Why broadband PLT is bad for EMC

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Broadband internet communication is here to stay, but its method of delivery is still controversial. This paper looks at the technology of Power Line Telecommunications (PLT) through the lens of an EMC specialist, and attempts to explain why broadband through PLT is a dangerous and divisive issue. Although the author was initially neutral regarding this technology, that is no longer the case. Hopefully this article will clarify the reasons.

Abstract

This paper first outlines the technology used in PLT systems, and the political support being offered to the technology, from the point of view of its effect on electromagnetic compatibility (EMC). The radio spectrum needs protection from other interferers, and there is a regime in place to provide this protection. Nevertheless, PLT has several features that mean that it is capable of creating such interference. These features are discussed, and some published field trial results are reviewed. Difficulties in achieving compatibility between the requirements for radio protection and the requirements for operation of the PLT system mean that there is no consensus as yet as to how PLT system components can be made compliant with EMC requirements. It is concluded that there is little prospect of an accommodation between the competing demands, so that if PLT is to become widespread it will be at the expense of the radio environment.

Contents

The technology of PLT

Power Line Telecommunication (or PLC, Power Line Communications, or Broadband over Power Line, BPL, in the US) is a means of transmitting broadband data over the installed base of mains electricity supply cables. It can be used in two ways:

- Access to the home, to deliver the data connection from the service provider;
- Networking within the home, for data interconnection between mains-connected devices.

The two applications use different frequency ranges: low frequency (1.6–10MHz) for access, high frequency (10–30MHz) for in-home, as specified for Europe in ETSI TS 101 867 [10]. Some systems combine the two modes of operation. Technical data particularly for the operation of access systems is scarce since there are a number of competing proprietary systems undergoing field trials. Coding schemes, spectral distribution and signal levels differ between systems and detailed data is not published, although some manufacturers give some outline information. In the UK, three systems have been trialled (see later), from Ascom (Switzerland), Main.net (Israel) and DS2 (Spain). Ascom's method [11] uses three 2MHz wide carriers at fixed frequencies modulated using GMSK with a data rate up to 1.5Mbps per carrier, to give an overall data rate of 4.5Mbps. Neither Main.net nor DS2 have published technical details of their systems.

On the other hand there is an established specification for the HomePlug network system which is in use in the US for in-home networking. This uses OFDM (Orthogonal Frequency-Domain Multiplexing) to modulate the data onto a series of carriers across the frequency range 4.5–21MHz, with notches at certain frequencies to protect the US amateur bands [12]. The delivered bit rate is about 14Mbps.

The generally accepted power level for adequate operation of a PLT system is –50 to –40dBm/Hz. Measured in a 9kHz bandwidth, as is standard for interference measurements at these frequencies, this implies a power level of around –10 to 0dBm, which across the differential 100 ohm resistance of the power network is 100–110dBμV (0.1–0.32V). This compares with the allowed levels for conducted emissions in the domestic environment, with which most if not all electronic product designers are familiar, of 60dBμV in a comparable frequency range – one hundred times lower.

Notching

One capability which is potentially to PLT's advantage is that it can be programmed, possibly in real-time, to use only certain parts of the spectrum;

dBs and units

The deciBel (dB) is widely used to describe radio frequency parameters. For power, it is ten times the logarithm of the ratio of two powers:

$$dB = 10 \log(P1/P2)$$

For voltage or current, it is twenty times the logarithm of the ratio of two voltages:

$$dB = 20 \log(V1/V2)$$

Thus +20dB means that P1 is 100 times P2, or V1 is 10 times V2; –20dB means that P1 is 0.01 times P2, or V1 is 0.1 times V2; 0dB means that the two quantities are equal.

To express absolute units, the dB is given a suffix: thus 0dBm is 1 mW, +20dBμV is 10μV, and so on.

Electric field strengths are expressed in microvolts per metre (μV/m) or deciBels relative to a microvolt per metre (dBμV/m); magnetic field strengths are expressed in microamps per metre (μA/m) or deciBels relative to a microamp per metre (dBμA/m). Voltage limits are usually expressed as deciBels relative to a microvolt (dBμV).

notches can be applied to protect given frequency ranges, for instance the amateur or broadcast bands. However, the basic requirement is that data is transmitted at a bit-rate that is acceptable to the user (an expectation that is a core aspect of the attractiveness of broadband internet access) and there is a direct trade-off between the bandwidth required for acceptable bit-rate and that which is available to the system after all necessary notches have been applied. In other words, protection of spectrum allocations through notching can only be achieved by a reduction of the operational bit-rate. In the limit, you can't notch out the whole spectrum. So while notching could in theory afford protection to some spectrum users, such as broadcasters or radio amateurs[1], others could still expect to suffer.

The suggestion of notching raises a further issue, which is that of intermodulation. When multiple radio frequency signals are applied to a non-linear system – and the mains supply network, with all its connected electronic equipment, will certainly include non-linearities – they "intermodulate" to produce frequencies that were not present in the original spectrum. Thus although the PLT signal itself may be confined to certain parts of the spectrum and avoid others, at the victim receiver the system intermodulation effects may create interference signals within the supposedly protected bands. Although this phenomenon has been accepted as a possibility, there is little or no research into its likelihood.

The European politics of PLT

Because it provides a way to deliver domestic broadband access that is alternative to other providers such as cable and telephone companies, PLT is viewed favourably by regulators on the grounds of extending competition. The "strategic goal" of the European Union, known as the "Lisbon Strategy", has been stated [9] to be

> *to become the most competitive and dynamic knowledge-based economy in the world*

and the broadband telecommunications infrastructure with cheap, high-speed Internet access is seen as a cornerstone of this policy. The local loop, or the "last mile" (delivery of the broadband data finally into the home or office) appears as a bottleneck in the process of liberalising the competitive environment for this infrastructure, particularly in breaking the perceived stranglehold of the "incumbents" (pre-existing telecom providers). Hence any technology which promises to unblock this bottleneck is regarded with encouragement by the European authorities. PLT is clearly such a technology.

Meanwhile, some European nations saw the potential RF interference dangers of this technology early, and implemented regulations which would allow them to control it if there was any threat of such interference becoming widespread. In Germany, the standard NB30 put down radiated emissions limits in the 1.6–30MHz range. In the UK, the Radiocommunications Agency standard MPT1570 was also published, though it covered a lower frequency range. Naturally, this put a brake on PLT activity in these countries, since investors were wary of supporting systems which might quickly turn out to be illegal, and it also meant that there were differences in approach across the European Union. (The response of the UK's Federation of Electronic Industries, FEI, to MPT1570 was that it was "unacceptably parochial".)

Because the EMC implications of PLT have been a barrier to its widespread implementation, the European Commission has been, in a manner of speaking, champing at the bit to get this barrier resolved, if not lifted altogether. In 2001 it placed a mandate on the standard bodies ETSI and CENELEC (mandate M/313) to create a standard for the EMC of Telecommunications Networks. This has been addressed by a Joint Working Group of the two bodies but the difficulties involved, particularly that of finding agreement on a set of limits for radiated emissions from the network which would satisfy all participants, have meant that such a standard is a long time coming.

In early 2004 the EC appeared to lose patience with this process, and sent a letter [2] to CENELEC and ETSI which requested them to:

> *Define a technical specification providing test methods and limits for radiated disturbance (and possibly consistent conducted disturbances limits) compatible with state of the art powerline communication infrastructure. This technical specification should be made available by 31/03/2004.*

Such a deadline, considering that the letter was sent in January 2004, was clearly unrealistic, although the Joint Working Group responded quickly by offering a draft Technical Specification [4]. The Commission subsequently issued a draft proposal [3] which included the following uncompromising statement:

See appendix for update

> *Member States should* ***remove any unjustified*** [*] ***regulatory obstacles*** *to deploy and operate electronic communications networks and services over powerlines, in particular on utility companies. … Until standards defining the limits and test methods have been harmonised under Directive 89/336/EEC, Member States should* ***consider as compliant with Directive 89/336/EEC*** *a powerline communications network which is made up of equipment compliant with the Directive … and which is installed and operated according to good engineering practices… (emphasis added)*

The text of the proposal goes on to talk about procedures for "where there is an indication of non-compliance or where there is a complaint about harmful interference being generated by the network", but such procedures are bound to be time-consuming – there is, for instance, a requirement in the proposal for "verification that the interfered products comply with the immunity requirements of the Directive" (how can a radio be immune from the frequencies it is meant to receive?) – and meanwhile the interference damage is being done.

Protection of the radio spectrum

Man-made interference to radio services can come either from intentional radio transmissions, on the same or adjacent channels, or from unintentional sources, typically electrical or electronic equipment, that generates RF energy as a by-product of its operation.

Interference between radio stations

The first of these has been recognised since the early days of radio and has been controlled by international treaty, the Radio Regulations of the International Telecommunication Union. This allows for procedures for detailed planning of radio services throughout the spectrum, both within nation states and internationally. These procedures ensure that each service can establish a "protection ratio", that is the minimum ratio between wanted and interfering signals that ensures satisfactory reception of the wanted signal. Radio services are then planned to provide this ratio with a high probability.

The spectrum planning system results in complex frequency allocation tables, such as the UK's [7]. These show the range of services that have to be provided for; in the HF spectrum these include broadcasting, air, land and sea mobile voice and data communications, and radionavigation. Some of these services are safety-critical. There are also "minority" users such as radio amateurs, radio astronomy, standard frequency and time transmissions and government monitoring stations who are concerned with receiving and analysing very low levels of radio signal. It is hardly surprising that many of these "stakeholders" have expressed grave misgivings about the spread of PLT [8].

The use of the HF spectrum

The slice of spectrum from about 1 to 30MHz (MF and HF) is unique in that it can support long distance communication, and so it is important to broadcasters and many other users. Sky-wave propagation in the HF bands enables an international broadcaster to reach a target country without having a transmitter within the target area. This has political consequences, since it means that an audience can be reached without the co-operation of that country's authorities – which cannot be said for other kinds of access, including any kind of internet delivery. The BBC's World Service, for instance, is broadcast on several HF frequencies and is heard by many people in countries that have no free media of their own.

As well as broadcasting, aeronautical and marine communications use the HF band for long-distance communication, when the mobile station is out of reach of ground-based VHF stations, which is a large proportion of their journeys.

Interference from other non-radio equipment

The second type of interference is caused by electrical and electronic equipment unintentionally creating RF noise in the vicinity of the receiver. This phenomenon has again been recognised for many years and a regulatory structure has been set up to deal with it. In Europe this structure is implemented by the EMC Directive, whose first essential requirement is that apparatus shall only be placed on the market or taken into service if [5]

[*] An earlier version used the word "remaining"

> *The electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended.*

This means among other things that virtually all electrical and electronic equipment, especially that which connects to the mains supply, has to meet limits on the amount of noise it injects into connected cables. These limits are contained in standards which derive from CISPR, the IEC committee responsible for control of radio interference. They are devised through a process which accounts for the protection ratio required by potential victim receivers, the likelihood of a source being in physical proximity and coupled to these receivers, and the probability of coincidence of operation of the source and the receiver. They apply through the operation of the EMC Directive to anything that is likely to cause such interference. Designers of mains-connected equipment for sale within Europe are by now familiar with these requirements, which constitute an extra but necessary burden on their desgns.

PLT's interference capability

Interference from PLT systems stands outside the general regime of interference control. The principal emissions are radiated from the supply wiring, onto which they have been deliberately injected, rather than accidentally as is the case with other sources such as fluorescent light inverters or computer power supplies. From access-PLT systems, the interference will be largely continuous rather than intermittent, and will potentially affect all households being supplied from a substation in a PLT-active zone, whether they are a subscriber or not. Even in-home systems could interfere with other parties connected to the same service entrance.

The nature of the interference

Whatever the coding system, the interference signal will stretch across the whole of the spectrum occupied by the modem's output, and will be broadband in nature so that within a given region of spectrum it will be impossible to tune it out. In the quiescent state some systems will create a pulsing type of signal which may or may not be subjectively less annoying than the continuous noise which occurs when the system is actually passing data. Some systems may use low-frequency carriers such that a continuous audible tone is present across the frequency range. Several bodies, notably the BBC and RSGB, have audio recordings of actual PLT interference available on their websites [15][16].

Dependence on quality of wiring

The mains supply wiring both to and within a domestic house was never intended to carry high frequencies. The connection between two points within a home looks like a complicated transmission line with many stubs terminated in unknown and changing impedances. At some frequencies the signal may be transmitted with little loss, but at others the attenuation can be severe, and this characteristic can change with time as users plug various appliances into the mains supply. This means that in order to work at all, the amplitude of the signal must be high enough to ride over any interference already present on the network, and must adapt to time-dependent changes in this interference and the network attenuation. Current-generation PLT systems are designed to do this.

A critical parameter which determines the amount of radiation that the mains wiring creates is the "Longitudinal Conversion Loss" (LCL) of the cable. Simply put, this is the ratio between the signal level which appears across the wires, intentionally, due to the desired data transmission, and which to a first order does not radiate; and the signal level in common mode – all wires together – which represents the leakiness of the cable and which contributes the lion's share of the radiation. Data cables which carry broadband signals, of which Ethernet is the most typical example, are very tightly specified for a minimum LCL, which ensures that the RF leakage from the data signal is kept to a low, known value. This is also true to some extent for telephone cables that are used to feed ADSL and VDSL broadband into the home.

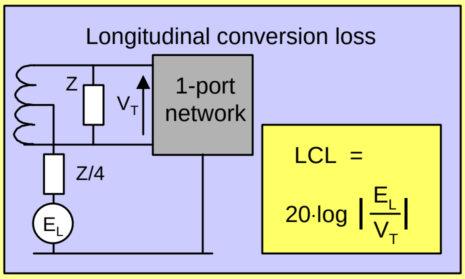
It is much less true for mains wiring. The most important aspect of cable design which affects LCL is the physical balance of the two wires which make up the cable. Each conductor must be tightly coupled to the other so that the interaction of each with the environment is identical. Then, provided the signal currents on the two wires are perfectly balanced, which can be ensured by suitable design of the terminal equipment, emissions from one wire exactly cancel the emissions from the other; this is the same as saying that the cable has a high LCL. Data cables are tightly twisted in a controlled way to achieve this. The connections at either end of the cable must be equally well controlled.

Not only is mains wiring not controlled in this way, it is commonly installed in direct contravention of these principles. For instance, the live wire can easily be carried off to a light switch and back again, separating it from its neutral return by several metres. The conductors in the cables that make up the ring main wiring, typically flat twin and earth, are never twisted together. At each junction box in the ring main, there are large, uncontrolled deviations in the wiring configuration of the live-neutral pair. And in the connected appliances (TVs, cookers, heaters, washing machines etc) there is every likelihood of unbalanced impedances between live, neutral and earth. None of this matters at the mains frequency of 50Hz, but at PLT frequencies of up to 30MHz it is critical. Even if the wiring is installed (as it should be in the UK) properly in accordance with the IEE Wiring Regulations, these are only meant to ensure electrical safety, and they have nothing to say regarding the high frequency properties.

CISPR 22 [6] gives a figure for poorly balanced unshielded twisted pair data cable LCL of 30dB, degrading by 7dB at 10MHz. This compares with 55dB for Category 3 data cable (rarely used now in new installations) and 65dB for Category 5, both also dropping by 7dB at 10MHz. The 30dB figure has also been suggested for mains cable, but this seems unduly optimistic since such cable is untwisted and, as explained above, is subject to many poorly terminated stubs and unbalanced loads along its length. A figure of 15-20dB would be more realistic. In other words, mains cable could be up to 50dB or 300 times worse than the most commonly installed data cable at controlling unwanted radiation.

Longitudinal Conversion Loss

LCL is the ratio of common mode (or "asymmetric") voltage in a network to the differential mode (or "symmetric") voltage that creates it. It is defined in ITU G.117 and measured as shown (the one-port network in this context is the cable):



Is PLT the same as other interferers?

PLT supporters propose that there should be parity (at least) between the emissions compliance requirements that a PLT system has to meet, and those applied to other devices, such as information technology, lighting, or household appliances. CISPR conducted limits, it is said, have been adequate to protect the HF spectrum so far and therefore any system limits should be no more onerous than levels derived from these. This argument overlooks a number of important points:

- A victim won't be able to get away from PLT interference. When a whole street or a whole building is wired for PLT, it will be pervasive and re-positioning the victim will not work. CISPR limits assume that mitigation by separation from a local interferer is possible.
- PLT is always on. CISPR limits incorporate a relaxation which takes into account the probability of non-coincidence in time of source and victim. For PLT, this factor has to be 1.
- EMC engineers know that the vast majority of products which comply with CISPR conducted limits do so with a good margin, often at least 20dB, in the frequency range above 2MHz. If CISPR limits do indeed protect HF reception, this factor should not be overlooked, since such a margin will not be enjoyed by a PLT product.

In fact, PLT modems are unable to operate anywhere near the mains conducted emissions limits in force in CISPR at the moment, as we shall see shortly.

Radiated or conducted?

It is often said that PLT is not intended to communicate via radiated signals. However, an elegant demonstration reported by Jonathan Stott [1] shows that even so, a PLT in-home system (using US HomePlug devices) does indeed do so. He describes the experiment as follows:

> *A HomePlug network was established. One terminal was a laptop PC using a USB-to-mains-PLT HomePlug device. The latter was plugged into a mains extension lead and thence into the mains wall socket. A set of Christmas-tree lights was also plugged into the same mains extension lead. The PLT network functioned as expected, communicating with a second terminal that was plugged in elsewhere. When the mains extension lead was then unplugged from the wall, so that the laptop PC's HomePlug device was no longer physically connected to the mains, the HomePlug network nevertheless continued to function. It was now functioning in effect as a Wireless LAN, using HF frequency spectrum. The lights acted as an antenna for the first terminal. This is possible since the particular USB-to-mains-PLT device draws its power supply from the USB connection and not from the mains and thus can still*

> *inject PLT signals. The mains wiring acted as the antenna for the second terminal. It could also be made to work (at lower capacity) with less obvious 'antennas' than the lights, e.g. by simply holding an exposed pin of the plug of the 'unplugged' HomePlug device.*

This suggests that a more appropriate response would be to regard the PLT system as an intentional radio transmitter and license it appropriately.

Cumulative effects

The foregoing discussion has concentrated on the emissions of PLT as they affect victim receivers in close proximity to the PLT system, generally within or near the subscriber's house. This is not the only threat that concerns radio administrations. If PLT were to be widely implemented within any country, the total radiated power available would be sufficient to increase the radio noise floor at distances remote from the source, potentially in other countries. If, say, an entire city was to be wired for PLT, this could form an aggregate transmitter whose RF energy was reflected from the ionosphere and illuminated a continent. In addition, an aircraft flying over such a city might find that its ability to receive HF signals was curtailed. The UK's Civil Aviation Authority has expressed its concern that "aeronautical services are under threat from cabled telecommunications services." Established HF propagation models exist for this phenomenon and a number of studies have been carried out to try and model the possible outcome.

The concern has focussed on several broadband technologies, including ADSL and VDSL. ERA report 2001-0333 [18] stated:

> *The study has found that the cumulative VDSL space wave emissions from a large city such as Greater London have the potential to increase the established ground level radio noise floor published by the ITU. In addition, considerable risk of interference is presented to Aeronautical mobile HF radio services sharing the frequency band.*

VDSL uses similar frequencies to PLT, but the radiating efficiency of PLT systems, which use mains cables rather than telecom cables, is that much greater. A different study, York EMC Services AY3525 [17], said:

> *the only technology that is likely to significantly increase the established radio noise floor due to cumulative skywave propagation is PLT….*

The problem with any such study is that for the time being it must remain theoretical, since it's impossible to validate the models used for prediction until there are sufficient installed systems to be statistically acceptable; but by then the roll out will be so advanced that it will be impossible to stop it. And the authors of these studies readily admit that their results are heavily dependent on the initial assumptions that they use, with regard particularly to the degree of market penetration and usage of the systems, and the figures that are assumed for the radiation efficiency of the cabling. For instance, the ERA report estimated that there was a 40dB "window" between the effects of pessimistic and optimistic assumptions for the various parameters. Even so, if the situation is likely to be bad for VDSL, it can only be worse for PLT.

Field trial results

Many field trials have been carried out on various systems in various European countries. Several of these were reported at the EC PLT Workshop in Brussels on 16th October 2003. Some significant points were [13]:

- Finland: from results of three installations, PLC is not compatible with HF radio services if the proposed emission limit is set to 55dBµV/m at 3m; this is about 40dB too high.
- Austria: put forward a proposal for a field strength limit of 14dBµV/m at 10m.
- Germany: initial findings about PLC applications suggest that, despite contrary assurances by the manufacturers, the ceilings in force nationally (NB30) cannot be adhered to.
- Netherlands: believes cumulative effects have been underestimated.
- Switzerland: conclusion from a trial in Fribourg is that PLC emissions exceed the German NB30 limit by up to 24dB near points of data injection and up to 18dB in urban areas.
- Spain: from trials in Madrid, Zaragoza and Sevilla, "There have not been any complaints from telecommunication users which could be caused by the operation of the PLT networks".

UK trial at Crieff

In the UK, Scottish and Southern Energy held trials with a total of three systems, from Main.net, Ascom and DS2, in Crieff in Scotland. The Radiocommunications Agency, the BBC, and the RSGB were all invited to make measurements on these trials, and all three have put their reports in the public domain, with the exception of the DS2 trial which was held later. The RA measurements were made only outdoors, in roadside locations, over 21st-25th October 2002. Their report [14] is no more than a summary of their measurement equipment plus a large number of plots, from 1.5–13.8MHz and 12.2–20MHz, which are difficult to interpret as the measurement bandwidth is not stated and the plots are confused by the multitude of ambient HF signals.

The BBC [15] and RSGB [16] reports are more comprehensive, giving details of both indoor and outdoor measurements and an assessment of whether interference due to the PLT systems was actually noticeable. Their visits were concurrent and occurred on 12th-13th November 2002. Both parties concluded that, within the houses, both the Main.net and Ascom systems had the potential to deny the use of the broadcast and amateur bands to the occupants of the subscriber's house, and probably also to neighbours. The systems had different characteristics and used different frequency ranges, so that it might be possible to select PLT frequencies that were sufficiently separated from the desired reception frequencies that these latter would still be useable. But the actual amplitude of interference was substantially greater than any level that would render co-channel interference harmless. The measurements made by the BBC team showed levels that were sometimes in excess of the NB30 limits by 20dB, thus confirming the German and Swiss findings reported above; and the fact that even the NB30 limits are too high to protect broadcasting and amateur radio, as quoted by Austria and Finland, was also confirmed.

Reading all three reports, one is struck more than anything by the manifold difficulties involved in making reliable and repeatable on-site measurements of this type of interference, especially in situations where a baseline cannot be obtained because the PLT operation cannot be fully switched off. This is no surprise to an experienced EMC test engineer, but it does not bode well for a compliance regime which relies entirely on investigation and resolution of interference issues on a case-by-case basis after a PLT system is installed, as is envisaged by the European Commission.

Compliance status of PLT devices

The EC's draft proposal on PLT quoted above refers to a system being "made up of equipment compliant with the Directive". Here is the nub of the question: how can PLT modems be made compliant with the EMC Directive? It is the case that some PLT modems are already on the market in Europe and are CE Marked, which means that their manufacturers believe that they meet the essential requirements of the EMC Directive. But there are no standards specifically for such devices and for now, no such device could actually meet the general standard for RF emissions from IT equipment [6]. This is because, as shown earlier, the level of RF voltage that must be put onto the mains connection is far in excess of the levels which are allowed for conducted emissions from all such products.

If these products can't comply with their applicable standards, how could they be CE marked? The only alternative available to their manufacturers is the Technical Construction File (TCF) route, according to Article 10.2 of the EMC Directive. This requires that the case for compliance is submitted to a Competent Body, who must provide a certificate which states that compliance with the essential requirements is actually achieved without recourse to standards. It is understood that all PLT modems on the EU market today do actually use such a TCF route for their CE marking, implying that there is a Competent Body somewhere in Europe which does believe that such a case can be made.

Because of the difficulty in justifying it, both the EC Association of Competent Bodies and the UK EMC Test Laboratories Association have drafted guidance urging caution:

> *The basic question for a Competent Body when reviewing this or any other TCF is "Does this equipment meet the essential requirement of the EMC Directive". Given that a PLT requires a good signal to noise ratio to operate it must inherently generate emissions that may be in excess of the current limits allowed in EN 55022 and may therefore cause interference to some receiving equipment. It is the responsibility of the manufacturer to demonstrate in their TCF that the equipment does not generate such emissions and hence does meet the essential requirements. If the CB is not satisfied that the TCF accomplishes this then it should not provide a positive report or test certificate. [19]*
>
> *As the topic of PLC is very controversial and developments and activities are on-going at several levels, Competent Bodies when asked to carry out a TCF assessment on a PLC system, should take all the latest developments and activities into account. … Although the situation with regard to these systems is still constantly changing, CBs should keep in mind that the systems must meet the requirements of Article 4 of the EMC Directive. [20]*

The sensitivity of both of these documents can be gauged from the fact that neither of them have been published yet. Their sub-text is that there is very considerable doubt that any PLT system could meet the essential requirements embodied in Article 4. So any Competent Body which provides a positive report or certificate is, to put it mildly, adopting an exposed position.

Opening the floodgates

The EMCTLA guidance quoted above touches on a consequence of PLT which has caused concern to many in the relevant administrations. It must be assumed that the mains supply already carries noise from other apparatus which may approach the limits of EN 55022, even if everything connected is in full compliance with the Directive. For PLT to operate at all, its signals must be greater than this minimum noise level, almost by definition; and so it must breach these limits, again by definition. As we have seen, this is indeed so, by several tens of dB, and if it were not, PLT could not operate. Yet all other mains-connected equipment, such as ITE, medical products, household appliances, lighting and so forth – is subject to the standard mains conducted emissions limits.

What is to prevent the manufacturers of such equipment, which after all forms the vast bulk of products placed on the market within the EU, from demanding to know why PLT has received such special treatment? Why, they would want to know, do we have to comply with these limits, at considerable extra cost to our industries, when this upstart technology alone is granted exemption? If PLT can flagrantly flout the limits, they would say, so can we. But of course, were they to do that, it would open the floodgates to an uncontrolled escalation of interference on the mains wires. More bluntly, it would drive a horse and cart through the principles of interference control established over decades.

Nevertheless, this exposes a contradiction at the core of the case for PLT. It can only operate if it is indeed granted special status to apply RF disturbances to the mains lines. It must, in fact, be regarded as a special case in the context of the EMC Directive. It cannot possibly comply with the requirement not to generate an electromagnetic disturbance exceeding "a level allowing radio and telecommunications equipment and other apparatus to operate as intended"; because, since the limits are set to achieve this requirement, it must itself exceed those limits and therefore breach the requirement.

Attempts to write a PLT equipment standard

Mindful of this contradiction, and parallel to other standards activities on PLT, CISPR is looking at ways to adapt the IT emissions standard (CISPR 22, or EN 55022 in its European incarnation) to apply in a meaningful way to PLT. The working group has produced a succession of drafts, each of which seems to have provoked more controversy than the last, in defiance of the established method of standards production in which consensus is reached by an iterative process of comment and refinement.

The approach they have taken has been to re-define the mains connection as a "multi-purpose port". It is measured once in the conventional way, with the established limits, with the communications function inactive; and it is then measured again, in a different way, with the communications function active, and with a different set of limits. The second way relies upon treating the live and neutral wires as a balanced pair, and measuring only the common mode signal through a network which applies a defined degree of longitudinal conversion loss (LCL, see earlier). The limits to be applied are those which have already been established for other types of telecom port, such as LAN or xDSL connections.

See appendix for update

Clearly, the LCL figure is crucial for this approach. The higher the value, the less interference is converted to common mode and so the easier the limits are to meet; or, the higher the level of differential signal that can be transmitted and just stay within the limits. The figure mooted in the first draft was 36dB across the whole frequency range. As was discussed above, this figure seems decidedly optimistic, and at odds with the figure already proposed for poorly balanced twisted pair of 30dB, worsening at high frequency; it is unlikely that any kind of mains cable network will be better than twisted pair. 15–20dB might be closer to the mark. But 36dB is still too low for the PLT operators, who would find it difficult to accept even this value with current technology. Hence the diverging responses in comments on the draft standard; and note that this situation reinforces the argument rehearsed above, that PLT is inherently incapable of meeting any acceptable interference standard.

Attempts to write a PLT systems standard

Meanwhile the CENELEC/ETSI Joint Working Group has produced a draft of its Technical Specification (NB: not a standard) for the measurement of emissions from an operating PLT network [4]. The first draft of this is restricted to limits and methods of measurement for electromagnetic emissions emanating from access powerline communications networks; in other words it doesn't apply to in-home networks. Additionally, for rooms or buildings where both the network and its connected equipment are used, measurements are to be made only outside those rooms or buildings. Over the frequency range from 0.5 to 30MHz, it applies a limit of 4dBµA/m, which is taken as equivalent to 55.5dBµV/m, at a distance of 3m. As has been observed earlier, some national administrations think that such a value is about 40dB too high.

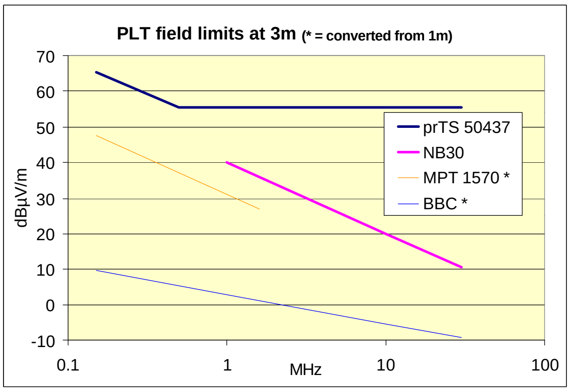
In a presentation to the EC's October 2003 workshop on PLC, the chairman of the Joint Working Group wryly observed the dilemma that was facing him regarding the question of limits:

1. Radio users and some administrations: Tighten existing limits by 30 dB

2. Telecom suppliers and operators and some administrations: Continue to apply existing limits

3. PLT suppliers and operators: Relax existing limits by 30 dB

(Or, as has also been observed, the spectrum users and PLT operators do actually agree on the values. They just disagree on whether they should take a negative or positive polarity.) The TS has yet to be published. Meanwhile, an Australian radio amateur has developed a prediction program [21] for determining the level of local interference that can be expected from a system which just meets the limits it suggests, at a given distance and frequency.



The graph above shows some of the limits that have been proposed, and demonstrates the wide variation between the values felt to provide protection for radio users (BBC) and the values that might be acceptable to PLT operators (prTS 50437).

Conclusions

A number of broad conclusions follow from the discussion outlined in this paper:

- PLT technology has the capability to create widespread interference, amounting to a denial of use, to users of the HF radio spectrum;
- This interference capability is inherent in the technology, particularly because of its use of standard mains wiring;
- Proposed technical fixes, such as frequency selective notches, have limitations and cannot satisfy all users of the HF spectrum;
- Attempts to find a compromise set of system radiated emissions limits which will satisfy both HF users and PLT operators are bound to fail, since there is 50–60dB between them;
- Similarly, attempts to create a product related emissions standard for PLT equipment involve unmanageable technical contortions and are also bound to fail;
- Nevertheless, the political imperative behind the expansion of broadband over PLT is sufficiently strong that in some countries it is likely to outweigh any imperative for protection of the radio spectrum.

Given that radio spectrum protection is assured by international treaty, the stage is set for substantial battles at the international level.

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Appendix

Commission recommendation 2005/292/EC

The Commission Recommendation published on 12th April 05 [3] includes the following wording (omitting the preamble):

> *2. Without prejudice to the provisions of points 3 to 5, Member States should remove any unjustified regulatory obstacles, in particular from utility companies, on the deployment of broadband powerline communications systems and the provision of electronic communications services over such systems.*
>
> *3. Until standards to be used for gaining presumption of conformity for powerline communications systems have been harmonised under Directive 89/336/EEC, Member States should consider as compliant with that Directive a powerline communications system which is:*
>
> *— made up of equipment compliant with the Directive and used for its intended purpose,*
>
> *— installed and operated according to good engineering practices designed to meet the essential requirements of the Directive.*
>
> *The documentation on good engineering practices should be held at the disposal of the relevant national authorities for inspection purposes as long as the system is in operation.*
>
> *4. Where it is found that a powerline communications system is causing harmful interference that can not be resolved by the parties concerned, the competent authorities of the Member State should request evidence of compliance of the*

> *system and, where appropriate, initiate an assessment.*
>
> *5. If the assessment leads to an identification of noncompliance of the powerline communications system, the competent authorities should impose proportionate, nondiscriminatory and transparent enforcement measures to ensure compliance.*
>
> *6. If there is compliance of the powerline communications system but nevertheless the interference remains, the competent authorities of the Member State should consider taking special measures in accordance with Article 6 of the Directive 89/336/EEC in a proportionate, non-discriminatory and transparent manner.*
>
> *7. Member States should report to the Communications Committee on a regular basis on the deployment and operations of powerline communications systems in their territory. Such reports should include any relevant data about disturbance levels (including measurement data, related injected signal levels and other data useful for the drafting of a harmonised European standard), interference problems and any enforcement measures related to powerline communications systems. The first such report is due on 31 December 2005.*

It is interesting that paragraph 6 shows that the Commission clearly envisages a separation between "compliance" of a PLT system and its capacity to cause interference.

CISPR 22

The amendment for PLT referred to in the text has been thrown out and a New Work Item has been proposed in its place, either for a new amendment or possibly to create a new part of CISPR 22 specifically for PLT equipment. The timescale involved in progressing such new work ensures that there won't be an EMC standard for PLT equipment for some years to come. Hence any PLT equipment currently on the market must for now be CE Marked under a Technical Construction File that has been vetted by a Competent Body. However, the new EMC Directive (2004/108/EC), due to be transposed into national law by 20th January 2007, does away with competent bodies and the TCF route. So a PLT manufacturer is going to have to take the responsibility on themselves for CE compliance in the future.

Meanwhile another modification to both EN 55022 and CISPR 22 has been to remove the LCL specification of 30dB for poorly balanced cables, on the grounds that this will never be used. A cynic might think that this is intended to neuter the argument (rehearsed in this article) that an LCL of 30dB is unrealistic for mains cable if it has been accepted for twisted pair cable.