Co-existence of PLT and Radio Services — a possibility?

J.H. Stott
Co-existence of PLT and Radio Services — A Possibility?

J.H. Stott

Introduction

This White Paper reproduces material produced for the IEE Seminar on EMC and Broadband for the Last Mile, held on 17 May 2005 at Savoy Place. It contains three sections.

Part 1 reproduces the author’s written paper, which also appears on pages 1/1-1/12 of the IEE Seminar Digest, IEE reference 05/11037, ISBN 0 86341 528 8.

Part 2 reproduces the slides used in the author’s presentation.
(Note that the audio files of the interference samples used are available here.)

Part 3 reproduces the posters that were displayed in the poster session.
(Note that these posters were also used for the BBC R&D Open Days 7-9 June 2005.)

Abstract

Power Line Telecommunications (sending data over mains wiring) unfortunately gives rise to unwanted emissions that can interfere with the operation of radio services, currently predominantly those in the HF range used for long-distance radio communication. Setting a simple emissions limit is bound to fail: no level exists which could permit PLT to operate while also protecting radio services. PLT and radio services simply cannot operate at the same time, in the same part of the spectrum, in the same place.

But that does not mean that co-existence is impossible. One possible solution is for the PLT system to avoid using parts of the radio spectrum that are locally occupied by radio services. This paper discusses such a possibility, including some experimental results that support its feasibility.

Additional key words: PLC BPL dynamic notching interference
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Co-existence of PLT and Radio Services — A Possibility?

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Part 1

The author’s written paper, which also appears on pages 1/1-1/12 of the IEE Seminar Digest, IEE reference 05/11037, ISBN 0 86341 528 8.
Co-existence of PLT and Radio Services — a Possibility?
Jonathan Stott, BBC R&D

1. Introduction

PLT is a means of transmitting data along an existing, ubiquitous infrastructure: mains-electricity wiring. It can be used for two distinct purposes:
- access — connecting the home to the outside world
- home networking — interconnecting apparatus within the home

In practice, access-PLT systems commonly embrace the home-networking function as well, since connecting your home to the Internet is of little value until your computer itself is connected.

Such reuse of existing infrastructure has obvious economic advantages, but comes at a price: mains wiring was never designed to carry the RF signals that PLT transmits along it. This presents challenges in making the PLT system itself operate with the desired throughput and reliability. However, there is also a problem for radio services: some of the transmitted PLT-signal energy escapes and can cause interference to them.

This paper examines the question whether radio reception, especially within the home, and PLT systems can coexist, and suggests a possible line of investigation which might prove fruitful.

2. Interference and its regulation

2.1. Interference between radio services

Of course, mutual interference between radio systems and services became an issue as soon as the second radio transmitter had been made, and so this topic is well studied and regulated. The ITU-R Radio Regulations [1] control which services can use which radio frequencies (the ‘Frequency Table’), and set out procedures for planning which ensure that transmitters operating on the same or nearby frequencies are sufficiently separated that the degree of mutual interference remains at acceptable levels, with high probability.

The procedure is based on knowing the appropriate protection ratios to apply for every circumstance. The protection ratio (PR) is the ratio $S/I$ of wanted-signal power to the interfering signal which must be met or exceeded for satisfactory reception to be assured. It is usually expressed in dB. The value of PR will depend on the particular combination of wanted and interfering signal

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1 Sect. 4 of Article S5 of the ITU-R Radio Regulations.

2 The definition of ‘power’ for this purpose depends on the customary way of specifying and measuring signal strengths for the signal types in question. This is a pragmatic and convenient approach; it is simply important to ensure consistency between definitions used to specify the PR and those used in its application.
types. It will also depend on the extent of overlap between the spectra of the wanted and interfering signals. When a band is solely or primarily used by one radio service on a channelised basis, as is the case for many of the broadcast bands, spectrum planning simply requires the appropriate PRs for those frequency offsets corresponding to co-, adjacent-, and 2nd-adjacent-channel… operation. These PRs are documented in the ITU-R and are applied together with propagation predictions for both wanted and interfering signals as part of the planning procedure. Addition of a new transmission is subject to restrictions on the (predicted) interference that it may cause to existing services within their agreed service area. A simple test is applied: does the field strength of the wanted signal, at a given location, exceed a certain minimum value, known as the minimum protected field strength. If it does, then its reception should be protected, and the interfering-signal field strength may not exceed that of the wanted signal divided³ by the PR.

Alternatively, in some cases a different procedure is mandated: the introduction of a new transmission is not allowed to increase the total interference power affecting a given wanted signal by more than some specified amount. The maximum permitted increase is usually small, e.g. 0.25 dB.

Interference between radio service transmissions is thus quite tightly regulated and planned. What of interference from non-radio-service origins?

2.2. Interference from non-radio-service sources

In principle, interference from other man-made sources is also covered in the ITU-R Radio Regulations (see quote from Article S15.12 in box). However, the responsibility is placed on Administrations.

Man-made interference comes about as an unwanted by-product of the operation of electrical apparatus.

Emissions limits for many types of apparatus have been set by CISPR. They inevitably take a rather broader approach than the ‘apply-relevant-PRs’ one taken in planning radio services. A simple spectral template is applied to radiated or conducted emissions. The level of protection given does not guarantee unimpaired reception, on the basis that, at least with historical interferers, emissions would typically be limited in place, frequency and time thus reducing the probability and impact of impairment occurring.

³ When, as usual, values are expressed in dB then this division simplifies to a subtraction of the PR in dB.

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In the European Union an EMC Directive [2] applies, whose underlying principle is intended to ensure that apparatus can be placed freely on the market with causing or suffering interference, see box.

Normally, presumption of compliance is achieved by following product standards that in many cases are derived from CISPR work.

Some CISPR standards are beginning to show their origins, in that they were derived from the need to protect analogue radio systems from appliances with switches, thermostats or motors, or simple harmonics of local oscillators. These examples are clearly isolated in time or frequency respectively, and appliances generally may have been less widespread physically in less affluent times.

In the context of today, some of the old assumptions may no longer be valid, and the standards may even be counter-productive. For example, something containing a microprocessor might generate a clock harmonic that exceeds the spectral template laid down in a standard. One way for the manufacturer to bring this into compliance would be to add some jitter to the clock so that its spectral lines are spread out — broader than the specified bandwidth of the measuring receiver — and thus it appears that its potential to cause interference has been reduced. However, suppose the radio service potentially affected uses a modern digital modulation system: COFDM. This distributes coded data over many regularly spaced carriers. A narrow-band interferer, even of relatively high level, causes little problem — it prevents reception of one carrier, but the error corrector in the receiver can cope with the resulting erasures. However, the same interfering power spread over several carriers (an outcome encouraged by the present standard) will cause reception to fail.

The emissions from digital broadband communication systems such as DSL or PLT represent a more extreme example since they may occur continually, and affect many MHz of spectrum. The rest of this paper will refer explicitly to PLT, since PLT emissions have so far proved in practice to be more problematic to radio services than present DSL installations. This is a natural consequence of the topology of mains wiring compared with phone wiring. However, the principles discussed could be applied to any interfering system, PLT or otherwise.

3. PLT-system emissions

3.1. Bands and radio services affected, and why we care

PLT systems at present are proprietary in nature, and in most cases manufacturers are very secretive about technical details — even down to general details concerning the spectrum they use. Most of the PLT systems currently in use appear to be restricted to the HF range.

The LF/MF bands are heavily used for broadcasting, including some on an international scale. Several bands in the HF range are heavily used by broadcasters, mostly for international broadcasting. However, some broadcasters, especially in the less developed part of the world, rely on HF broadcasting to provide their own national services, exploiting NVIS propagation. Certain parts of the HF spectrum (“Tropical Bands”) are reserved for this use by these countries.

LF/MF/HF bands have historically used AM, the original analogue modulation method used since the very start of broadcasting. However, a digital replacement, DRM, has been developed and standardised. It can be used in all three bands. Launch of commercial services is expected this year and

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4 COFDM is used in digital broadcasting systems for terrestrial radio and television broadcasting.

5 An exception is the HomePlug 1.0.1 specification to which many manufacturers adhere.
is expected to start a transformation of the use of these bands since it offers a significant improvement in quality.

These bands below 30 MHz are of special value since the long-distance propagation from which they benefit is unique to this frequency range. They enable tropical countries to provide national broadcast coverage without the need for infrastructure, and international broadcasters to target countries which would otherwise be closed to them. Other radio users benefit from the long range too: radio amateurs, ships, aircraft and military amongst others.

There are signs that in the quest for increased capacity, PLT vendors are turning their attention further up the spectrum, above 30 MHz. This means that the 87.5-108 MHz band used for FM broadcasting could be affected.

3.2. Experimental evidence

Access PLT in Crieff

BBC R&D has had the opportunity, thanks to Scottish & Southern Energy, of seeing three different types of access-PLT systems serving some of their electricity customers in Crieff in Scotland. The equipment was made by Main.Net, Ascom and DS2.

The first two of these were seen in 2002. Measurements and audio recordings of the impact on reception of HF broadcasting were made in PLT-customers’ homes, and in one instance recordings were made in the house of a non-equipped neighbour. These are reported in [3]; note that you may download audio samples and assess the impact for yourself.

The DS2 system was assessed in a second visit in 2004. Unfortunately on this occasion we were unable to make measurements and recordings in a directly comparable way as the DS2 representative would not permit measurements within homes using their system [4].

HomePlug

BBC R&D has also examined some examples of home-networking PLT products. Co-operation between PLT vendors in this part of the market seems to be further advanced in that there exists at least one standard (HomePlug6 1.0.1) to which many vendors adhere, so that inter-working between equipment from different vendors is possible.

We examined products from Devolo and Corinex, but there are many others. See [4] for some more information, including a description (and a downloadable video) of an experiment that showed that under certain circumstances this apparatus can function as a Wireless LAN. This clearly confirms the existence of PLT emissions in the very practical way of using them to transmit data!

3.3. Some emissions-limit proposals

Many proposals have been debated for setting emissions limits for PLT equipment. A selection is shown in Figure 1. To enable comparison they have, where necessary, been converted to indicate the permitted field value at a common reference distance of 1 m from the interference source. (Some proposed regulations specify the field strength at 3 m distance. Note that in typical homes it is very unlikely that a receiver can be used in a position so that it is 3 m away from all mains wiring.)

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Fig. 1: Various proposals for radiated-emissions limits compared with the minimum protected field strength, in the LF/MF/HF broadcasting bands

The bold solid line indicates the minimum protected field strengths for broadcasting in the LF/MF/HF broadcasting bands. Wanted broadcast signals of this strength would be entitled to protection from interference from other radio services. Applying the necessary protection ratios would show that interfering signals would have to be substantially weaker in strength. The ‘EBU’ proposal for limiting emissions from PLT and other line-transmission systems requires just this (lowest, chain-dotted green line). See [5] for details of its derivation, which actually followed the ‘permit a modest increase in equivalent noise floor’ approach. Interference at a higher level than this proposal would cause audible interference to reception of AM and disrupt reception of the digital DRM system.

The K.60 curve is from ITU-T (the Telecommunication Sector of the ITU), and is perhaps typical of proposals reflecting the needs and wishes of the PLT industry. As can be seen, it would permit emissions to be of similar strength or stronger than the wanted broadcasting signals — obviously unsatisfactory for the listener.

The remaining curves shown originate in proposals by regulatory authorities in Germany and the UK, and were presented as compromise proposals. They are compromises inasmuch as they lie
between the extremes (albeit perhaps rather nearer to the needs of the PLT operators than of broadcast listeners). However, they allow little satisfaction to either camp: the permitted emissions are still too high for broadcast listening to be usable, but too low to permit operation of most PLT systems at any worthwhile capacity. So nobody wins.

Note that other proposals have been couched as limits on *conducted emissions* in the LF-HF range. Of course, it is the *radiated emissions* that actually affect the radio receiver. So any conducted-emissions limits have to be interpreted to judge what effect on a receiver they permit — but none of this alters the fact that emissions affect receivers.

### 3.4. An unwelcome conclusion

The uncomfortable but inescapable conclusion is that there is no satisfactory outcome based on the setting of blanket limits. This is perhaps supported by the long period of debate on this subject without any resolution in sight.

Quite simply it appears that radio reception and PLT operation cannot try to use the same frequency in the same place at the same time. Mains wiring is ubiquitous throughout the home. PLT normally operates as an ‘always-on’ resource. So if PLT uses the same spectrum as radio services that are received in or near the home (broadcasting, amateur radio…) then *interference and conflict is inevitable*.

### 4. Notches — a possible way forward?

#### 4.1. Principle

PLT and radio services received in the home cannot use the same spectrum without conflict.

But conflict can be avoided if PLT does not use any frequency that a home listener wishes to receive. This could be achieved by introducing one or more notches — parts of the spectrum in which there is a substantial reduction in emissions.

#### 4.2. HomePlug example

HomePlug 1.0.1 is a PLT system for home networking. It is OFDM-based, and the specification calls for notches 30 dB deep in each of the HF bands allocated to radio amateurs in the USA. The need to afford some protection from interference to one class of radio users is thus acknowledged.

The notches appear to do what the specification says. We have purchased sample units from two manufacturers (see Figure 2), and they behave essentially identically (and inter-work properly). Figures 3 and 4 show example spectra of the signal that they inject onto the mains, measured using a differential transformer. The many notches corresponding to the radio-amateur bands can be seen in Fig. 3, while Fig. 4 confirms that the required depth is achieved, and the similarity in performance of the two examples from different manufacturers.

The notches do not help broadcast-band recep-
tion (with the exception of a small part of the 7 MHz band which is used for broadcasting in Europe but is allocated to amateurs in the USA, and hence notched).

Fig. 3: HomePlug spectrum measured using a differential transformer connected to the mains. The notches corresponding to numerous radio-amateur bands are clearly visible (but note the resolution bandwidth is too great to show their precise shape clearly).

Fig. 4: details of the HomePlug spectral notch for the 7.0-7.3 MHz (US) amateur band. The notch depth and width are as required by the specification.
4.3. Problems of fixed notches

The problem with the use of fixed notches is precisely that: they are fixed.

They cause loss of flexibility. The Frequency Allocation Table of the Radio Regulations is revised from time to time at World Radio Conferences to reflect changing needs for spectrum as old services perhaps decline and others become more important. E.g. the spectrum available to broadcasting in the HF range was increased by the Conference of 1992, and further revisions in the HF range are under consideration at present. Widespread deployment of devices with notches fixed in place for their lifetime would thus disempower World Radio Conferences.

They also cause loss of capacity for the PLT systems, since the bandwidth in which they can operate is permanently reduced. This in turn means that it is less likely that notches will be provided wherever listeners need them.

4.4. Programmable notching

If fixed notches are too inflexible, is there a more flexible alternative?

Some manufacturers now speak of providing programmable notches, as a means of mitigating interference problems. While being welcome, in that it acknowledges interference concerns, this does raise further questions, such as:

- Who does the programming?
- Is a bureaucratic procedure involved? Would it require an interference complaint to the national regulator for each instance? How long would it take to respond?
- Who decides whether a notch should be implemented to protect a particular transmission? They would be in the position of potential censor.7
- How many notches are available simultaneously?

If a manual process is involved, then for access PLT systems it is likely that the system operator would seek to maintain control. There will be an obvious desire to maximise system capacity by minimising the number of notches. An in-home-only system could in principle be under the control of the user, but with potential problems in the ease of use by the uninitiated.

Radio services in the HF band tend not to use the same frequency all the time, since the nature of ionospheric propagation means that different frequencies must used at different times to support a particular path. This includes a strong element of daily variation. So to protect reception of a particular broadcaster would require different notches at different times of day. It is easy to conclude that it would be unwieldy to cater for this with a manual system (perhaps from a call centre) when there are perhaps many different listeners with different tastes in broadcaster, and schedules are themselves changing.

4.5. Dynamic notching

This leads to a further idea: notches should be provided automatically whenever and wherever in the spectrum they are needed to protect local reception.

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7 This could set a difficult precedent. Certain countries are known to jam incoming international broadcasts, in contravention of the Radio Regulations. However, it would be difficult to make a formal complaint about this if their broadcasts were inaccessible in the UK and elsewhere because of local PLT interference.
By making it automatic we should avoid

- bureaucratic delays
- the cost overhead for access-PLT operators in supporting frequent requests
- potential accusations of censorship by bureaucracy or operators
- bewilderment of the public who might otherwise have to administer home-PLT systems

The method would cope with the frequently varying schedule at HF. Furthermore, by only applying protection where it is needed the capacity of the PLT system would be greater than if blanket fixed notches were used.

So much for the principle, how could it work?

One obvious method would be for all receivers in the vicinity of the PLT system to communicate to it what spectrum they were tuned to. However, this is impractical, given the large number of receivers in service, none of which is equipped with this facility, and, considering portable receivers might be in use, would require some kind of wireless network to implement it. It would have the advantage, for PLT system capacity, of limiting notches to the services actually being received.

What we actually propose is that any PLT system should regularly cease transmission for brief periods, during which it observes the occupancy of the spectrum. A notch is inserted wherever radio signals of sufficient strength to be receivable in the home environment are found. Thus in principle radio reception in the home would be protected. The proportion of the spectrum that would be notched is greater than with the ‘ideal’ system of the previous paragraph but the remaining PLT capacity would still be much greater than if blanket notches were applied.

Now, the idea of requiring short periods of ‘radio silence’ from the PLT system is not itself onerous. Indeed, something like it is probably happening anyway. The PLT network has to resolve contention: each terminal has to be sure no other is transmitting before transmitting itself. Furthermore, those PLT systems which use OFDM or related methods adapt by adjusting how much data they send on each carrier according to how well that carrier is working. The presence of radio-signal ingress is one of the factors which would reduce the capacity of a particular PLT carrier. So the basis for ‘radio silence’ and ‘spectrum-occupancy analysis’ may well exist in some existing PLT designs.

At first it would appear that the PLT system would need to be equipped with an antenna. This would be undesirable for a home-PLT network, but perhaps acceptable for an access-PLT network. The latter would only need one antenna per substation network, since the use of frequencies could be controlled by the master modem.

However, it would obviously be preferable to avoid the need for an antenna. Could the mains wiring itself be used, on the basis that if it can radiate interference it must also function as a receiving antenna? That is the question we set out to resolve with a simple experiment.

5. A first experiment

We conducted a brief experiment to determine how readily the occupancy of spectrum in broadcasting bands could be assessed by measurement of signals present on mains wiring.

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8 If you have to implement a wireless network anyway, the point of the PLT system becomes questionable.
We fed a spectrum analyser with signals derived from the mains by one of two methods, either sampling the differential voltage appearing on the mains using a differential transformer\(^9\) or sampling the common-mode current on the mains using a current clamp. To put the results into context we also installed a calibrated loop antenna outside the building at some 11 m distance from the building. This meant that we would know the field strength of any broadcasts we identified on the mains. If broadcasts of strong enough field strength to be justified protection could not be identified by sampling the mains then we would know that the proposed method is not suitable.

A sample result can be seen in Fig. 5, which shows the spectrum of part of the 15 MHz broadcasting band.

![Fig. 5: spectrum of part of the 15 MHz broadcasting band, comparing the signal received using the calibrated loop antenna (red curve, left-hand scale in \(\text{dB} \mu \text{V/m}\)) with that measured as a differential voltage across the mains supply at a wall socket (green curve, right-hand scale in \(\text{dB} \mu \text{V}\)).](image)

It is immediately striking how close a correlation there is, and how even broadcast signals much weaker than the minimum protected field strength of 40 \(\text{dB} \mu \text{V/m}\) (for AM signals in the HF band) can still be clearly discerned in the mains-voltage curve.

Note that the vertical alignment of the two traces is arbitrary, but chosen to make visual correlation easy. The correlation is not exact, for which two reasons may be surmised:

- signals at HF are subject to fading, and the two traces were not made sequentially, not simultaneously (the spectrum analyser was a single-channel instrument)
- the loop antenna is directional, just as the mains-acting-as-antenna may also be supposed to have some directivity, and these directivity patterns are unlikely to be the same.

In examining the figure, you may find it helpful to be aware that HF broadcasting frequencies are multiples of 5 kHz, but with a nominal channel bandwidth of 10 kHz.

\(^9\) With appropriate measures for safety and to block 50 Hz.

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6. Discussion and further work

The results shown in the previous section are very encouraging and suggest the proposed technique merits further examination. It would require further work to bring it to fruition, and this is clearly a job for PLT-system developers, not a broadcaster\(^\text{10}\).

The idea is not a perfect panacea for all problems for all radio services. Radio amateurs receive very weak signals that are only present for relatively short periods. The system proposed here would clearly provide a notch when a radio amateur was transmitting in the vicinity — but when the amateur is transmitting, they are not listening and do not need the notch. When they are listening, they are not transmitting and the notch would be removed again, leaving any weak signals they would wish to receive masked in interference. So there is probably a case for amateur bands to be notched permanently, as in HomePlug, but preferably with scope for (very occasional) revision of the details of the notch frequencies in the event of changes in the Frequency Allocation Table.

As already noted, other services also use the HF band, and some of them use weak signals. Most of these services do not need to operate in the immediate vicinity of homes, and so have not been expressly targeted in this suggestion. It may be argued whether their frequency bands should be included in the dynamic notching process. Unfortunately, just because their receivers are further away does not mean that they are not affected. The interference generated at a distance by a single PLT system may indeed be truly negligible, but when a large number of PLT installations is in service the cumulative effect of them all could still be significant, see [6]. This requires further investigation by those responsible for these services. It would appear that HF reception on board aircraft is likely to be the most critical case.

7. Conclusions

PLT systems do give rise to emissions that can interfere with the reception of broadcasting and other services. Interference with reception of HF broadcasting has been clearly demonstrated and may be verified by downloading the audio examples from [3]. It is clear that satisfactory reception in the home is not possible when a PLT system is in use in the vicinity and is operating in the same part of the spectrum.

The ITU-R Radio Regulations require “all practicable steps” to be taken to prevent “harmful interference” to radio services — which include broadcasting.

‘Notching’ has been proposed as a solution. However, there are snags. If bands are notched permanently (as in HomePlug’s notching of the US radio-amateur bands) then the right of World Radio Conferences to revise frequency allocations is diminished, and the capacity associated with those parts of the spectrum is permanently lost by the PLT system. If they are manually notched only in response to complaints there arise both cost and delay in processing complaints, and the process is open to accusations of censorship.

A system of dynamic notching may be the answer. A simple experiment reported here shows that measurements of voltages on the mains, as could be performed by PLT equipment in regular brief ‘quiet periods’, can distinguish the parts of the spectrum that are occupied and should not be used by the PLT system for the time being. In this way coexistence of PLT systems and broadcast recep-

\(^{10}\) The author regrets that he has already been misquoted in print to the effect that “the BBC has developed a dynamic-notching PLT system”; the true extent of our work is the simple experiment reported here.
tion in the home may perhaps be possible — a constructive alternative to the inevitable stalemate of the standards process.

The idea requires further work to bring it to fruition. It has to be done before there is mass roll-out of PLT systems, and be done with the active involvement of the PLT industry. It is unlikely to happen without strong pressure from the regulators whose responsibility it is to assure that radio apparatus can “function as intended”.

Note that notches must be deep enough to reduce interference to an acceptable degree and that dynamic notching may not be appropriate for the bands used by radio amateurs — the other radio service that along with broadcasting is intended for reception by the public in their homes.

The possibility of cumulative interference to other services such as aviation should also be investigated carefully.

Extension upwards in frequency of PLT systems could threaten reception of other broadcast band including the “FM” band 87.5-108 MHz.

8. Acknowledgements

The author wishes to thank his colleagues John Salter and Susannah Fleming for their major contributions to the work reported here, and acknowledges the kind assistance of Scottish & Southern Energy in facilitating measurements in Crieff.

9. References


   Note that a successor Directive, containing similar wording to that quoted, will supersede it: http://europa.eu.int/comm/enterprise/electr_equipment/emc/directiv/dir2004_108.htm.


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Part 2

The slides used in the author’s presentation. (Note that the audio files of the interference samples used in the presentation are available here.)
Co-existence of PLT and Radio Services — a Possibility?

Jonathan Stott
BBC Research and Development

IEE Seminar: EMC and Broadband for the Last Mile
17 May 2005

The Problem

- Power-Line Transmission sends data along mains wiring, can be used for:
  - home networking
  - access (connecting the home to the Internet)
- Commendable re-use of resource, but
  - signal energy escapes as radio-frequency emissions
  - can cause interference to radio services
PLT spectrum usage now

| Access         | many different secret standards...
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<tbody>
<tr>
<td>HomePlug</td>
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<td>Amateur</td>
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<td>Broadcast</td>
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Points of note from fig.

- The HomePlug home-networking system has notches
  - coincident with amateur allocations in USA
- PLT uses spectrum also used for radio broadcasting
  - interference can occur if PLT escapes as emissions
  - does this interference happen?
PLT interference example

- Recording made in subscriber’s home
- Consumer radio tuned to HF broadcast
- Representative of ITU-R recommended minimum protected field strength (40 dBµV/m)
- MainNet access PLT system

 Couldn’t switch it off, had to compare:
- Quiescent (only carrying ‘housekeeping’ traffic)
- Busy (transferring data)

To hear the audio clips (.wav) associated with the next slide, please click on the appropriate waveform.
PLT interference example

Audible clicks → Heavy interference

So, clearly, there is a problem here to try to resolve

Quiescent modem  Busy modem

Notches — a solution?

- Experience indicates PLT and radio services received in the home cannot use
  - same spectrum, at
  - same time, in
  - same location

- Are notches in PLT spectrum the answer?
  - HomePlug has fixed notches in amateur bands

Ascom seem to have recognised this in their choice of bands
HomePlug spectrum

- Specification requires 30 dB notches
  - for each amateur band in the USA
  - no help to broadcasting
  - they seem to be achieved

![Graph showing HomePlug spectrum with notches]
HomePlug spectrum

Fixed notches: problems

- Fixed notches have two major problems:
  - frequency allocations can *and do* change
  - PLT loses access to this spectrum permanently
    - all broadcast and amateur bands?
- Better to notch ‘when necessary’
  - human intervention undesirable (censorship)
  - could it be automatic?
Flexible-notching idea

- PLT apparatus must ‘listen’ (sample the spectrum) in regular quiet periods
- PLT should only use parts of spectrum which:
  - are empty, or
  - contain signals too weak to justify protection
- Did experiment to test principle

RF-sensing experiment

- Is RF ingress into mains sufficient to detect presence of signals needing protection?
- Measure broadcast field strength
  - calibrated loop antenna, well outdoors
- Measure RF voltage on mains, indoors
Is this idea workable?

- Even signals below minimum broadcast protection requirements detectable
  - so possibly feasible way to co-exist with PLT?
  - obviously of less help to radio amateurs…
- Requires dynamic programming of deep notches for each broadcast signal
- Testing/legislating could be complicated!
Conclusions (1)

- PLT interferes with indoor radio reception
  - if uses same frequency at same place and time
- Can co-exist if provide deep-enough notch at reception frequency
- Detect broadcast signals needing protection
  - measure spectrum on mains in quiet period
  - experiment suggests this is feasible

Conclusions (2)

- Automatic technique has benefits, it
  - avoids cost of manual intervention
  - avoids censorship issues
  - minimises loss of PLT capacity
Conclusions

- Possible snags
  - needs legislation to drive development
  - specification, testing, enforcement difficult
  - radio amateurs still need blanket notches
- Alternative is continued disagreement!
  - co-existence with present PLT systems impossible

Thank you for listening!

- … and to John Salter & Susannah Fleming
- More reading available at

Please see demonstrations in Poster Session!
Co-existence of PLT and Radio Services — A Possibility?

J.H. Stott

Part 3
The posters that were displayed in the poster session. (Note that these posters were also used for the BBC R&D Open Days 7-9 June 2005).
New sources of interference to broadcasting

Introduction

Various systems for conveying data along existing wires (phone, mains electricity) have recently been developed and some have already been introduced. Making use of existing wiring infrastructure in this way offers obvious advantages, but has the potential to cause interference to radio systems, given that the cables used were never designed for data transmission.

The BBC welcomes — and recognises the value of — general access to high-speed connectivity. After all, it operates one of the largest and most popular web sites in Europe. However, the bulk of BBC services are delivered to listeners and viewers making use of radio waves. For this reason it has to ensure that its broadcast radio and television services are protected from interference.

BBC Research and Development has been particularly involved in protection of the spectrum below 30 MHz since public roll-out of ADSL and PLT systems was first under discussion.

The importance of spectrum below 30 MHz

The spectrum below 30 MHz is of particular value because it supports long-distance propagation. At the low frequencies used for long- and medium-wave broadcasting, ground wave propagation is dominant during daytime. At higher frequencies, as used for short-wave broadcasting, and also in the case of medium wave at night, long-distance propagation by sky wave occurs.

This long-distance propagation is a unique property of this frequency range, and is used by many radio services. It is of great value for broadcasting, both within a country (e.g. providing national coverage with a single long-wave transmitter) and for international broadcasting, where it provides the only way for BBC World Service to access 'closed' countries. Others who exploit the long-distance propagation include radio amateurs, aviation and the military, amongst others.

Recognising the importance of these frequency bands, with their unique large-scale coverage possibilities, the BBC was a founder member of Digital Radio Mondiale, a consortium established to develop a digital system bringing better quality and user convenience to these bands. BBC R & D has participated extensively in this development which is planned to reach the fruition of regular scheduled broadcasts matched by the availability of consumer receivers around the end of 2005.

Digital Subscriber Line, DSL

DSL systems connect the home to the outside world using signals sent along the telephone wiring above the voice frequencies used for telephony. The system that is now widely rolled out in the UK is called ADSL. It uses frequencies up to 1.1 MHz and thus has the potential to interfere with long wave and the LF part of medium wave. This potential was confirmed before roll-out in early experiments kindly hosted by British Telecom. BBC R & D engineers were able to show that the effects of emissions from the early-generation equipment could be reduced to insignificant levels by adding a suitable cheap common-mode choke.
Practical experience of what is now a substantial scale ADSL roll-out suggests that there have not been many problems of interference with broadcasting — the few recorded complaints all proving to be faulty installations that, once rectified, were satisfactory.

A later version of ADSL, ADSL 2+, extends the frequency range up to 2.2 MHz and thus spans all of the long and medium wave broadcasting bands.

**VDSL** is another DSL system offering higher bit rates. It would use frequencies covering much of the HF band and thereby might cause interference to short-wave reception. Again, BT gave BBC R&D engineers access to an experimental site. This confirmed that interference to HF reception could occur. VDSL has not yet been rolled out in the UK. It remains to be seen whether practical deployments will (like ADSL) cause less interference than the experiment with prototype equipment suggests.

**Power-Line Transmission, PLT**

Power-Line Transmission makes use of mains-electric wiring to carry data. It comes in two flavours: access, used to connect the home to the outside world, and home-networking, used to connect appliances within the home. BBC R&D engineers have performed experiments on both, but unfortunately in this case only after deployment of access PLT and the mass marketing of home networking. Simply stated, both (as examined) cause interference to reception of short-wave broadcasting.

The **HomePlug 1.0** system is a home-networking PLT system that is becoming commonly available; it too has been examined by BBC R&D (note the ‘wireless’ experiment further below). In this case a group of companies has produced an agreed specification. Equipment from different vendors can be mixed in a network and operate satisfactorily.

**Access PLT** at present exists in essentially proprietary competing systems whose technical details are mostly kept secret. BBC R&D engineers have performed limited experiments on 3 types, all operated in Crieff by Scottish & Southern Energy who kindly hosted the experiments. In one visit, measurements were made of Ascom and Main.Net systems inside homes of users (and one neighbour). A later visit examined the DS2 system, but comparable measurements could not be made as the DS2 representative would not allow measurements inside customers’ homes.

The simple conclusion from all these experiments is that reception of radio broadcasting is not possible inside a home where PLT is deployed and operating on the same frequency at the same time. This can also be true if the PLT system is deployed in the neighbouring property. Some proponents appear to have recognised this: the Ascom system uses discrete bands which appear to have been chosen to avoid broadcasting bands (but unfortunately with inadequate filtering) while the HomePlug system has 30 dB notches corresponding to the bands allocated to radio amateurs in the USA.

A further concern is the interest to provide PLT systems of ever-greater capacity. To achieve this seems likely to require the use of frequencies above the HF bands, thus raising possible threats to more broadcasting systems, e.g. those that operate in the VHF Bands I, II and III.
Protecting radio from unwanted emissions

The operation of radio services is governed by the International Radio Regulations drawn up by the ITU-R. These govern all questions of interference between radio services, but also include a clause requiring protection to be given against other sources of interference, see panel.

The European EMC Directive is primarily aimed at ensuring that apparatus can be placed on the market without undue hindrance. Nevertheless a key article requires that emissions are kept at a level which does not stop radio systems operating as intended, see panel.

However, specific proposals have been made for governing emissions from DSL and PLT networks. Most of these proposals would not provide anywhere near adequate protection for broadcasting, or indeed radio services in general. BBC R&D made a counter-proposal which was taken up by the EBU and supported by other radio users. It was based on the concept of limiting the rise in the 'noise' floor encountered by a radio receiver; and already had a substantial element of compromise built in for the case of indoor reception (the normal case for broadcasting below 30 MHz). BBC R&D made measurements (supported by others from RSGB and MoD) of the noise floor at domestic suburban and other locations, showing that contrary to frequent assertions, the noise levels given in an ITU-R Recommendation (P.372) were not optimistic.

Some of the proposals from other bodies set a limit to common-mode current when the PLT modem is connected to a special test 'load'. This concept is based on applying measurements of LCL, Longitudinal Conversion Loss, which are of little relevance to mains wiring structure where much of the unwanted emissions are caused by currents flowing on stubs, as formed by the wiring of light switches.

Quotation from the ITU-R Radio Regulations

"S15.12 § 8 Administrations shall take all practicable and necessary steps to ensure that the operation of electrical apparatus or installations of any kind, including power and telecommunication distribution networks, but excluding equipment used for industrial, scientific and medical applications, does not cause harmful interference to a radiocommunication service and, in particular, to a radionavigation or any other safety service operating in accordance with the provisions of these Regulations."

(Quotation from Art.4 of Directive EMC 89/336/EEC. A superseding Directive will have similar wording.)
Does PLT use radio spectrum?

PLT systems clearly use spectrum *along* the mains wiring. It is usually denied that they *make any use of radio waves*, although it may be wondered, when the wiring path is long and circuitous, and the cable attenuation substantial, whether the signal may well travel by radiation from one end of the cable to be received again by the other end. That is conjecture, but Dr Markus Wehr of RBT in Germany demonstrated that HomePlug equipment can function as a *wireless LAN* — with no direct wired connection at all! BBC R&D has reproduced this demonstration and captured it on video.

Are notches key to co-existence?

PLT and radio services received in the home cannot use the same frequency at the same time without conflict. Inserting a *notch* of sufficient depth in the PLT spectrum can remove the conflict.

The HomePlug system has fixed notches to protect the USA radio-amateur bands. This principle could be extended to include broadcasting bands as well. One snag is that radio frequency allocations may be changed from time to time by World Radio Conferences. This could perhaps be dealt with by firmware upgrade (depending on the technology used). The other snag (for PLT) is that notching out all the broadcast and amateur bands, permanently, would reduce the PLT capacity.

Providing notches *only when needed* would increase the available capacity. However, to do this manually would involve great effort and expenditure and would raise awkward questions of censorship. This can be avoided if a system could be devised that automatically avoided frequencies in use by radio services. One possibility is to arrange for the PLT system to cease transmission for brief but regular periods so that it can sample the spectrum to detect radio services.

BBC R&D performed an experiment which demonstrated that the presence of radio transmissions can be detected effectively by measurements made on the mains wiring. This is what PLT apparatus implementing automatic notching would have to do in a ‘gap’ with no PLT transmission. Of course much further development of this idea by the PLT industry would be required to bring this solution to the market.
Conclusions

The spectrum below 30 MHz is important to radio services including broadcasting since it has unique properties of long-distance propagation. This makes it the only way for international broadcasters like the BBC World Service to reach many countries. The new radio system Digital Radio Mondiale has been developed for this reason.

Systems that exploit existing wiring infrastructure (telephone or mains electricity) to convey data all have the potential to cause interference to radio services. However, they are not all equal in the degree of problems that they cause.

ADSL (using telephone wiring) has the potential to cause interference to long- and medium-wave radio reception, as was confirmed in an experiment before the UK launch of ADSL. However, a simple fix is possible, and practical experience since roll-out suggests there are few problems.

VDSL will extend the frequency range used so that it has the potential to cause interference to short-wave radio reception. It is not yet clear whether it will present significant difficulties in practice, nor whether any simple fix is possible.

In contrast, PLT systems currently in service (access and home-networking) definitely cause interference to home reception of short-wave broadcasting. The different topology of mains wiring, with its stubs, is in part responsible for this.

The only way for PLT systems and in-home reception of broadcasting (or other services) to co-exist is for them not to use the same frequency at the same place at the same time. This suggests that notches may provide a way forward.

However, notches must be sufficiently deep and provided wherever and whenever they are needed. Notching out all the relevant bands (extending the example of the HomePlug system) is one solution, although it limits future flexibility in radio-service frequency allocation and restricts the capacity of PLT.

A more flexible approach whereby notches are provided when needed is an attractive alternative, but only if it is automatic in operation. BBC R&D has performed a simple experiment demonstrating the feasibility of detecting which radio spectrum is in use, by making measurements on the mains wiring. This has the potential to be developed into an automatically notching PLT system.

Further Reading

BBC R&D White Papers (nos. 4, 12, 13, 55, 63, 67 and 99 are particularly relevant) may be downloaded via http://www.bbc.co.uk/rd/pubs/whp/index.shtml.


The International Radio Regulations are available from the ITU in Geneva, see: http://www.itu.int/publications/default.aspx.