, but to reduce the BPL interference to a level that will permit weak signal reception, an additional 20 dB or greater attenuation is required. This is the solution that Motorola Corp. used at the ARRL HQ test installation to reduce the emissions from the HomePlug modems to acceptable levels.

The experience in the United States indicates that BPL operators will not automatically notch amateur frequencies. Instead they wait for interference complaints before notching and notch only those areas where they must.

RAC has concerns that if all frequency band exclusions and exemptions requested by participants in the RABC reply to this consultation were implemented, it would leave little room for BPL in the spectrum below 30 MHz. This would force IC to make decisions about which services could be protected.

RAC understands that harmful interference is interference that the operator cannot avoid as compared to interference which is temporary in nature and disappears or varies with time. BPL is harmful interference; it is continuous. Changing frequency or operating time will not allow the radio operator to avoid BPL interference.

SOLUTIONS

In searching for a solution, it became evident that BPL should not be allowed on overhead Medium Voltage (MV) power lines below 30 MHz. There are currently two trials in the United States which accomplish this. At the ARRL HQ, Motorola has installed a hybrid system using a wireless link to the customer’s Low Voltage (LV) power lines.

Current Technologies has a BPL installation in Cincinnati which avoids the HF spectrum by using the frequencies between 30 and 50 MHz. This part of the spectrum has comparatively little occupancy, making it relatively easy to notch out locally used frequencies, while leaving enough bandwidth for future increases in speed. This installation uses the HomePlug system using HF frequencies on the LV lines to the customer's premise.

Both of these solutions avoid having BPL on MV power lines below 30 MHz. Such systems should be investigated. There are probably other solutions such as the use of cable, fibre or wireless to extend the internet signals to the customer, thus avoiding any use of HF frequencies.

CONCLUSION

RAC has shown that there are methods of protecting the HF bands for authorized users while still permitting certain designs of BPL to be deployed. RAC therefore respectfully recommends that the following principles be followed;

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1. Do not permit BPL on MV lines below 30 MHz,
2. Ensure that both Access and In-premise BPL adequately notch or avoid all locally used frequencies including all HF (1.7 to 30 MHz) Amateur Radio authorized frequencies, and
3. Measurements of allowable BPL signal leakage use a more appropriate 20db/decade rather than the FCC 40 db/decade factor.
4. The permitted emission levels be reduced to 1 uv/m (preferably 0.3 uv/m) at 30 m.

The HF frequencies are a unique resource and must be preserved. Protecting authorized users of these frequencies from BPL interference would be impossible if BPL is allowed on MV power lines. The added cost to Industry Canada to enforce regulations, performance degradation from notching, and the continuous struggle to eliminate interference by all authorized users, would have a disastrous effect on the use of the HF bands and especially to the Amateur Radio community, and by extension to the communities that they so willingly serve.

Yours sincerely,

Earle W. Smith, VE6NM
President
Radio Amateurs of Canada Inc.

ANNEX A

http://www.conformity.com/0507/0507low.html

Low Frequency Radiated Fields: Equipment And Issues

by the Editors of Conformity

This article will review common techniques and their basis for measuring emitted fields below 30 MHz. This region is often thought of as starting at about 9 kHz (the borderline frequency for many computing device requirements) but occasionally is extended down much further, as in the measurement of power line harmonics or in certain military standards. The further below 30 MHz we get, the more important an understanding of how inductive and radiated fields are linked becomes. There are three main areas which differentiate LF (low-frequency) measurement from the more familiar techniques employed for HF (here, taken as above 30 MHz):

1. *Antennas:* Most HF measurements are specified in terms of electric field strength, and require that the measurement be conducted with antennas that are sensitive to electric fields. In contrast, LF measurements are taken with antennas that are sensitive to magnetic fields and with antennas that are sensitive to electric fields, depending on the standard involved.

2. *Near Field vs. Far Field:* LF measurements are often taken in the near-field. The lower the frequency, the more likely this is to be the case. In the near-field, the details of the source—whether it is loop-like or dipolar—and the type of antenna it is measured with, have a large impact on the measured result.

3. *Scaling:* Many standards specify limits at a particular distance. Extrapolating measurements taken at a different distance to the specified distance can be tricky in the near field.

Equipment For LF Measurements

Describing the changes in equipment that occur as you lower the frequency of measurement below 30 MHz is the easy part. Two types of antenna are commonly employed: magnetic loop antennas, which are sensitive to magnetic H-fields but insensitive to electric fields, and electric field antennas, which are sensitive to electric E-Fields but insensitive to magnetic fields.

Both types are available in active and passive models. Active models have solid state buffering built into the antenna to reduce antenna factor variation and interaction with the measuring equipment.

Loop antennas are available in a variety of sizes. Since loops sense magnetic fields by induction, the loop antenna's unloaded voltage output is proportional to the number of turns in the loop and the rate of change of magnetic flux across the loop's plane, which is proportional to the loop's area and the frequency of operation.

LF loop antennas used for EMI measurement are electrostatically shielded. The sensing loop winding is placed inside a conductive tubular shield that is grounded, but has a break at one point. Note that if this break were not present, the loop would be shielded against magnetic fields as well, because the outer shield would act as a grounded, shorted turn.

As stated above, the sensitivity of the loop antenna is proportional to the number of turns and the loop area. The antenna factor, which is added to the spectrum analyzer/receiver reading, moves in the opposite direction – more sensitive antennas have lower antenna factors. So, it would appear at first glance that more area and more turns would always be better in a loop antenna. Unfortunately, this is not the case, because the inductance of the antenna goes up in proportion to the area and to the square of the number of turns. This inductance appears as the dominant term in the antenna's source impedance, which increases with frequency. If this becomes significant in comparison with the load presented by the spectrum analyzer and cabling (typically 50 ohms), the sensitivity will drop. If the inductance is very large, self-resonances can also result in the antenna. To limit this effect, several measures can be taken:

1. Sometimes the frequency range of a large loop antenna will be restricted, and measurements at higher portions of the LF range will be taken with a smaller antenna (quite common)

2. Tuned matching circuits may be employed

3. An active high-impedance buffering amplifier can be used

E-field antennas are wire-like. At high frequencies, they are familiar as dipoles, biconicals, and log-periodics. At low frequencies there are balanced (short dipole) and unbalanced forms, such as whips. For some important standards (e.g., NEBS GR-1089, MIL-STD-462), which require E-field measurements, a 1-meter active whip with a planar counterpoise is specified.

At low frequencies, a whip is non-resonant because it is much shorter than a quarter-wavelength. Such antennas "look like" a voltage source with a small series capacitance—their source impedance is large, negative, and reactive. In contrast to loop antennas, whose impedance starts low and increases with frequency, electric field antennas start with very high impedances that decrease with rising frequency, so the use of active electronic buffering (usually via a battery-powered FET circuit) is common.

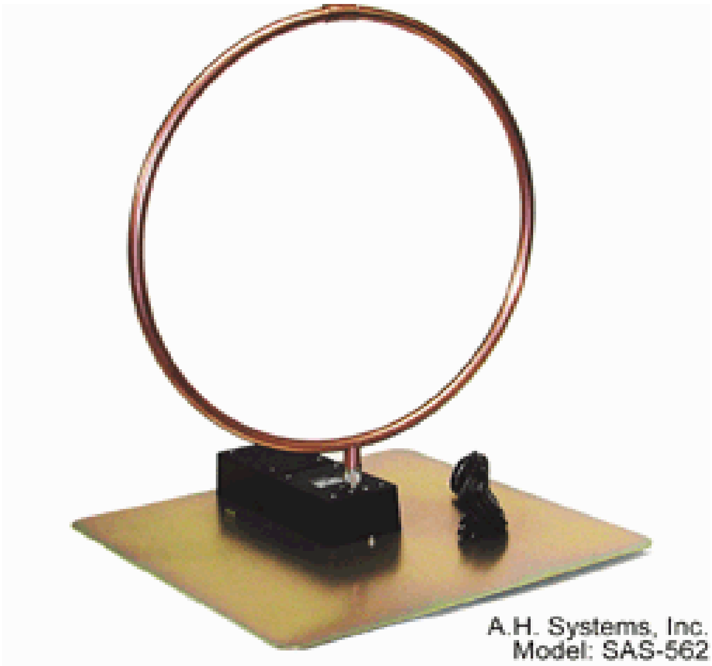


Figure 1: A typical shielded loop antenna for low frequency measurement. Although it measures H-fields, these values are often converted to equivalent electric field strength values under the questionable assumption of far-field conditions (see text).

A.H. Systems model SAS-562 Loop Antenna

A.H. Systems' Loop Antenna delivers high performance for a wide range of magnetic field testing. Whether used in a set to measure shielding effectiveness or individually to satisfy specific requirements, the Loop Antenna is an efficient, low cost solution.

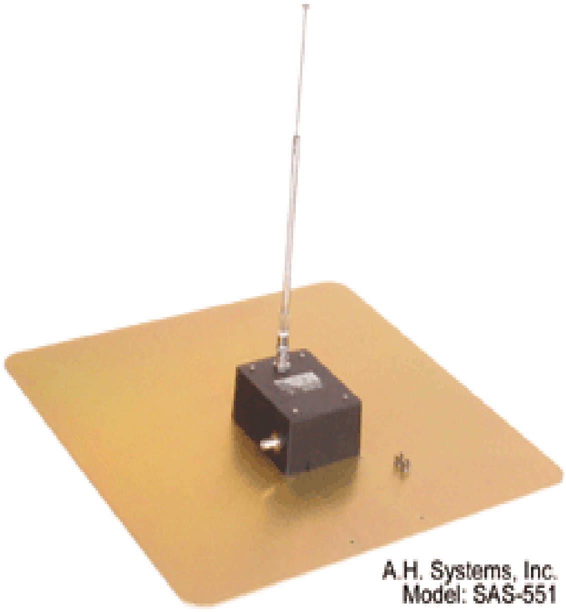


Figure 2: An active whip antenna for electric field measurements.

A 1 meter whip length is typical.

A.H. Systems model SAS-551 Passive Monopole Antenna

A.H. Systems' Passive Monopole Antenna provides superior performance in electric field measurements. The Passive Monopole Antenna is used for transmitting to perform shielding effectiveness and immunity testing.

Test Sites And Equipment Usage

In the HF range, accurate measurements require careful characterization of the test site via site attenuation measurements and height scanning during testing. The motivation is to control the effects of constructive and destructive interference from multiple signal paths.

At low frequencies, where measurement is usually in the near field, neither site attenuation nor full height scanning (such as the typical 1 – 4 meter FCC/CISPR scan) play as large a role (note, however, that in the emerging field of Broadband over Power Line, BPL, one of the alternate methods of measurement in the FCC's Rule and Order does include a low frequency height scan) as it does in the HF range. At low frequencies there is no formal LF equivalent of site attenuation, although gross anomalies such as screen room resonances or large nearby conductive objects should be avoided.

The basic usage of LF antennas is in many ways similar to that employed at higher frequencies. The measured field is the logarithmic sum of the indicated signal from the analyzer/receiver, adjusted for cable loss, preamplification (if any), and antenna factor. The antenna factor denotes the voltage to field strength conversion characteristics of the antenna as a function of frequency.

Usually, the standard to which a piece of equipment is being tested will determine the placement and orientation of the measuring antenna. For example, it is common for a magnetic loop antenna to be mounted on a tripod at 1 or 2 meter height, and rotated for maximum signal. E-field monopole whip antennas are oriented vertically, and placed in a fixed position. In military testing of modules the antenna will have its counterpoise bonded to the test table plane; in GR-1089 testing, the counterpoise is bonded to the facility groundplane.

The use of the spectrum analyzer/receiver is not changed much at lower frequencies, although the resolution and detector function are typically changed. For FCC/CISPR measurements, the most common settings will be 9 kHz resolution and the use of the mid-band ("B") quasi-peak settings. To speed swept measurements, peak detection can be used, with quasi-peak confirmation for those signals which approach or exceed the limit.

The biggest area in which LF measurements vary from HF measurements is in the way distance is used to extrapolate measurements taken at one distance to estimate what they should be at a different (typically larger) distance. At higher frequencies, we don't think about this much—we often assume that field strength falls off linearly with distance. This works pretty well if we are "far enough" away—i. e., in the far field. To understand what is going on, we need to understand the way fields are generated from different sources, and how they behave in the near field.

Sources And The Near/Far Field Transition

Two idealized sources are important for understanding the situation at low frequencies and the difference between the near and far field. Although simple, these models capture the essential behavior of actual equipment. Consider the sources modeled in Figures 3 and 4. The first is a small time variant charge dipole ("Hertzian dipole)," while the second is a time variant current loop (Figure 3).

Magnetic Components

$$\hat{H}_r = 0$$

$$\hat{H}_\theta = 0$$

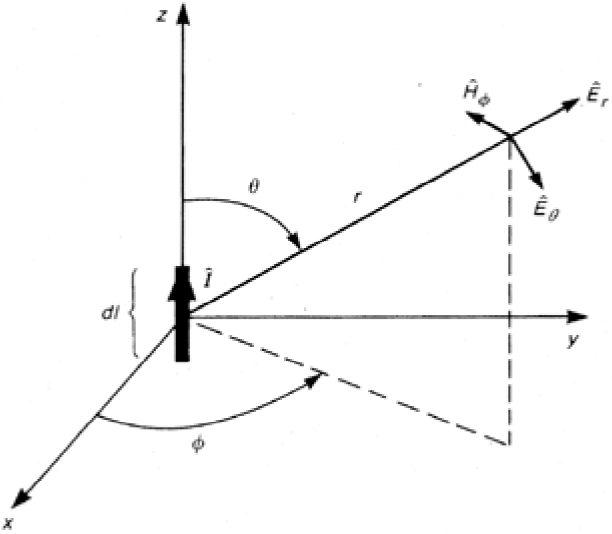
$$\hat{H}_\phi = \frac{\hat{I}\,dl}{4\pi}\beta_0^2 \sin\theta\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right)e^{-j\beta_0 r}$$

Electric Components

$$\hat{E}_r = 2\frac{\hat{I}\,dl}{4\pi}\eta_0\beta_0^2 \cos\theta\left(\frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)e^{-j\beta_0 r}$$

$$\hat{E}_\theta = \frac{\hat{I}\,dl}{4\pi}\eta_0\beta_0^2 \sin\theta\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)e^{-j\beta_0 r}$$

$$\hat{E}_\phi = 0$$

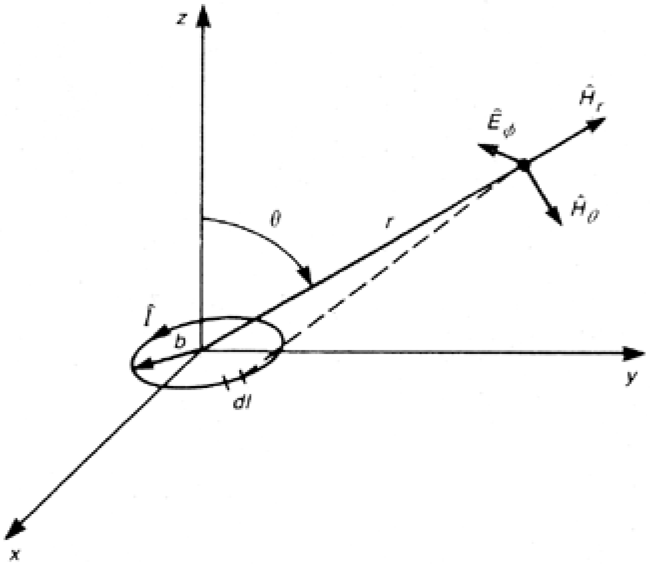


$$\beta_o = \frac{2\pi}{\lambda}$$

$$\lambda = \frac{c}{f}$$

$$\eta_o = \sqrt{\frac{\mu_o}{\varepsilon_o}}$$

Figure 3: A Hertzian dipole is a small, idealized electric field source. In the far field, E and H fields are radiated. Their strength is inversely proportional to distance. In the near field, “inductive” components are dominant, but fall off rapidly. From C. R. Paul [2].



Magnetic Components

$$\hat{H}_r = j2\frac{\omega\mu_0 \hat{m}\beta_0^2}{4\pi\eta_0}\cos\theta\left(\frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)e^{-j\beta_0 r}$$

$$\hat{H}_\theta = j\frac{\omega\mu_0 \hat{m}\beta_0^2}{4\pi\eta_0}\sin\theta\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)e^{-j\beta_0 r}$$

$$\hat{H}_\phi = 0$$

Electric Components

$$\hat{E}_r = 0$$

$$\hat{E}_\theta = 0$$

$$\hat{E}_\phi = -j\frac{\omega\mu_0 \hat{m}\beta_0^2}{4\pi}\sin\theta\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right)e^{-j\beta_0 r}$$

Note: m = I (pi*b^2) = I *Area

Figure 4: A current loop (sometimes called a magnetic dipole) radiator reverses the near field behavior of the inductive magnetic and electric fields. Here, the magnetic field is stronger in the near field. From C. R. Paul [2].

Let’s look at the dipole first. If there were charges, but no variation, we know from elementary physics that the E-field strength falls off with the cube of distance. Also, for a static charge dipole, there is no magnetic field. However, when current flows back and forth along the dipole (varying the charge concentration at the ends), the situation gets more interesting. The inverse cube behavior is still present for the electric field, but new terms appear inverse (1/r) and inverse square ($1/r^2$) behavior. In addition, magnetic field terms emerge—these have inverse and inverse square behavior—but there are no inverse cube magnetic terms.

An analogous situation exists for a current loop, with a reversal of roles (Figure 4). Here, a steady DC current would generate a magnetic field with a 1/r3 dependence. If the current varies sinusoidally instead of staying constant, an inductive magnetic component and an inductive electric component which vary as $1/r^2$ are generated. Finally, just as in the case of the Hertzian dipole, there are electric and magnetic fields which fall off more slowly, as 1/r.

The 1/r electric and magnetic fields are coupled—they are the radiating electromagnetic field which propagates away from the source at the speed of light. The higher order terms are inductive—energy is stored in these fields, but is taken out again as the fields change. Now, if we look closely at the expression, each “r” term has the coefficient $\beta = 2\pi / \lambda$. We can rewrite the terms as $1/(\beta r)^n$, where n is 1, 2, or 3 as follows:

$$\frac{1}{(\beta r)^n} = \frac{1}{\left(\dfrac{r}{\lambda/2\pi}\right)^n}$$

So, the relative strength of the different terms depends on the ratio of the distance to the term (λ/2π). When r = (λ/2π), all components are the same strength. This is the dividing line between the near and the far field regions. At a distance greater than this, we are in the far-field, and the behavior is essentially inverse with distance. This is the radiated energy field, where the electric and magnetic fields are coupled. At distances closer than this, the higher order inductive terms predominate, and fields fall off more rapidly.

In the near field, how rapidly the measured E and H-Fields appear to fall off will depend both on the source type AND the antenna used to take the measurement. For example, if an electric-field sensitive antenna, such as a whip, is used in the near field to measure a source that is more or less dipolar, the measured level will decrease with the cube of the distance. However, if this same source is measured with a loop antenna, only the H-fields will be measured, and they will appear to fall off as the square of the distance.

As another example, take the measured behavior of a coil operating at approximately 100 kHz. Such a coil might be part of a security system, and RFID reader, or even part of a power supply. Measurements taken at multiple distances with a loop antenna, such as at 1, 2, and 4 meters would show that an inverse cube dependence for the magnetic field. However, if these measurements were taken with an electric field antenna (assuming the field were above the noise floor) an inverse square dependence would be noted.

The FCC and some EU standards (e.g., CISPR 11) specify limits below 30 MHz in terms of electric field strength, but mandate measurement with a loop antenna, which measures magnetic fields but is insensitive to electric fields. The antenna factors supplied for this purpose convert from magnetic to electric field strength by assuming a conversion ration of 51.5 dB, which corresponds to assuming an E/H relation of 377 ohms. While this E/H ratio obtains in the far field, it is not true in the near field. This difference is caused by the fact that the near field ratios increase by different powers of distance in the near field. This idea is captured by the ratio of E/H, which is termed the “wave impedance.” (Figure 5). A dipolar source is “high-impedance” in the sense that in the near field, the inductive electric field is relatively stronger than the induced magnetic field. Conversely, a current loop source is “low impedance” in that the reverse is true.

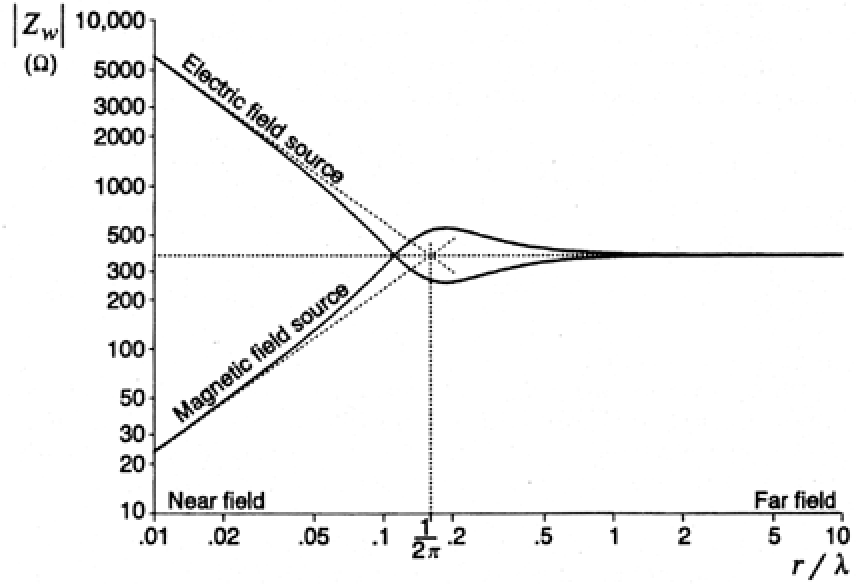
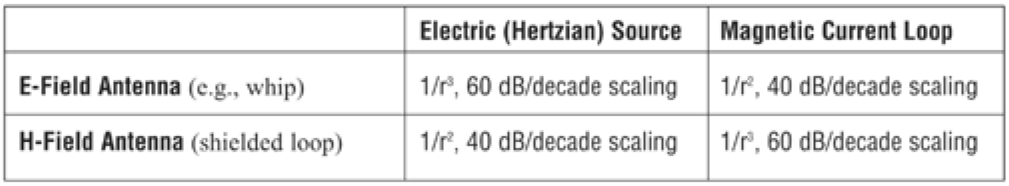


Figure 5: The wave impedance of idealized electric and magnetic field sources as a function of distance from the source. The wave impedance is the ratio of electric to magnetic fields. In the far field, it becomes 377 ohms regardless of the details of the source structure. From J. P. Mills, [5].

Table 1 shows the relationship between the type of source, the type of antenna used for measurement, and the near-field dependence of the measurement. Now, a few words about the regulatory importance of scaling.

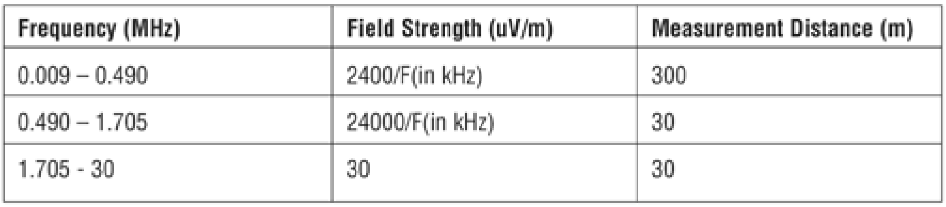


	Electric (Hertzian) Source	Magnetic Current Loop
E-Field Antenna (e.g., whip)	$1/r^3$, 60 dB/decade scaling	$1/r^2$, 40 dB/decade scaling
H-Field Antenna (shielded loop)	$1/r^2$, 40 dB/decade scaling	$1/r^3$, 60 dB/decade scaling

Table 1: The antenna "picks out" the type of field it is sensitive to. This determines the "measured" dependence on distance and the measured scaling factor.

The Importance Of Scaling

Some standards specify field strengths at distances that are too great for practical measurement. Sometimes the distance is such that it exceeds available test site space; on other occasions, the signal being measured is below the equipment noise floor at the specified distance; and sometimes both factors come into play. Consider the FCC's default requirements for field strength below 30 MHz (47 CFR § 15.209) shown in Table 2.



Frequency (MHz)	Field Strength (uV/m)	Measurement Distance (m)
0.009 – 0.490	2400/F(in kHz)	300
0.490 – 1.705	24000/F(in kHz)	30
1.705 - 30	30	30

Table 2

If a measurement is made at less than the specified distance, it must be scaled, or extrapolated, for comparison with the limit. Fields fall off as a function of distance. Depending on the type of source (loop-like or dipolar), the type of antenna (magnetic or electric), and the electrical distance between the EUT and the antenna, the right extrapolation number might be 20, 40, or 60 dB per decade of distance. 20 dB/decade corresponds to the (1/r) fall off of field strength in the far field. 40 and 60 dB/decade correspond to $1/r^2$ and $1/r^3$ behavior.

Since the source type isn't always known or ideal, the FCC has adopted the following approach:

- It is acceptable to measure at closer than the specified test distance
- Above 30 MHz, use inverse distance (20 dB/decade) scaling
- Below 30 MHz (our topic today), either
    - Use inverse distance squared (40 dB/decade) OR
    - Experimentally determine the appropriate distance by measuring the drop off rate between two or more points

This approach is sensible, and provides a predictable rule for comparing measured data to limits. It isn't always perfect, as a couple of numerical examples may make clear. That is, there can be multiple interpretations that give substantially different results.

Example 1 (Fun with scaling factors): Imagine that a transmitter is operated at 29.9 MHz, and is measured to have a field strength of 3000 uV/m at a distance of 3 meters. Since it is operating below 30 MHz, the application of the default 40 dB/decade scaling factor would extrapolate this to a 30-meter field strength of 30 uV/m, which is just at the limit. Note, however, that if the same transmitter had operated at 30 MHz, the required scaling factor would have been 20 dB/decade, and the 30-meter extrapolated measurement would be 300 uV/m, ten times higher!

Which is correct? Physically, the second one is, as at 30 MHz (and of, course 29.99 MHz) the far field starts at about 1.6 meters. If the second option of experimentally determining the rate of signal attenuation with distance had been chosen, it would have been found to be 20 dB/decade. But, the rule as written seems to allow both interpretations.

Example 2 (Crossing the near/far field boundary): Consider a compact, loop-like transmitter operating at 13.56 MHz, such as a handheld RFID tag reader. At this frequency, the near/far field boundary is at approximately 3.5 meters. If measurements are taken in the near field, for example at 1 and 2 meters from the device, the roll-off will appear to be inverse cube (60 dB/decade.) If measurements are taken at 5 and 10 meters, the roll off will appear to be inverse, or 20 dB/decade. And, if the default rule is chosen, the distance correction factor will be 40 dB/decade.

Some Concluding Thoughts

Near field measurements are straightforward. The additional equipment required is neither complex to use nor particularly expensive to obtain. More interesting is the physics behind the interpretation of the measurement. An understanding of the source type and how it interacts with the antenna clears the confusion that sometimes arises in interpreting the measurements made and comparing them to limits specified for different field types and at different distances. ■

References

1. Electromagnetics, 4th ed., J. D. Kraus, McGraw-Hill, 1992

2. Introduction to Electromagnetic Compatibility, C. R. Paul, Wiley-Interscience, 1992

3. CISPR 16-1-4:2003, " Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances," Sections 4.2 and 4.3

4. "Electromagnetic interference reductions in electronic systems," Jeffrey P. Mills, 1993 PTR Prentice-Hall.

Thank you to A.H. Systems for providing examples of antennas. For more information about their products, visit www.ahsystems.com

ANNEX B

A Review of the Proposed Industry Canada BPL Allowable Radiation Levels from the Perspective of Amateur Radio

by

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for

Radio Amateurs of Canada, Inc.

16 November, 2005

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Summary

This document analyzes the effect of the proposed BPL radiation levels on amateur radio operators. Since amateur radio operators often, and usually operate with signals near the background noise level, that level was used as the reference. It was found that the proposed BPL levels are at least 37 dB above the reference level at a distance of 30 meters and will cause serious interference. At greater distances the BPL level is reduced, but probably less than the far field reduction since the radiating power line is much longer than its distance from the amateur antenna. Recommendations are made.

1.0 Introduction

This document was written in order to present a an analysis of the likely effect of BPL interference on amateur radio communications. Industry Canada is proposing the use of signals in the frequency range of 1.705 to 80 MHz, which will be conducted by, but ideally not radiated from, ordinary power lines.

The analysis is based on the relative levels of BPL interference and background noise from all other sources, since these other sources currently provide the ultimate limit on the weakest signals which can be used. To have an insignificant impact, the BPL signal should be at least 10 dB below the other noise, thereby raising the noise floor by, at most, 0.4 dB.

Being able to hear and decipher the weakest possible signals is of particular interest to amateur radio operators, as will be described in section 2.0.

Section 3.0 examines Industry Canada's definition of the maximum allowable level of BPL interference, and tries to consider the effect of the spacing between the BPL radiator and the amateur antenna.

Section 4.0 reviews ITU document ITU-R P.372-8 (Ref 1), entitled "Radio Noise", which is considered to be the best source of information on measured values of radio noise. The lowest noise level likely to be encountered in Canada is to be used as the reference level. This section is presented in the ITU format of dB above kT_0b, and a comparison with the proposed BPL levels is made.

Section 5.0 converts the data format from dB above kT_0b to electric field strength in dBμV/m in a 9 kHz bandwidth in order to make the information more intelligible and to provide a with the signal levels in amateur radio receivers.

Section 6.0 presents the conclusions.

Section 7.0 presents the recommendations.

Section 8.0 provides the list of references.

The appendices explain the calculations used to produce the results in the various tables and figures.

2.0 The Proposed Allowable BPL Levels

Industry Canada proposes in paragraph 6.2a of their document "Consultation Paper on Broadband Over Powerline (BPL) Communications Systems, SMSE-005-05 (July 2005) (Ref 2), the following allowable electric field strengths:

Frequency-MHz	Field Strength-µV/m	Measurement Distance-Metres
1.705-30.0	30	30
30-80	90	10*

* was originally 3 metres

Table 2-1: Emission Limits

It is the author's understanding that the measurement bandwidth is 9.0 kHz, in accordance with ITU/CCIR procedures for field strength measurements.

One question to be asked is whether or not these measurements are in the near field or the far field. If in the far field, then the voltage level as $(\text{range})^{-1}$ as shown in table 2-2 (Ref 3, page __). The characteristics of the power line radiator make this unlikely, since the power line may be several kilometres long, with low level radiation from most of it and higher levels from points of discontinuity, for example, branch circuits. Ref 3, p. 33-20 cites a distance of $>> 2a^2/\lambda$, where a is the largest linear dimension of either antenna. It should also be noted that there will probably be other BPL circuits in the vicinity. In urban areas there could be parallel lines 153 metres (500 feet) away and, in rural areas, on 1.61 kilometres (1.0 mile) centers.

It is understood that the radiation characteristics of power lines are under investigation. It would be highly desirable to determine the actual rate of reduction of siganl level with distance away from the power line.

The BPL levels at 30 to 80 MHz and 10 metres separation may be similar, at 30 metres separation to the lower frequency levels at 30 metres, or they may not. They may be even higher.

Distance	Level- µV/m	Level- dBµV/m
3m	300	49.5
10m	90.0	39.1
30m	30.0	**29.5**
100m	9.00	19.1
300m	3.00	9.5
1km	0.900	-0.9
3km	0.300	-10.5
10km	.0900	-20.9

Table 2-2 : Maximum BPL Level with Distance, Assuming Far Field Conditions

3.0 The Nature of Amateur Radio Communications

Amateur radio is highly susceptible to BPL interference for the following reasons:

1) There are 10 amateur radio bands in the frequency 1.705 to 80.0 MHz. range, as shown in table 3-1-1. The range 1.705 to 30 MHz is suitable for long distance communications using ionospheric reflection.

2) It uses low powered transmitters (1000 watts or less) and highly sensitive receivers. The maximum transmitter power is defined by the Canadian government. The use of antennas with gain will allow an increase in the EIRP. The receiver characteristics are shown in table 3-2-1 and figure 3-2-1. Signal levels S0 through S9 are defined in the second column of table 3-2-1. These levels are then converted to the equivalent field strengths at 1.9 and 52.0 MHz with an isotropic antenna. (the calculations are shown in the appendix.) The last two levels (shown as 10 dB NF and 3 dB NF) show the equivalent internal receiver noise. With other antennas, the antenna gain is higher, and the required electric field strengths are reduced by the antenna gain. Gains for typical antennas are shown in table 3-2-2.

3) The antennas are typically located close to power lines and other sources of interference. On a typical 15.2 by 30.5 metre (50 by 100 foot) urban or suburban lot, a power line runs along the front or the back, with a power feed to the house. The primary voltage on the line is typically in the range 2,400 to 7,500 volts, alternating current at 60 Hz, and there may be a higher voltage present as well. The primary voltage is converted to 120/240 volts by local transformers.

The distance from a rear power line to the house is typically 6 to 15.2 metres (20 to 50 feet) while a front power line may be within 2 metres (6.6 feet) of the front of the house.

The amateur radio antenna will typically be at the rear of the house or on the roof. The maximum distance from the powerline to the antenna is about 30.5metres (100 feet), but will usually be somewhat smaller. If the BPL signal is present on the 120/240 volt secondary line as well, the distance to the antenna will probably be even less.

4) Many, if not most, amateur radio operators specialize in communicating with other operators at the maximum possible distances and, thus with the weakest intelligible signals. As a result, it is important that the level of BPL signals should be kept below the background noise level. A value of 10 dB below is suggested.

Band-Meters	Frequency Range-MHz	Center Frequency-MHz	Bandwidth-kHz
160	1.8-2.0	1.9	200
80	3.5-4.0	3.75	500
40	7.0-7.3	7.15	300
30	10.1-10.15	10.125	50
20	14.0-14.35	14.175	350
17	18.068-18.168	18.118	100
15	21.0-21.45	21.225	450
12	24.89-24.99	24.94	100
10	28.0-29.7	28.85	1700
6	50.0-54.0	52.0	4000

Table 3-1-1: Canadian Amateur Radio Bands in the range 1.705 to 80.0 MHz

		160 meters,	1.9 MHz	6 meters	52.0 MHz
S Meter Level	Rec. Input µV into 50 Ohms	µV/m	dBµV/m	µV/m	dBµV/m
S9	50.0	3.08	9.8	84.4	38.5
S8	25.0	1.54	3.8	42.2	32.5
S7	12.5	0.772	-2.2	21.1	26.5
S6	6.25	0.385	-8.3	10.5	20.4
S5	3.13	0.193	-14.3	5.28	14.5
S4	1.56	.0961	-20.3	2.63	8.4
S3	0.781	.0482	-26.3	1.32	2.41
S2	0.391	.0241	-32.4	0.658	-3.6
S1	0.195	.0120	-38.4	0.329	-9.7
S0	.0977	.00600	-44.4	0.165	-15.7
10 dB NF*	.0615	.00379	-48.4	0.104	-19.7
3 dB NF*	.0205	.00123	-58.2	.0346	-29.2

Table 3-2-1: Conversion between S Units, Incident Electric Field and Frequency

Assumes isotropic antenna
* in a bandwidth of 2.1 kHz

Antenna	Gain dBi	References
Isotropic	0.0	Ref 3, p. 32-4
Short Dipole	1.76	Ref 3, p. 32-4
Half Wave Dipole	2.15	Ref 3, p. 32-4
2 Element Yagi	6.4	Ref 4, p. 9-3
3 Element Yagi	7.2	Ref 3, p. 32-26
4 Element Yagi	8.4	Ref 4, p. 9-14
5 Element Yagi	10.3	Ref 5, p. 20-33
6 Element Yagi	11.2	Ref 5, p. 9-4
7 Element Yagi	12.0	Ref 5, p. 9-15

Table 3-2-2 : Typical Antenna Gain

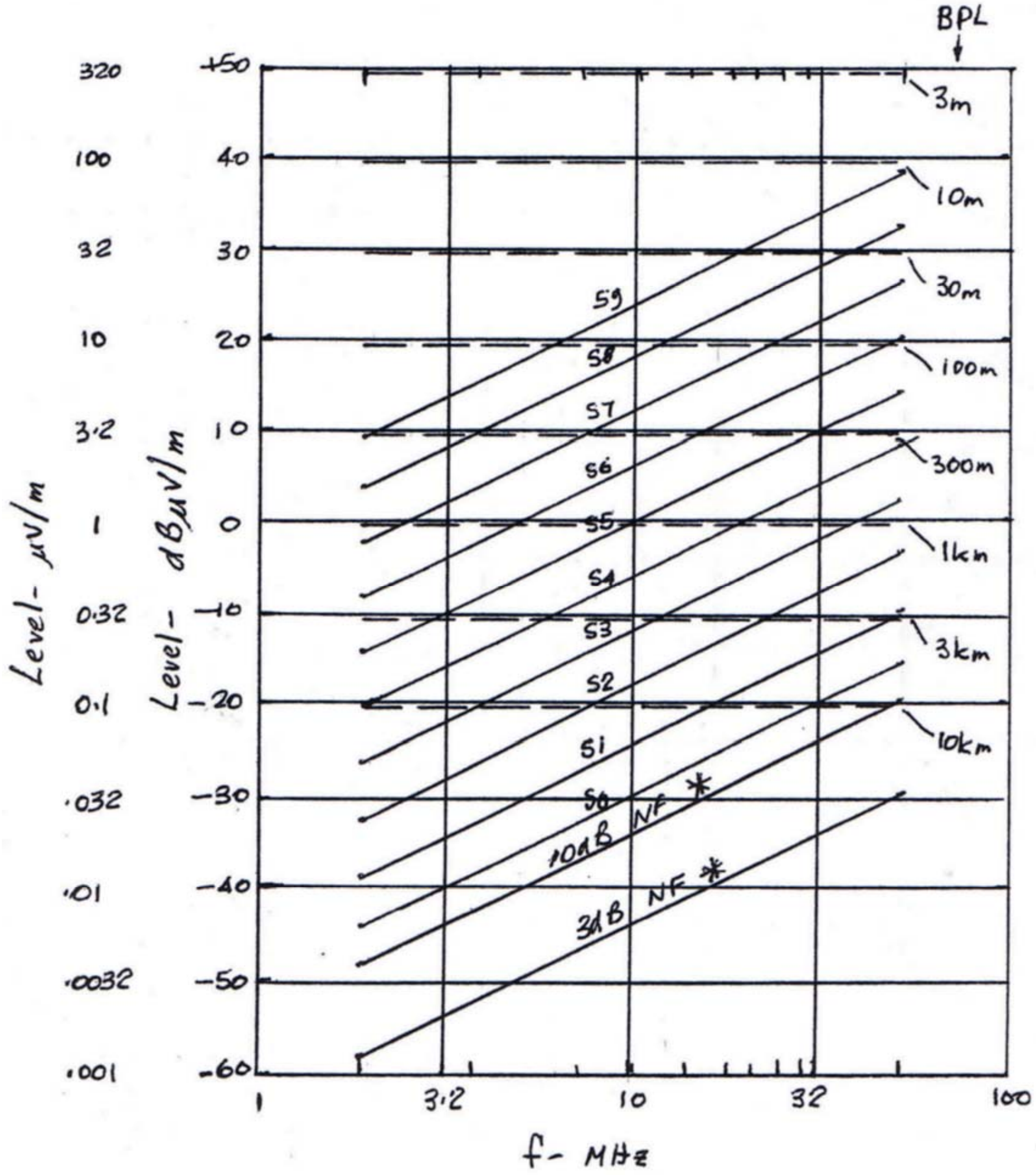

Figure 3-2-1: S Meter Readings versus Electric Field Strength Plus Proposed BPL Levels, Receiver With Isotropic Antenna

4.0 Realistic Levels of Background Noise

A review was made of the ITU document ITU-R P.372-8 titled "Radio Noise" (Ref 1) in order to determine the lowest values of noise , both natural and man-made. Reviewing all of the plots of the expected value of F_{am} for Canada produced a lowest minimum of 10 dB and a highest value of 50 dB. Figure 4-1 is a portion of figure 24b of the ITU document, covering the frequency range 1 to 100 MHz. The exact value of the curve vary slightly on the different figures, but the overall shapes are the same. Also included in the original ITU figure are the straight lines segments for quiet rural man-made noise and galactic noise.

The proposed BPL level of 30 µV/m at 30 metres was converted to F_{am}, as described in the appendix, and was added to figure 4-1 for comparison. See also table 4-2. As has been discussed already, the extrapolated values assume far field conditions, which is by no means assured. As well, the victim antenna will usually be less than 30 meters from the power line.

In the frequency range 1.9 to 52 MHz, the maximum proposed level of the BPL signal at 30 metres varies from 37 to 41 dB above the combination of man-made quiet rural noise and 40 to 79 dB above the minimum identified natural noise levels. It should be noted that the values used are all nominal, and that the worst case (lowest) levels of background noise could be 10 to 20 dB lower.

It was suggested that the combination of quiet rural man-made noise and the galactic noise be used as the values of background noise. Is this realistic? Clearly, levels well below them have been measured.

Table 4-1 shows the various levels of man-made noise and the levels of galactic noise in units of F_{am}. Table 4-2 shows the allowable levels of the BPL, assuming far field conditions apply.

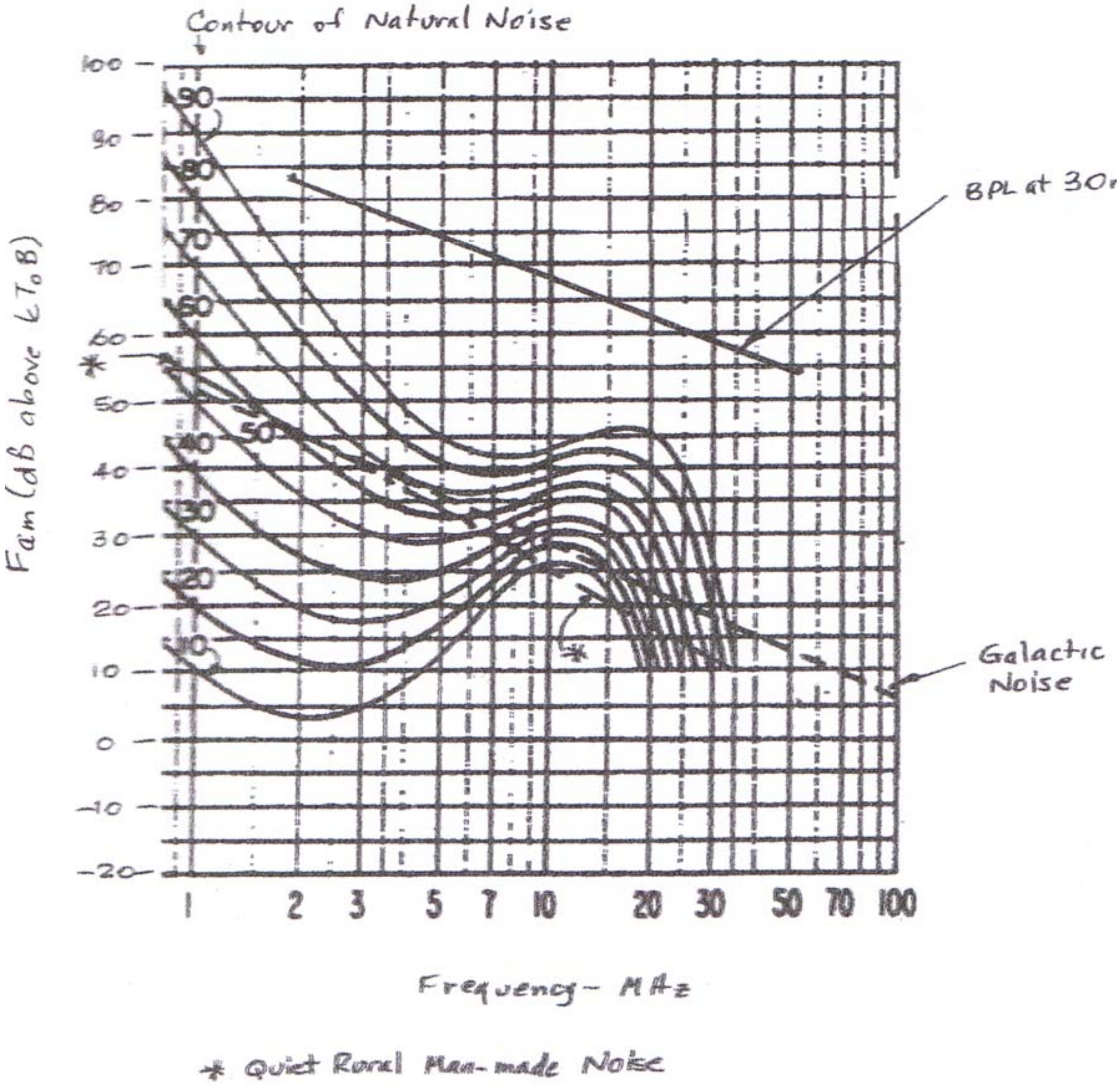

Figure 4-1: Typical ITU Noise Curves of F_{am} Over the Frequency Range 1-100 MHz
with BPL noise Added

Noise Environment	1.9MHz	10.0 MHz	30.0 MHz	52.0 MHz
A. Business	69.1	-	-	29.2
B. Residential	64.8	-	-	24.9
C. Rural	59.5	-	-	19.6
D. Quiet Rural	45.6	-	11.3	X
E. Galactic	X	29.0	-	12.4

Table 4-1 : Man-made noise levels in F_a Form- dB(kT_0b)

Distance	Level-dBµV/m	F_{am} at 1.9 MHz	F_{am} at 52.0 MHz
3m	49.5	103.4	74.7
10m	39.1	93.0	64.3
30m	**29.5**	**83.4**	**54.7**
100m	19.1	73.0	44.3
300m	9.5	63.4	34.7
1km	-0.9	53.0	24.3
3km	-10.5	43.4	14.7
10km	-20.9	33.0	4.3

Table 4-2: Conversion of BPL levels to F_{am} (dB above kT_0b)

5.0 The Same Results in Microvolts Per Meter

The results of section 4.0 were converted from Fam to µV/m using equation (8) of Ref 2.with b=9.0 kHz. See table 5-1 and figure 5-1. This was done to present the results in a form compatible with figure 3-1. The BPL signal at 30 metres distance is huge.

Environment	1.9MHz	10.0 MHz	30.0 MHz	52.0 MHz
A. Business	+15.2 5.75	–	–	+4.1 1.60
B. Residential	+10.9 3.51	–	–	-0.2 0.977
C. Rural	+5.6 1.91	–	–	-5.5 0.531
D. Quiet Rural	-8.3 0.385	–	-18.6 0.117	X
E. Galactic	X	-10.5 0.299	–	-12.7 0.232

Table 5-1: Man-made Noise: Conversion From F_a to Microvolts per metre-dBµV/m/µV/m

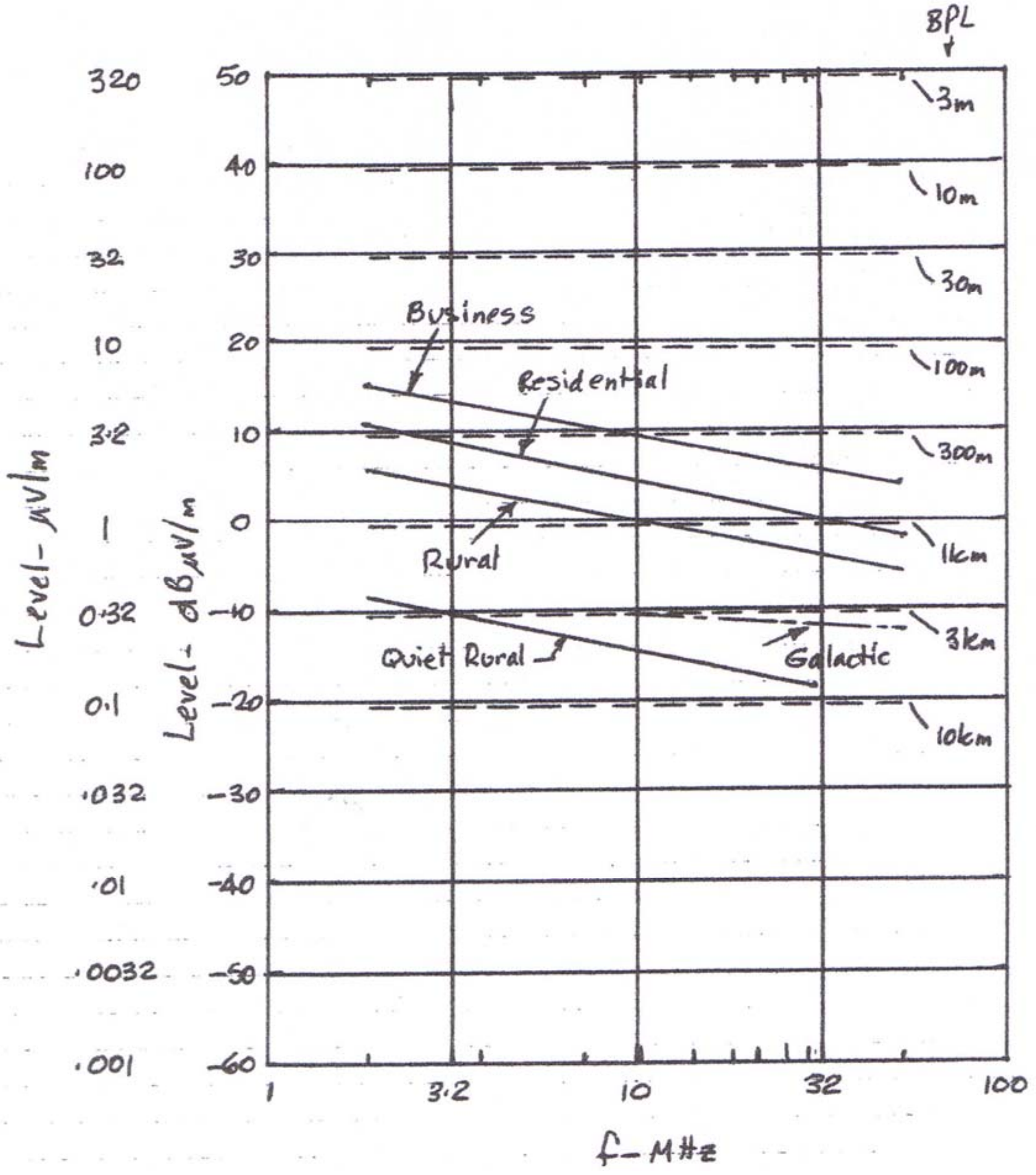

Figure 5-1: BPL Versus Man-made Noise Levels

6.0 Conclusions

The proposed levels are much too high and are unworkable.

7.0 Recommendations

1. Notch out all amateur radio bands in the frequency range. Output filters will probably be required in order to get the levels low enough.

2. The harmonic levels are not specified, and could be a problem for the amateur radio bands above 80 MHz, for example 2 meters (144 to 148 MHz)

3. Study the radiation characteristics of typical, realistic power lines.

4. Detailed mapping of the interference levels on each power line should be carried out, including different locations both along and at right angles to the line.

5. Techniques to lower the "hot spot" levels should be investigated.

6. The effect of BPL radiation propagated from long distances by the ionosphere should be investigated.

8.0 References

Ref 1: Radio Noise, ITU -R P.372-8 International Telecommunication Union, Geneva, Switzerland

Ref 2: Consultation Paper on Broadband over Power Line (BPL) Communications Systems, Document SMSE -005-05, July 2005, System Management and Telecommunications, Industry Canada

Ref 3: Reference Data for Engineers: Radio, Electronics, Computer and Communications, Edward C. Jordan, Editor in Chief, ©1985 Howard W. Sams, and Co., Indianapolis, Indiana, USA

Ref 4: (The) W6SAI HF Antenna Book, William I. Orr, W6SAI, ©1996, CQ Communications, Inc. Hicksville, NY, USA

Ref 5: The ARRL Handbook for Radio Amateurs, 2001, ©2000 The American Radio Relay League, Inc., Newington, CT, USA

Appendices

Calculations

Table 3-2-1:

A) S meter levels:

S9 = 50 µV
S8 = 50/2 = 25 µV
S7 = 25/2 = 12.5 µV, and, ultimately,

S0 = 0.09765625

or, SN = $0.09765625 \text{x} 2^N$ µV

B) Volts per metre calculation:

1) Effective (capture) of an antenna =$A_e = G\lambda^2/4\pi$ (Ref 3, page 32-3)

$= Gc^2/4\pi f^2$ m^2

where:

A_e = effective area-m^2
G = antenna power gain-ratio
c = velocity of light in air = $3 \text{x} 10^8$ metres/sec
f = frequency- Hz

2) In free space, in the far field:

$S = V^2/377$ w/m^2 (Ref 3, p.__)

where:

S = radiated power density-watts/m^2
V = electric field strength-volts/metre
377 = 120π = "impedance" of free space

3) Power received by antenna:

$P_R = A_e \text{x} S$ (Ref 3, p. 33-20)

$= A_e \text{x} V^2/377$

$= Gc^2 \text{x} V^2/4\pi f^2 \text{x} 377$

4) For an isotropic antenna, G = 1.0, and:

$P_R = 9x10^{16}xV^2/4\pi f^2x377$

$= 1.900x10^{13}V^2/f^2$ watts

C) Noise Temperature and Level Calculation:

$nf = 1+ T_A/T_R$ (Ref 3, p. 34-11)

where:

nf = noise factor-power ratio
T_A = amplifier equivalent temperature
T_R = reference temperature-290 Kelvin (K)

In dB,

$NF = 10 \log_{10}nf$

Power available = kT_Rb watts (Ref 3, p. 34-12) = P_R (in B) above)

where:

k = $1.38x10^{-23}$ Joules/Kelvin
b = bandwidth-Hz, in this case, 2.1 kHz

Table 4-2:

Conversion between F_a and dBμV/m

From Ref 1, equation 8 (page 3):

$E_n = F_a + 20 \log_{10}f_{MHz} + B - 99.0$ dBμV/m

where:

f_{MHz} = center frequency-MHz
$B = 10\log_{10}b$, b in Hz, in this case 9 kHz