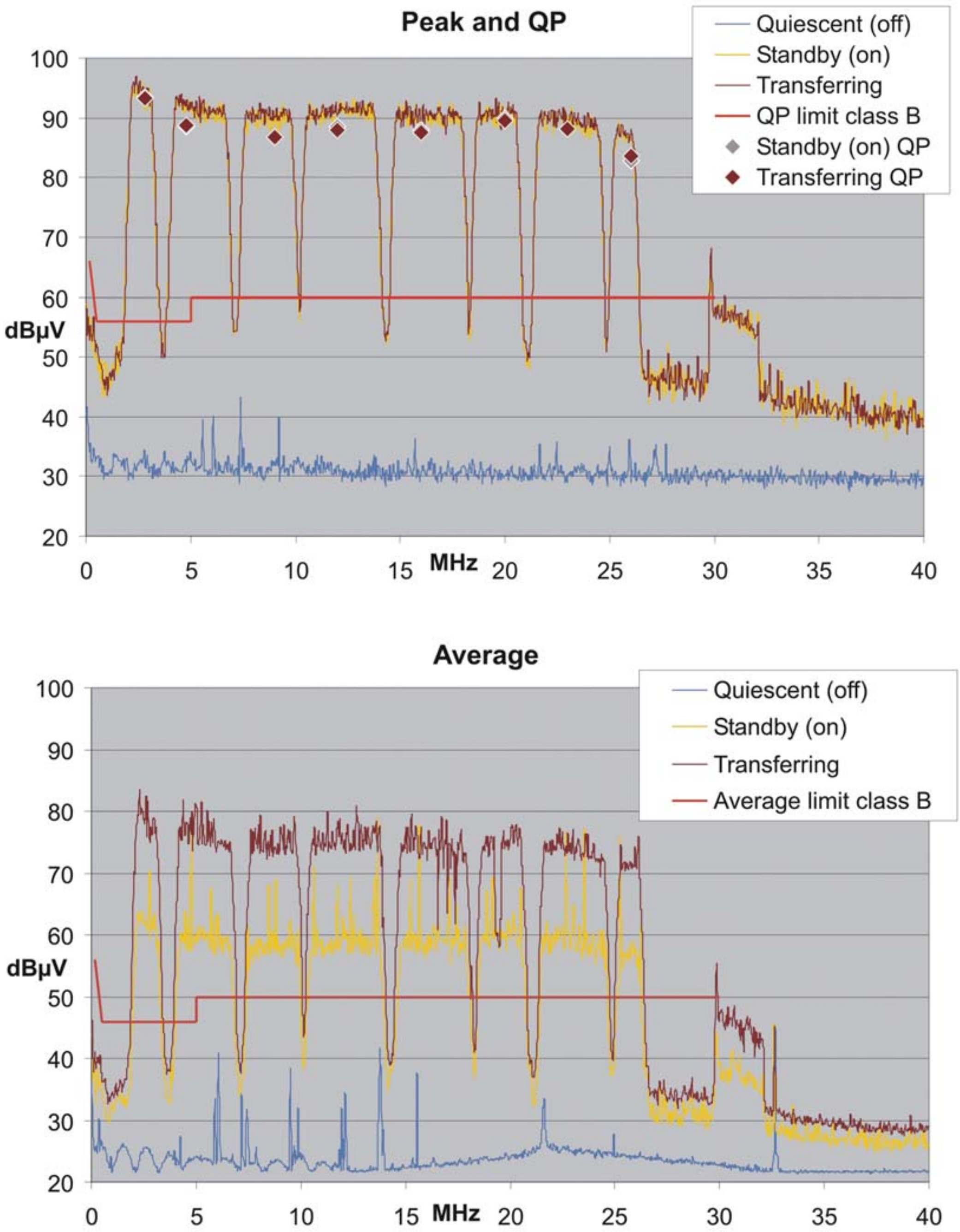
Greedy PLT

An EMC Journal Supplement



The headline result here is that for both average and quasi-peak limits, the system is approximately 30dB over the CISPR limit, not at isolated frequencies but over large swathes of the conducted emissions range.

The Summit PLT Group

Protecting the electromagnetic environment

Contents

There has been much concern with respect to certain PLT products causing interference to the radio spectrum. A significant number of EMC experts have been appalled by what can only be described as contempt by the EU authorities supported by BIS, Ofcom and BT.

The purpose of this supplement is to bring together in one publication all those articles that have been published on PLT in The EMC Journal, outlining the reasons why these modules should never have been allowed on the market.

The Summit PLT Group

Protecting the electromagnetic environment

Press Release

On August 27th 2009, a number of leading experts and organisations met in London to discuss the non-compliance of products with the EMC Directive, and in particular issues associated with 'Greedy PLT.'

The cause of this meeting was the non-compliance of certain PLT***** products, that use excessive radio-frequency emissions to obtain high data rates, interfering with radio reception and other equipment (e.g. slowing broadband speeds). The term "Greedy PLT" was coined to describe these products.

The Group agreed that their overall aim was:

To get all products that do not conform to the appropriate CISPR limits either removed from the global market, removed from use, or modified to comply.

Specific actions are being taken by the Summit PLT Group, some of which may be the subject of future press releases.

Background

CISPR limits for radio frequency emissions are published in international standards that are endorsed by the European Union as a basis for CE-marking under the EMC Directive. They have an established history, representing a well-proven compromise between environmental loss and commercial gain.

The Summit PLT Group agrees that attempts to bend or avoid meeting these limits have serious consequences for radio services, and can also have deleterious effects on many other types of equipment.

Such attempts would also damage the integrity of the "level playing field" for electronic products, which has so far been achieved by the consistent application of relevant international standards.

*** PLT** (PowerLine Technology), also called PLC (PowerLine Communications), BPL (Broadband over Powerline) and PLA (PowerLine Access), uses electronic modules that plug into standard mains sockets to send broadband digital signals over the electrical power wiring in a house.

This avoids running additional cables (e.g. Ethernet) to connect computers together (e.g. for video gaming) or to connect computers to televisions (e.g. to watch TV programmes downloaded from the Internet). It causes excessive emissions because mains cables are not suitable for this type of use.

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Ofcom

In early September 2009 the following statement was posted on the Ofcom website, probably in response to complaints with respect to PLT from various sources. There are many EMC experts who believe that this statement is fundamentally flawed and also indicates that Ofcom are not taking their responsibilities seriously. Many of the reasons for this thinking can be found in the various articles contained in this supplement.

Ofcom statement posted September 2009 at http://www.ofcom.org.uk/radiocomms/ifi/enforcement/plt/

What does PLT equipment do?
Power line telecommunications (PLT) apparatus uses a technology that can carry data on mains wiring around the house and is used to connect computers or other digital devices.

It reduces the need for additional wiring in the home, offers high data rates and is easy to install. As a result it is proving useful and popular, with around 750,000 Pairs of equipment estimated to be in use in the UK today.

Is PLT equipment new to market?
Yes. Although PLT technology has been in existence for some years, its proliferation as a mass market product is a relatively recent development.

How many brands of PLT apparatus are there on the UK market?
There are about 25 brands of PLT apparatus on the market in the UK. The largest supplier is British Telecommunications plc (BT). BT includes Comtrend UK Limited's PLT apparatus as part of its BT Vision package. This apparatus is required to comply with the EMC regulations.

What is electromagnetic compatibility (EMC)?
Electromagnetic compatibility is the engineering process which limits the natural electromagnetic fields produced by electrical appliances. This ensures that household products (for example, television, video or kettle) can all work within the home without disrupting each other.

Most electrical equipment produces an electromagnetic field as a natural by-product of its operation; an "electromagnetic disturbance". That disturbance can in turn affect the operation of other nearby equipment. For that reason, manufacturers aim to keep this disturbance to an acceptable level so that different products, particularly household products, can all operate in the home.

There are legal requirements about acceptable levels of electromagnetic disturbance.

What are the EMC legal requirements?
In common with other electronic products sold in the UK, PLT apparatus is required to comply with the Electromagnetic Compatibility Regulations 2006 (the "EMC Regulations") which are based on a European Directive.

These regulations aim to ensure that the electromagnetic disturbance generated by electronic equipment does not exceed a level above which other equipment (including radio and telecoms equipment) cannot operate as intended (and that the equipment itself has an adequate level of immunity to electromagnetic disturbance).

These requirements are described in the legislation, and are referred to as the 'essential requirements'.
In short therefore, the EMC regime provides a set of rules across the EU to ensure the levels of electromagnetic disturbance are regulated.

Who does the law on EMC apply to?
The person who places products on the market (usually the manufacturer or the importer) is responsible for compliance and must ensure that equipment meets the essential requirements and does not produce an excessive level of electromagnetic disturbance. Failure to meet this core obligation can result in a criminal offence.

How does a manufacturer demonstrate compliance?
Evaluation of electromagnetic disturbance is carried out by conducting engineering tests. Compliance can be demonstrated through self assessment or by involving an accredited organisation known as a "notified body".

As an alternative to carrying out an assessment, the equipment can be manufactured and tested against reference standards (called harmonised standards because they are harmonised across the European Union). If that is done, then there is a legal presumption of compliance.

What is Ofcom's role under the EMC legislation?
The UK Government department for Business Innovation and Skill (BIS) is responsible for overseeing the EMC Regulations.

Enforcement powers are delegated to Ofcom where there is a radio spectrum protection or management issue. Ofcom can bring criminal prosecutions and can suspend sales if it believes an offence is taking place.

In connection with our functions we engage with BIS, the EU Commission DG Enterprise and other Member States through Administration and Cooperation Groups (ADCO).

What enquiries and complaints has Ofcom received about PLT?
Over the past 12 months Ofcom has received 143 individual PLT interference complaints; all from radio enthusiasts. Of these 121 have been investigated and referred to the apparatus supplier who has resolved 104. The solutions employed include replacing the apparatus, hard wiring and conventional wireless alternatives.

All of the complaints relate to the inability to receive radio transmissions in the High Frequency (HF) band (3 to 30MHz).

There are many other users of the HF Band including long range aeronautical and oceanic communications, the Ministry of Defence and international broadcasters. Ofcom has not received complaints of interference to these services.

Has Ofcom investigated PLT equipment?
Yes. Ofcom has exercised its enforcement functions under the EMC Regulations. Ofcom has investigated alleged breaches of the EMC regulations resulting from the supply of Comtrend PLT apparatus by BT.

What has Ofcom found?
On the evidence, Ofcom has not so far found that there is a breach of the EMC essential requirements. Ofcom has therefore decided against taking further enforcement action at this time. Ofcom is working together with Comtrend and BT to reduce any negative effects in individual cases and we support them in doing so.

It is recognised that EMC compliant equipment may still, in certain circumstances, have the capacity to cause interference to other radio communications equipment. This may happen due to the manner in which it is installed or operated.

Evaluating the complaints received and the evidence so far obtained, Ofcom has concluded that there does not at present appear to be significant public harm arising from this situation.

Is there an EU harmonised standard for PLT?
No. The EU has not yet published a suitable harmonised standard for this type of apparatus. The mass marketing of PLT equipment is a recent development.

Are existing EU harmonised standards for other products helpful?
Existing harmonised standards are helpful only to a limited extent because they are not specifically intended for this type of equipment. Ofcom believes the electromagnetic disturbance produced by this technology is an inevitable by-product of its operation and not attributed to poor design or manufacturing.

Would the development of an EU standard for PLT help?
Yes. At present, testing and assessment takes place against a backdrop of wider technical uncertainty than is normally the case and there is an increase in the take-up of this apparatus across Europe.

The development of such a standard would be an important step. The standard could be used by manufacturers and Notified Bodies to assess performance against recognised benchmarked values.

If the apparatus complied with the harmonised standard under the Regulations, there would be a legal presumption that the apparatus met the essential requirements.

It is clear that the public interest (and the interests of manufacturers and suppliers) across Europe would be best served by the publication of a suitable standard. This is an aspiration of the EU Commission which Ofcom supports.

Is the EU taking action?
Yes. The EU Commission is aware of concerns resulting from the proliferation of PLT in the EU and in response, issued a mandate (M/313) to the European Committee for Electrotechnical Standardisation (CENELEC) to produce a PLT harmonised standard. Work on this is currently taking place.

(Also, in 2005 the EU Commission issued a 'recommendation' 2005/292/EC giving guidance to Member States on enforcement issues related to PLT.)

Is Ofcom studying the issue further?
In view of the concern expressed by stakeholders Ofcom commissioned an independent study into the likelihood and extent of interference caused by PLT apparatus. This study is due to be completed in November 2009 and will involve consultation with the Radio Society of Great Britain and other stakeholders. We will be publishing the results. It is hoped that the results will increase knowledge about the effects of PLT equipment and contribute to the development of manufacturing techniques and product design.

What else can Ofcom do?
Ofcom can provide advice and assistance to those who complain of interference with radiocommunications equipment. Any individuals who wish to report specific cases that may be caused by PLT apparatus, or any other source, should contact Ofcom's advisory team on 0300 123 3333 for further assistance.

We continue to liaise with BIS and other interested stakeholders in respect of PLT interference and will provide further updates on any significant developments.

RSGB

The RSGB press release posted on the RSGB site - http://www.rsgb.org/news/pla_dispute_law.php - and reprinted below, is self-explanatory and needs no further comment.

RSGB News

September 2009

RSGB goes to law over PLA dispute with Ofcom

The RSGB continues to take the Power Line Adaptor compliance fight to Ofcom.

Following Ofcom's statement on PLT/PLA on the 3 September 2009 and the RSGB's response statement issued on the 4 September 2009. The Society has now received a formal reply from Ofcom following the Society's earlier formal complaint to Ofcom regarding non compliance PLA's and Ofcom's interpretation of the EMC Directive regarding these devices.

The RSGB continues to find Ofcom's responses and position totally unacceptable and has recently met with and instructed its lawyers to investigate a legal challenge on the Ofcom position.

The RSGB will continue the fight to protect the radio spectrum against non compliant devices which cause unacceptable levels of interference particularly to the HF bands. We will issue further statements as the case develops.

A low level of complaints *is not* evidence of compliance

(An update on the EMCIA's position on PLT)

By EurIng Keith Armstrong, C.Eng, MIET, MIEEE, www.cherryclough.com

The two months since the last Edition of the EMC Journal was published have been busy ones for PLT.

It was not my intention to follow my article "The EMCIA's Position on PLT" [1] with another one on PLT, but three important things have happened to make me change my mind:

1) In August there was a meeting of leading experts and organisations in London, to discuss the EMC non-compliance of PLT in particular (but all products in general)

2) Also in August, DG Enterprise postponed listing EN 55022:2006 under the EMC Directive for over two years, to 1 October 2011. This was against the opinions of almost all the delegates at their EMC Working Party, and also against the advice of all the standards people consulted. See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2009:197:0003:0003:EN:PDF

3) In September, Ofcom published their update on PLT, which you can read at: http://www.ofcom.org.uk/radiocomms/ifi/enforcement/plt/

I'll briefly discuss the first two items, but it's the third one I really want to focus on here, and that is the subject of the title.

1) The meeting of leading experts and organisations was originally called because of the non-compliance of 'broadband PLT' products with the EMC Directive, and the apparent refusal of any of the enforcement authorities to do anything about it.

One expert pointed out, however, that PLT has been around for years, using low data rates and frequencies below 150kHz, and causing no interference problems at all. It even has its own emissions standard listed under the EMC Directive: EN 50065-1.

All agreed that they were concerned with any product that caused interference to the radio spectrum, which meant that they were not concerned with PLT *as such*, but with the more recent 'broadband PLT' that does not comply with CISPR emissions limits.

One of the experts said that his wife, while proof reading something he had written on this topic, had described it as 'Greedy PLT' – a rather nice term for something that gobbles up more spectrum than it should.

They agreed the following:

a) They would target any products that exceeded the appropriate CISPR limits at any time.

b) Their desired outcome was to get all products that did not conform to the appropriate CISPR limits removed from the market, and – for products already in use – to get them either removed from use, or modified to comply with the CISPR emission limits.

c) The geographical area over which they are concerned to protect the radio spectrum is global. Naturally, they can't address the whole world at once, right from the start, so they intend to start in the UK and cover the social, economic, political and technical aspects of raising the profile of non-compliant products.

This group of experts came together just before items 2) and 3) above became public knowledge, arguably revealing the contempt of the various authorities in the EC and the UK for the EMC Directive and National implementations of it. Clearly, the group is sorely needed.

Why focus on CISPR limits? The EMC Directive [2] allows two routes to compliance with its Essential Requirements: the 'Standards Route' and the 'Technical Documentation File'.

The standards that can be used under the standards route all base their emissions limits on the CISPR limits. The 'TDF' route does not have to use any standards at all, and so is useful where products are difficult to test to standards (e.g. very large and don't fit in a test chamber, or custom equipment only ever assembled on its user's site) and also useful for start-up companies who find it hard to afford full-compliance testing costs and so rely on their EMC design skills and a few lower-cost tests.

However, whatever the 'route to compliance' chosen, all products have to comply with the Essential Requirements in Article 5:

> *Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:*
>
> **(a) the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;**
>
> *(b) it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use.*

CISPR is the only international organisation whose principal task has been setting emissions limits to protect the radio spectrum, and they have been successfully doing this for decades to the widespread satisfaction of the entire EMC industry.

So the group of experts chose compliance with the appropriate CISPR limits as the 'yardstick' for determining whether a product complies with emissions requirement highlighted above. It doesn't matter how a manufacturer claimed compliance with the EMC Directive – the crucial issue, the 'acid test' (if you like), is whether its emissions exceed the CISPR limits at any point during its operational cycle.

If they do, the product *must* be exceeding the level above which radio and telecommunication equipment or other equipment cannot operate as intended (because CISPR has spent hundreds of man-years determining this), and therefore *must* be considered to be non-compliant with the EMC Directive.

Actually, the CISPR limits are not that tough, and there are plenty of technical arguments showing, and examples of, products that comply with the CISPR limits and yet still cause interference. The limits were designed as a reasonable compromise between the cost of products to the consumer and the probability of interference to his neighbour.

For example, the CISPR limits for the domestic environment admit that they might not protect radio receivers that are closer than 10 metres – yet most modern households are not even as large as 10 metres in any direction, yet contain dozens of electrical appliances and electronic products. Surely a modern emissions limit needs to protect radio receivers at 1m distances?

So, by hanging their hat on compliance with the CISPR limits, the group of experts (who have yet to agree a collective name) cannot be blamed for being over-zealous.

2) The 1998 Edition of EN 55022 is currently listed under the EMC Directive. It is passing strange for a standard that covers the products experiencing the most rapid advances in technology – Information Technology and Telecommunications – to be eleven years old. Postponing its 2006 Edition for a further two years is going to cause all sorts of problems for all EMC test labs and many manufacturers, so the European Commission's DG Enterprise (who do not employ any technical staff) must surely have had a very good reason for going against the combined advice of their own EMC Working Party and all the standards experts they consulted?

Well, the reason was in fact this: the 1998 version includes some text that describes how its mains emissions limits (CIPSR limits!) are to be applied to tested products. Like all such text it requires a certain technical competency to understand correctly. The 2006 Edition makes the text easier to understand by including a graphic, a decision-tree or flow-chart, and the inclusion of this is the sole reason for its postponement.

Why? (I hear you asking) Well, certain manufacturers of Greedy PLT products claim to comply with EN 55022:1998, relying on the fact that most politicians, bureaucrats, journalists and EMC enforcement agencies in Europe do not have the technical competence to understand the words in its text explaining how to apply its mains emissions limits.

But the graphic in the 2006 Edition would have made that text easier to understand, at which point one would have to be rather dim not to realise that the Greedy PLT products could not actually comply with EN 55022 as they were claiming.

So the European Commission postponed listing the 2006 Edition of EN 55022 under the EMC Directive, which will cause untold difficulties EMC test labs and manufacturers, for no other reason than enabling the manufacturers of Greedy PLT products to continue to fool (almost) everyone that they really do comply. Let's just take a moment to review just what benefits Greedy PLT products bring to our modern world:

i) They allow broadband Ethernet access in the home without having to route any new cables, which can cause unsightly lumps under carpets

ii) Er, that's it.

So who uses broadband Ethernet in their homes? Well, mostly it is teenage multi-player gamers, and people with an Internet TV service, such as BT Vision, who can use it to connect their computer to their TV without having to use an Ethernet cable.

I think it would be a very strange person indeed who could claim that this was a good enough reason for allowing Greedy PLT manufacturers to continue to flout laws that everyone else has to meet. Yet, this is exactly what DG Enterprise has just done. Proof that truth is stranger than fiction, no doubt, but that is little consolation.

Interestingly, Richard Marshall [3] is not the only EMC expert to have pointed out that Greedy PLT could satisfy 95% of their market's data transfer rate requirements if they reduced the amplitude of the signals they put on the mains to a level that would allow them to scrape in under the CISPR limits.

I understand that the PLT manufacturers choose not to take this quite reasonable step, because somehow they know that DG Enterprise will continue to allow them to get away with using their Greedy technology, and that all the EMC enforcers throughout the European Union will follow the EC's lead, because they either do not have the competence or the balls to stand up to the EC.

3) So now we eventually come down from the giddy heights of EC bureaucracy, to our own beloved Ofcom in the UK. When Ofcom subsumed the Radio Agency and its Radio Investigation Service a few years ago, people wondered how it was that an organisation that was working for the telecomm's and radiocomm's industry could also police that same industry.

In UK agriculture, this same approach to combining 'poachers' and 'gamekeepers' in one Agency caused various health crises, and it seems the same chickens are now coming home to roost with Ofcom. (Did you like the deft use of an agricultural cliché, there?)

Anyway, I assume that by now you have all visited the Ofcom PLT webpage whose URL I provided earlier. You might also like to visit: www.theregister.co.uk/2009/09/04/power_line_networking/, to see Bill Ray's take on the RSGB's repudiation of Ofcom's September update on PLT.

As for the group of experts mentioned in 1), the initial reactions of four of them to the PLT update were:

Expert 1): Obviously Ofcom have decided they can't be bothered to examine the RSGB's detailed case (dated 31st July 2009) for non-compliance. Their PLT update is not even accurate in so many respects, not least that it mentions M313, which is specifically aimed at cable radiation and excludes modems.

Expert 2): Having briefly examined the release, I feel that what has been left out is more important than what has been included. Virtually every section either has inaccuracies or areas that need further information.

Expert 3): Quote: "On the evidence, Ofcom has not so far found that there is a breach of the EMC essential requirements." This is clearly not true.

Expert 4): The Lord Nelson approach! (see panel below)

Horatio Lord Nelson, commanding the English Fleet, is said to have put his telescope to his blind eye and said "I see no ships".

Although the quotation is almost certainly incorrect, the expression is now commonly used whenever someone refuses to see what is plainly obvious to all, if they would only take the trouble to look.

I'm sure that Ofcom's September PLT Update will be written about extensively in the future, not least their decision to pay for an 'independent study' of Greedy PLT, when they have already been provided with all the information that any reasonable enforcer would need to get any other product taken off the market in double-quick time.

The Ofcom PLT update states that all of their 143 complaints to date are from "radio enthusiasts" – but the UKQRM website (http://www.ukqrm.org/) also lists incidents where Greedy PLT has interfered with wireless computer mice and other non-radio-reception interference incidents. It also shows that *Greedy PLT can slow down a broadband internet connection.*

The not-so-subtle message being given out by the Ofcom PLT update is that the only people complaining are hobbyists – that *nothing serious* is being affected.

The unspoken assertion is that since most of us receive our media digitally, either over the air or by the Internet, we should care less about the hobbies of a few nerds. This argument is incorrect, as shown in c) below, because digital media don't give us any indication of interference, they just stop working and people assume the products are broken.

However, the radio amateur and shortwave listening community are the radio spectrum's "canaries in a coal mine" (see following panel). Because of the sensitivity of their activities, they are often the first to notice interference, and the majority of us ignore their complaints at our peril.

What started out as a few complaining hobbyists, could become an interference menace that could even threaten the UK Government's "Digital Britain" initiative [4].

Canaries (the little yellow singing birds, not the islands off the North African coast) were until surprisingly recently used by miners to indicate problems with air quality underground.

Being so sensitive to air quality, they provided a warning of poisonous or flammable gases before they became too dangerous to the (much larger) miners.

For background, see: http://en.wikipedia.org/wiki/Animal_sentinels, and http://news.bbc.co.uk/onthisday/hi/dates/stories/december/30/newsid_2547000/2547587.stm

The expression "Canaries in a Coal Mine" is now widely used wherever an especially sensitive or aware group of people detect a serious problem that is not yet apparent to the wider populace, see for example the climate change website:
http://www.canariesinacoalmine.com/countdown.php.

The pop group of the same name have nothing to do with our subject, but you might enjoy their music.

Now, at last, we come to the issue I would like to focus on, that is the title of this article, the Ofcom statements that:

> *"Evaluating the complaints received and the evidence so far obtained, Ofcom has concluded that there does not at present appear to be significant public harm arising from this situation."*

They are clearly tying compliance with the Essential Requirements of the EMC Directive to the number of complaints received and some kind of public harm issue. They are forced to rely on this extremely dubious approach, because any test lab that tests Greedy PLT products shows that they are always at least 30dB above the CISPR limits, and Ofcom have been provided with such tests results even if they have never tested PLT themselves.

The test itself takes about an hour and any EMC test lab can do it and provide a report for under £400. Tim Williams did it himself, and described his results in detail in [5]. They correspond very closely with the full-compliance laboratory test results that the RSGB have provided to Ofcom, and others have provided to Trading Standards.

dB can be a tricky concept, so to get things in perspective I'll just point out that having emissions 30dB above the CISPR limit is the equivalent of plugging *at least* 1,000 barely-EMC-legal products into the same mains socket, and all operating them all at the same time. (Some experts argue it is equivalent to 100,000 barely-legal products.)

However, to return to the title and main focus of this article: a low level of complaints *is not* evidence of compliance, for several very good reasons, many of which are sufficient to give the lie to this approach entirely on their own:

a) The EMC Directive's Essential Requirements (quoted earlier) are clearly concerned with the *ability* of a product's emissions to interfere with radio receivers (etc.). They are not concerned with whether a product actually does interfere and cause complaints, but with whether it *could*.

   So having a low number of complaints of interference *cannot be used as an argument* for compliance with the EMC Directive. (And Ofcom's comment about 'public harm' has nothing at all to do with any concepts of legal EMC compliance.)

b) The claim that a low level of complaints means that a product must therefore be compliant with the EMC Directive, is based on the well-worn fallacy that where there is no evidence of a problem, there must therefore be no problem.

   This common but mistaken belief was explored in some detail in my article "*Absence of proof is not proof of absence*" [6], which pointed out that William Cowper had seen through this false logic about 200 years ago.

   Whenever you hear someone using this sort of an argument, it means one of two things:

   - either they are insufficiently educated to understand the logical fallacy in what they are saying; or,
   - they know very well what they are saying – but assume that you won't catch them out (which is rather insulting).

   The latter usage – where they are trying to put one over on you – is very popular with politicians, and with less-than-safety-conscious manufacturers trying to defend product liability lawsuits by fair means or foul. I believe that Ofcom personnel are well-educated, so assume they are using such a discredited argument because someone has told them what to say.

c) Modern digital technologies do not reveal interference like their analogue forbears did, leading to under-reporting of interference cases.

   In the 'old days' of analogue, interference was obvious as noise or distortion, and one could easily distinguish between, for example, motor car ignition, hair-driers and other receiver's local oscillators. But these days our digital radio and television either give a good sound and picture, or they give nothing at all. So when they are interfered with, the user assumes they are broken and takes them back to the shop for repair or replacement.

   This is exactly what caused the demise of ITV Digital in 2002, with a financial loss of about £600 million and loss of 1700 jobs. The Government had only permitted them to transmit with a weak signal, so interference was a big problem. Being digital products, many customers received no picture at all and simply assumed their sets were broken.

   All our media have already gone, or are rapidly going, digital, so complaints of interference will be replaced by products being returned under warranty. Of course, when the returned sets are tested back at the factory they are found to be working perfectly. Replacing the product with a new one will probably result in the same problem occurring again and again with each customer.

   Dealing with no-fault warranty returns represents a large cost on UK manufacturers and agents for overseas companies. But I suppose the bright side is that there will be lots of extra business for repair shops, for out-of-warranty products. Unfortunately they will never be able to fix the 'fault' in the product.

   I wonder if Intellect (http://www.intellectuk.org/) are lobbying Ofcom to protect their manufacturing members from this unjustifiable cost to their businesses? They should be!

   For digital communications, like Ethernet and xDSL (used to carry broadband Internet over telephone wires) the effect of interference is to slow the data rate. Many's the office Ethernet system that goes slow due to interference – which could simply be due to an Ethernet cable in a ceiling void being routed too close to a fluorescent light fitting – but because the digital protocols hide the interference from the system's users, their typical response is to assume some large software task is being carried out, or "there must be a lot of people logged on".

d) [7] makes certain assumptions about how many people can be bothered to make an official complaint. British people are not great complainers, preferring to grumble to try to get sympathy, rather than remove the reasons for the complaint.

   Along these lines, I am reliably informed that, some years ago, the new Labour Government in the UK wanted to decrease the number of complaints of radio interference. They achieved this by removing the interference complaint forms from Post Offices and making them only available by download from a website (as now), and requiring them to be accompanied by a fee, which might be refundable if the complaint was found to be justified.

   These measures immediately reduced the rate of interference complaints to one-tenth of their previous levels. I leave it to the reader to decide whether the effect of the measures was to cause some actual interference problems to fail to be brought to official attention.

e) Issue 83 of the EMC Journal carried a Banana Skins column, as usual. This one was unusual in that it was dedicated to a report by Pete Alsop, an Ofcom Senior Field Engineer. He's one of the guys that goes out to find out the truth, and fix, complaints of interference, and he and his colleagues have an enviable record of success.

Pete had responded to a request of mine to Ofcom to show what technologies were causing the most complaints of interference, and here are the top three offenders for the whole of the UK for the period January 2007 to May 2009, a period of 31 months:

Lighting Systems	252 complaints
Thermostats	223 complaints
Aerial Amplifiers	197 complaints

Pete pointed out that, generally speaking, their work results from devices that have been incorrectly installed and/or have developed a fault of some description, not as a result of being poorly designed with regards to EMC.

If we consider lighting systems, there must be about as many as there are people living in the UK – about 60 million. Many of these lighting installations will be over a decade old, so it is hardly surprising that age, damage, faults, etc., could make this technology the worst case for causing interference, with 252 complaints over the surveyed period of 31 months, an average rate of about 8 complaints/month, or 0.13 complaints per month per million installed systems.

At the time of writing that column, the Ofcom PLT webpage said there were 81 complaints of interference due to PLT. Ofcom have stated that there were no complaints about PLT before August 2008, when a magazine carried an article about it.

All of the 81 complaints about PLT had arrived over a period of about 10 months, an average rate of about 8 complaints/month – just as bad as the worst-case offender, lighting systems. However, at that time only 423,000 BT Vision products had been purchased, and if we ignore that at the start of the period there were far fewer products sold, and if we assume that all BT Vision customer use their PLT units (which they don't), we get 18.9 complaints per month per million Greedy PLT products installed. (The real figure will be significantly higher.)

So we can say that the rate of complaints from Greedy PLT is already running *at least* at *145 times the rate* of Ofcom's worst-case interferer, lighting systems.

The reason for this very high rate, is that the interference complaints about PLT are all caused by its *intentionally-designed high levels of mains emissions*, not due to age, damage, faults, bad installation, etc., the causes of the vast majority of the complaints about all other technologies. (PLT units are almost impossible to install incorrectly, you just plug them into the mains socket and plug the Ethernet cable into them.)

The September PLT Update from Ofcom now says that the total number of complaints is 143. This represents an average rate of 11 complaints/month, showing that the rate of complaints is increasing. I understand that it is actually running at 14 complaints per month at the time of writing, making Greedy PLT the technology that is causing the worst interference over the whole UK.

If we assume that all Ofcom complaint rates stay constant – which they won't because the number of PLT products in use is increasing rapidly – PLT complaints would top Ofcom's all-time list of complained-about technologies in about 18 months. Will Ofcom then still be claiming that the level of complaints indicates there is not a problem?

BT Vision's marketing goal is to sell 3 million of their products by 2010. Reaching this marketing goal implies a complaint rate of over 57 per month. And if everyone in the UK used a Greedy PLT, like everyone uses a lighting system, the Ofcom complaint rate would be around 1,140 per month. But by then the issue would have had so much national media exposure that complaint rates would probably be 10 times higher than these estimates, if not more.

f) How many complaints would it take Ofcom to say that Greedy PLT was non-compliant?

This is not specified anywhere in the September Ofcom PLT Update, making its statements rather obviously based upon political obfuscation than legal or technical definitions.

g) Richard Marshall's excellent article [7] used careful reasoning to show that the number of complaints received by Ofcom (at the time he was writing) were consistent with Greedy PLT actually being a 100% reliable *interferer* and therefore non-compliant with the EMC Directive.

He based his argument solely on calculating the likelihood that a Radio Amateur or Short-Wave Listener would find themselves within 150 metres of one of the 423,000 owners of a BT Vision product (which bundled a Greedy PLT unit solely to avoid customers having to run unsightly Ethernet cables from their computer to their TV).

So Ofcom's figures for the number of complaints do not show that Greedy PLT is compliant, as they claim, but exactly the opposite!

Ofcom's complaint figures actually indicate that Greedy PLT products are 100% reliable interferers, or 'jammers' as such technologies are sometimes called.

To sum up, a (claimed) low level of complaints of interference from Greedy PLT products, cannot justifiably be used to claim that such products comply with the EMC Directive.

The conclusions of the September Ofcom PLT update are therefore completely incorrect.

[1] Keith Armstrong, "*The EMCIA's position on PLT*", The EMC Journal, Edition 83, July 2009, pages 19-21, www.theemcjournal.com

[2] EMC Directive, http://eur-lex.europa.eu/LexUriServ/site/en/oj/2004/l_390/l_39020041231en00240037.pdf

[3] Richard Marshall, "*Headroom for PLT: is it necessary? (Signal/Noise ratio considerations for PLT)*", The EMC Journal, Issue 81, March 2009, pages 30-31, http://www.compliance-club.com/PLT/Richard%20Marshall%20EMCJ%20Issue%2081.pdf

[4] See the Editorial: "*Call it what you like...it still interferes with the Radio Spectrum*", The EMC Journal, Issue 83, July 2009, page 5, www.theemcjournal.com, and the UK Government's Digital Britain site: http://www.culture.gov.uk/what_we_do/broadcasting/5631.aspx/

[5] Tim Williams, "*RF Emissions of Powerline Ethernet adaptors*", The EMC Journal, Edition 82, May 2009, pages 15-18, http://www.compliance-club.com/PLT/Tim%20Williams%20EMCJ%20Issue%2082.pdf

[6] Keith Armstrong, "*Absence of proof is not proof of absence*", EMC Journal, Issue 78, September 2008, pages 16-19, www.compliance-club.com/pdf/Issue78.PDF

[7] Richard Marshall, "*BT Vision; the radio interference iceberg*", The EMC Journal, Issue 83, July 2009, pages 22-24, www.theemcjournal.com

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The EMCIA's position on PLT

By EurIng Keith Armstrong, C.Eng, MIET, MIEEE, www.cherryclough.com

Last year, the EMC Industries Association (www.emcia.org) chose me as their President, a decision that they have not yet come to regret (but its still early days). If you haven't heard of the EMCIA, it's probably because it has been run for the benefit of its members and has kept a low profile as far as the rest of the world is concerned.

But recently, the EMCIA has decided that there are various issues in EMC that are not being correctly addressed, and that it ought to try to play a part in getting them resolved, for the benefit of all. The first issue they have decided to address is the situation surrounding PLT (powerline technology), also known as broadband-over-powerline (BPL) or powerline communications (PLC).

If in your house you use an Ethernet adaptor that communicates by using the mains power cables in the wall, instead of a dedicated Ethernet cable, you are using PLT.

Some background: the Single European Market, with its CE Marking directives for products, was created for two reasons:

i) To achieve the economies of scale that had been observed to work so well in Japan and Northern America, by converting the differing import regulations of the various European nations into a single set, so that a single product design could be tested for compliance and sold to all of them.

ii) To keep cheap rubbish out (more accurately: protect responsible manufacturers from non-compliant products that could increase safety risks beyond those generally considered tolerable by Europeans, or damage the very important radio spectrum).

Well, item i) has been achieved, but not ii). Enforcement of regulations has an associated cost, and most European Union (EU) Member States apparently decided that they would enjoy the economic benefits of membership whilst saving money by not doing very much enforcement.

This is the governmental equivalent of being a teenager (who can confusingly now be 30 or more years of age) who prefers to live with his/her parents because of the financial benefits, but who doesn't actually want to help with the housework.

As many of us know from personal experience, such situations usually do not last for ever, and so it has proved for the EU. Discovering in 2005 that between 30 and 50% of products actually supplied in the EU did not comply with EU Directives they are supposed to [1], worried the European Commission (EC) greatly, because societal studies show that when such 'free loading' exceeds 15% they risk the collapse of the society itself.

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This has resulted in the first change to the CE marking approach in the EU, since its inception – EU Regulation 765, 2008 on Accreditation and Market Surveillance. From the 1st January 2010, "Reg 765" will require Member States to perform at least a specified minimum of effort in enforcing EU Directives in their countries, and they will have to provide figures to show that they are, in fact, doing their bit.

So it's very ironic, that whilst one part of the EC was busy being worried about the lack of product compliance, another part of it (DG Enterprise) was busy adding to the problem by encouraging the use of PLT – a technology that comes nowhere near complying with the EMC standards notified under the EMC Directive, which are intended to protect the radio spectrum from intolerable interference.

The original justification given by DG Enterprise for permitting the use of PLT, was that it provided competition for delivering broadband Internet services, especially to remote places where running additional cables would be very costly.

Since the mains cables already exist, why not use them to carry the data? Well, the reason, well established by numerous investigations and field trials, is that the mains cables make very good antennas for the MHz frequencies needed to communicate the data, and since the data has to be sent over them at a very high level because of all the noise on the mains, PLT ends up broadcasting its signals all over the short-wave radio communication bands (known as the HF spectrum or HF bands).

This is known as 'Access PLT', but it has not been a commercial success and since other technologies are now a better bet for the future it is unlikely to ever take off. But PLT is also used for distributing high-rate data inside the home, where it has recently found a niche for distributing HDTV from room to room, or replacing Wi-Fi for people whose walls and floors attenuate 2.45GHz too much.

Whereas Access PLT had *some* political justification – however misguided this might appear to those who were concerned to protect the HF spectrum – there is *no political justification* for in-house PLT (unless you believe there is a political reason to turn people into couch potatoes), and yet DG Enterprise continues to support it.

Lay waste to the HF spectrum, causing untold difficulties and increased costs for the BBC, NATO, MOD, etc., spoil a natural resource that has huge safety benefits during large-scale disasters as well as providing an alternative broadcast medium for those who can't or won't use internet access, not to mention damaging the hobbies of many Radio Amateurs – all so that people don't have to string extra wires around in their homes? It hardly seems an equitable bargain.

You will find a wealth of technical detail about PLT and the test standards in Tim Williams' excellent analyses in Issues 80 and 82 (January and May 2009) of the EMC Journal, plus Richard Marshall's article in Issue 81 (March 2009) – and also in the articles by those same two independent EMC experts in this Issue.

There is also a wealth of historical documents on PLT posted on the EMC Journal's website at **www.theemcjournal.com/plt.** I recommend you read the correspondence between ADDX and DG Enterprise – for myself, I have never read such well-written technically-competent questions, and I never even *imagined* ever reading such arrogant, weasel-worded, patronising replies, which failed to address any of the questions and were devoid of any meaningful technical content.

All this excellent material leaves me free to discuss the EMCIA's concerns about PLT in this brief article using a general, more hand-wavy approach, as follows.

A) PLT is an extremely noisy technology

The mains noise emissions from a single Ethernet-over-Powerline product, widely sold throughout the EU, is conservatively equivalent to that of *at least* 1,000 products that only just meet the limits in their relevant harmonised emissions standards.

This is like having the total mains noise emissions of all the houses in a small village injected into the mains distribution at one point in a house! And of course this could conceivably happen in every house or apartment in a town, or even in a large city.

I have seen a technical argument that seems quite reasonable, that estimates the figure to be more like *100,000* products that just about meet their emissions limits, on the basis that the PLT device blankets the major portion of the HF spectrum and is always on – equivalent to plugging in the mains noise of all the households in a *small town* – at just one point in each house.

B) Many warnings have been given about PLT

Several theoretical investigations by leading organisations (York University, ERA Technology, NATO, BBC, RSGB, Netherlands Broadcasting Authority, etc.) over recent years have all shown that PLT technology must be expected to cause a significant increase in the background noise levels in the HF (short-wave) bands worldwide, if deployed Europe-wide.

Some of the research indicated that an Access PLT system covering the whole of Greater London would significantly raise the noise floor in the HF bands as far away as Plymouth, while others claimed it would be detected as far away as Moscow.

They also showed that near to a PLT product, HF reception could be rendered impossible for a radius of several hundred metres.

Field tests in Japan found that these predictions are not unreasonable, and that a single PLT system could also interfere with Radio Astronomy in the HF bands at distances of up to 219km, and its harmonics could interfere at UHF at up to 12km.

The HF bands are used for vital communications with impacts for safety, national security and defence, and proved invaluable in coping with both 9/11 in New York and the Boxing Day tsunami, when the 'normal' telecommunications and radiocommunications (including cellphones and the emergency services' own systems) all failed. So the raising of the noise floor in the HF bands can have very serious safety consequences.

C) An example of one PLT vendor's claims of EMC compliance.

Recent correspondence on the subject of one particular product has revealed the claims made for compliance with the EMC Directive by the product's manufacturer, when challenged. EMC enforcement agents throughout the EU seem content to accept these claims, despite them being erroneous in <u>every</u> respect.

Claim 1: Our product conforms to the EMC Regulations as amended, and the Product has been tested by an accredited independent Test House. The tests carried out simulated the conditions in which the Product is likely to be used.

Rebuttal 1: Their Declaration of Conformity referred to CISPR/I/89/CD as the test standard used by the test house. But this is not a harmonised standard, so cannot be used to provide a presumption of conformity to the EMC Directive.

Worse, it is just a committee draft which was widely criticised and subsequently (and acrimoniously) withdrawn from IEC website. It is a totally discredited document.

The actual emissions when measured are at least 30dB above the maximum limits set by the relevant harmonised standard. A level that – when measured in all of the EMC test houses that anyone in the EMCIA has ever visited – would unquestionably result in a 'failure to comply' report.

Claim 2: Customers and enforcement agencies have also looked at our product and have had it tested for EMC regulations compliance.

Rebuttal 2: From our contacts throughout Europe, we understand this claim to be untrue, or – at the very least – intentionally misleading. Yes, they may have "looked at our product" – but they have certainly not formally endorsed its compliance with the EMC standards.

Claim 3: Our product design has a 'notching out' feature that can be used to block out the frequency that is the cause of problem in 'short wave' region of the electromagnetic spectrum.

Rebuttal 3: They can only block their emissions over a part of the spectrum – since some of the spectrum must remain unblocked to allow data to be communicated. Emissions in those unblocked parts of the spectrum still contravene the essential requirements of the EMC directive.

Also, recent analysis has shown that, in real life, 'notching' (e.g. to protect Digital Radio Mondiale) will have limited effectiveness, maybe none, due to intermodulation in the rectifiers that are certain to be connected to the mains supply.

Claim 5: We have sold about 75,000 products, but enforcement officials in the UK have only received 81 complaints, only 3 of which have not been resolved.

Rebuttal 5: There are several excellent reasons why the number of complaints (whether resolved or not) cannot provide any real understanding of the potential of any product to cause unacceptable interference. See Richard Marshalls article elsewhere in this Issue. What other product of similar sales volume would be regarded as satisfactory if it had received "only" 81 complaints?

D) Other manufacturers are likely to copy PLT emissions

Because certain vendors are (so far) being allowed to get away with selling Ethernet-over-Powerline PLT products that do not comply with the relevant harmonised emissions standards, using laughably incorrect compliance justifications such as those given above, many manufacturers of other classes of product will probably become interested in copying their emission levels.

By doing so, they can remove costly and large components from their product's mains filters. High-volume manufacturers could save millions of GB Pounds each year, a persuasive argument at any time, but especially so in today's difficult economic climate.

Of course, having such products on the market would quickly make noise levels on the mains supply network very much higher than they are at present, making it likely that PLT products would no longer work as well.

More importantly – this would add to the damage that the PLT products are doing to the HF spectrum – on which many specialist users (including UK Coastguard, Defence and National Security) rely, and would have significant safety implications.

DG Enterprise has recently started to claim that because there has been a low level of complaints of interference due to PLT products, this shows that they actually comply with the Essential Requirements of the EMC Directive (but see Rebuttal 5 above).

Although such statements are logically and technically incorrect [2], since they are being made by the people who have overall responsibility for the EMC Directive - manufacturers will be able to copy such statements in their EMC Technical Documentation and use them as justification for their non-PLT products having similar extremely high levels of conducted mains emissions.

The result would be that the value of the HF bands will be compromised forever, and for no good reason – PLT products would no longer be reliable, so very few people would use them anymore.

[1] Ivan Hendrikx, "The Future of Market Surveillance for Technical Products in Europe", Conformity, April 1, 2007 (but not a joke!), www.conformity.com/PDFs/0704/0704_F01.pdf

[2] Keith Armstrong, "Absence of proof is not proof of absence", EMC Journal, Issue 78, September 2008, www.theemcjournal.com

After the EMC Directive

By Tim Williams, Elmac Services

Does the EC think that standards are a waste of time? It has always been legally permissible to comply with New Approach Directives without actually testing to their listed harmonised standards, the aim being that whatever other approach is used should meet the Essential Requirements of the Directive. But what we are seeing now in the case of Power Line Communications (PLC, occasionally Power Line Telecommunications, PLT) is a situation in which manufacturers of such products are complaining about their inability to meet these standards, twisting out of doing so by using rejected draft documents as if they were legitimate, and doing this apparently with the full support and encouragement of the European Commission.

In the past year, complaints about interference from PLC products, and particularly about in-house Ethernet-to-Powerline adaptors that are on all the time, have been fired at the European Commission and at enforcement authorities from all directions. The response, when it comes, has been to shrug off the complaints as if they are irrelevant. A widely-circulated letter to an MEP from the Vice-President of the EC [1] says

> *"Power line adapters" are covered by Directive 2004/108/EC on "electromagnetic compatibility" (EMC), which provides Member States (in the case of the UK OFCOM) with ample provisions to correct situations of interference. The relatively few problems that occurred can be handled within its context. PLC technology does not interfere into military services since they typically do not operate in areas where there is a risk of interference. Emergency services now use advanced digital radio technologies to communicate. Shortwave broadcast reception has further been substituted by internet radio."*

This article will look at some aspects of the response and draw some conclusions for European regulation – conclusions which may surprise some people.

The Discussion Document

The European Commission's EMC Working Party last met at the end of June 2009, and PLC was one of the topics on the agenda. The Commission had circulated a "Discussion Document On The PLC Standardisation State Of Affairs" [2] in May, for the EMCWP to consider. In it, it was suggested that as of October 2009, manufacturers of PLC products will not be able to use EN 55022:2006 or any other harmonised standard for demonstrating compliance. This was taken to be because of a new testing flowchart which appears in this edition and which, it was felt, forced a PLC manufacturer to apply a conducted emission test which the PLC industry claims it didn't have to do under the previous 1998 edition; and October 2009 is the date from which the 1998 edition is superseded, as published in the *Official Journal of the EU*. The document includes what sounds like a sob story for PLC:

> *Any market surveillance check of PLC products conducted after October 2009 with the EN 55022:2006 test methods will show test results substantially above the limits of Table 1 & 2. As a result, PLC manufacturers have the impression that, even if their technical file is convincing, they run a serious risk of a sales ban by market surveillance authorities.*

The Commission had clearly been briefed in this regard by PLC manufacturers, not for the first or only time. A written question to the Commission in April [3], over the signatures of a number of MEPs, started by saying

> *Recent amendments to European standard EN55022 throw into jeopardy the future of powerline communications (PLC) technologies by imposing artificially low electromagnetic emissions limits that will make it impossible to place PLC equipment on the EU market from October 2009.*

Consequently, the Discussion Document for the EMCWP proposed one of two "solutions", either:

> *- to postpone the date of withdrawal of EN 55022:1998 which is the only standard with which PLT/PLC are able to comply. The new date could be discussed with CENELEC and industry so as to give reasonable time before the mandate deliverables can be referenced in the OJEU. However, for PLC/PLT equipment, which would continue to use the 1998 version, this solution postpones the benefits of all the other non controversial improvements which have been integrated in the 2006 version.*
>
> *- to render inapplicable to PLT/PLC the branch "mains" in the 2006 version (Article 6.4.b "publish with restrictions"). Thus, PLC/PLT technologies would still benefit from the non controversial improvements in the 2006 version.*

But it is *not true* to say that such technologies could comply with earlier versions of the standard, i.e. CISPR 22: 1998 or its EN equivalent. The later 2006 edition has, in the flowchart in Annex C, explicitly referred to the "mains type" as a potential type of telecommunications port which must be tested according to the established limits for mains terminals. This aspect of the flowchart has been maintained by CISPR/I in the face of pressure from the PLC industry for it to be modified; moreover, it has been maintained into the replacement for CISPR 22, the draft CISPR 32. This shows that CISPR/I regard it as imperative that the established limits should be applied *whatever the* *notional function of the mains connection*. The CISPR/I approach has a solid technical foundation, which is operative regardless of the type of equipment which is connected to the mains.

CISPR emissions standards exist to protect the radio spectrum. The radio spectrum is a valuable and irreplaceable natural resource, like air and water, but its true value is only really appreciated when it is no longer available. These emissions standards, their test methods and limits, are based on a rigorous, well documented approach* and many decades of experience in real-world prevention of radio interference.

The third edition of CISPR 22, published as EN 55022:1998, was drafted before the question was raised of whether a PLC mains connection should be treated as a telecommunications port. It has no Annex C flowchart (although, in their discussion document, the Commission don't seem to know this) and does not explicitly state that a telecommunications port could be a "mains" type. However, it applies, without qualification, limits for conducted disturbance at the mains terminals. Nothing in the standard would disapply this to a PLC modem. These are exactly the same limits as are referred to in the Commission's document as "too low to be complied with by today's PLC technologies". Therefore there is no difference as far as the mains terminals are concerned between EN 55022:1998 and EN 55022:2006. Any manufacturer whose equipment breaches the limits for mains terminal disturbance voltage in tables 1 or 2 of EN 55022:1998 and yet who has declared unqualified compliance to that standard, has done so incorrectly.

Consequently, there is no change in status when EN 55022:1998 is withdrawn in October 2009. So the "two solutions" proposed in the discussion document are illusory. The first would not change the situation that a PLT modem which cannot comply with the mains terminal disturbance limits, cannot comply with the EMC Directive through the harmonised standards route. The second clearly sets the Commission at odds with CISPR/I.

The implication of the Commission's two suggested solutions is that they regard the approach taken by CISPR/I as inconsistent with the purpose of the EMC Directive, and are looking for ways to circumvent it. This has serious consequences for the application of harmonised standards, which are largely based on CISPR requirements.

In the event, the outcome of the Working Party meeting was inconclusive; the point regarding the lack of difference between EN 55022:1998 and :2006 was made clear to the Commission, who nevertheless "reserved their position". It is obvious that the Commission had been incorrectly briefed by the PLC lobby (and had accepted that briefing), who for some reason think that they can "get away with" inadequate compliance to EN 55022:1998. What is that reason?

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* Interested parties may care to look at CISPR 16-4-4, "Statistics of complaints and a model for the calculation of limits for the protection of radio services"; of relevance to this argument, it contains, in its new Annex A, values of the classical CISPR mains decoupling factor which were determined by measurements in real LV AC mains grids in the 1960s. It is deemed that these mains decoupling factors are still valid and representative.

The advice to Notified Bodies

A previous article [4] has pointed out that the actual levels that one particular device puts on the mains supply are 30dB over the limit, over 75% of the conducted emissions frequency range. That device is said to use CISPR/I/89/CD, a withdrawn draft from 2003, in order to "tweak" CISPR 22 to allow compliance, and [4] discusses why this is not acceptable. But another source has suggested using a rejected CISPR document to allow a PLT device to claim compliance. This is ECANB (Group Of Notified Bodies Under The EMC Directive) TGN17 Version 1.0: April 2008, "Technical Guidance Note TGN on Assessment of Powerline Telecommunications (PLT) Equipment" [5]. It says

> *CISPR/I/257CD "CISPR 22 Limits and method of measurement of broadband telecommunication equipment over power lines" replaces the older CISPR/I/89CD. Thus it may be the basis for assessment by Notified Bodies until an amended CISPR 22 comes into force.*
>
> …
>
> *Notified Bodies when being consulted to provide an opinion on PLT conformity assessment should base their opinion on the following:*
>
> *a) Measurement of PLT emission should be done according to CISPR I 257CD (depending on the outcome of the voting this clause may need to be revised).*
>
> *b) Additional mitigation measures can be recommended to be implemented as described in CISPR/I/258DC* [which refers to notching and power management].

CISPR/I/257/CD having been swiftly rejected, TGN17 has now (a year later) been revised. For over a year Notified Bodies, and by extension manufacturers wishing to perform their own assessment, had an official imprimatur – ECANB is recognised as a source of guidance by the EC – for using a failed method. But the revised TGN is hardly any different; it merely repeats most of the relevant parts of CISPR/I/257/CD in its own text, and adds a description of mitigation techniques which is derived from (but not the same as) CISPR/I/258/CD. This in itself introduces problems, partly because the TGN now clearly diverges from the present thinking in the CISPR working group, and partly because some of the techniques are either patented or not yet commercially available. The guidance in the new TGN now reads

> *Notified Bodies when being consulted to provide an opinion on PLT conformity assessment are strongly encouraged to base their opinion on the following:*
>
> *a) Measurement of PLT emissions have to be done according to what it is described in clause 2 of this TGN.*
>
> *b) Additional mitigation measures have to be implemented according to what it is described in clause 3 of this TGN*

Note the difference between "strongly encouraged" and "should". In neither case is the word "shall" used. Even so, the

ECANB view is clearly at odds with the approach taken by CISPR.

The EMC assessment

At this point it would be as well to remind ourselves of the wording of the second edition EMC Directive 2004/108/EC. Annex II.1 says

> *The manufacturer shall perform an electromagnetic compatibility assessment of the apparatus, on the basis of the relevant phenomena, with a view to meeting the protection requirements set out in Annex I, point 1. The correct application of all the relevant harmonised standards whose references have been published in the Official Journal of the European Union* ***shall be equivalent to*** *the carrying out of the electromagnetic compatibility assessment.*

Point 3 says

> *In accordance with the provisions set out in Annex IV, the manufacturer shall draw up technical documentation providing evidence of the conformity of the apparatus with the essential requirements of this Directive.*

And Annex IV.1 says

> *The technical documentation must enable the conformity of the apparatus with the essential requirements to be assessed. It must cover the design and manufacture of the apparatus, in particular:*
>
> *— a general description of the apparatus;*
>
> *— evidence of compliance with the harmonised standards, if any, applied in full or in part;*
>
> *— where the manufacturer* ***has not applied harmonised standards, or has applied them only in part****, a description and explanation of the steps taken to meet the essential requirements of the Directive, including a description of the electromagnetic compatibility assessment set out in Annex II, point 1, results of design calculations made, examinations carried out, test reports, etc.;*
>
> *— a statement from the notified body, when the procedure referred to in Annex III has been followed.*
>
> (My emphasis)

From these points, we can understand that while a manufacturer *could* apply harmonised standards in full, *he doesn't have to*. If he doesn't, then he has to document how he thinks he's met the essential requirements in such a way that the conformity can be assessed; but the Directive doesn't say who is to do the assessing, except that the documentation must be held "at the disposal of the competent authorities". Reference to CISPR/I/257/CD, and even to CISPR/I/89/CD, would almost certainly be accepted by anyone who is not familiar with the detailed technical arguments that have gone into their rejection.

Now, this has always been the case since 2004/108/EC was published; there is nothing new in it. But various correspondence with Trading Standards and Ofcom (the competent authority in the UK) as well as statements from the EC themselves have all indicated repeatedly that these authorities believe that PLT modems, which clearly don't meet the limits in the harmonised standards, nevertheless have been legally placed on the market. This, even though there is plenty of evidence that these units are not designed such that "the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended" (the EMC Directive's first essential requirement). To quote a senior EC official, "Why make legal products illegal?" This leads us to reinforce a very significant conclusion (and I apologise for the triple negative):

Non-compliance with a harmonised standard's limits does not mean non-compliance with the EMC Directive.

This is dire news for CISPR and for the effort to protect the radio spectrum through the application of standards. It is clear that, as ITE, PLT modems should fall under CISPR 22; and that if their emissions are above the well-established limits for mains conducted disturbance, they cannot comply with CISPR 22; and therefore, there is no justification for them to be placed on the market, end of story. There are plenty of precedents to show that non-compliance with applicable standards mean effectively that a technology is outlawed. There is no reason for PLT modems to be treated as a special case, despite the lobbying by their supporters, nor should there be. They are used in the same electromagnetic environment as other products, all of which are subject to the same regulatory environment. But we now have clear evidence that the body responsible for the regulations agrees with the view, put forward in [3] quoted above, that the limits in the standards are "artificially low". The consequent conclusion must be that they are artificially low for all products.

If the standards can be discarded in such a cavalier fashion, why does anyone bother to work for their development, and why does anyone bother to observe their limits, or even test for them? And what price the EMC Directive itself? If anyone thought the Directive was about protecting the radio spectrum, think again. If spectrum protection collides with commercial protection, the spectrum loses.

References

[1] Letter to Caroline Lucas MEP (and others) from Günter Verheugen, Vice-President of the European Commission, 21st April 2009

[2] Discussion Document On The PLC Standardisation State Of Affairs, European Commission Enterprise And Industry Directorate-General, Brussels, 19 May 2009

[3] WRITTEN QUESTION by Alejo Vidal-Quadras (PPE-DE), Fiona Hall (ALDE), Satu Hassi (Verts/ALE), Pilar del Castillo Vera (PPE-DE) and Erika Mann (PSE) to the Commission, 2nd April 2009; see **http://tinyurl.com/mvc2th**

[4] RF Emissions of Powerline Ethernet adaptors, Tim Williams, EMC Journal no 82 May 2009, pp 15-18, **www.theemcjournal.com**

[5] Technical Guidance Note TGN on Assessment of Powerline Telecommunications (PLT) Equipment, ECANB TGN17; Version 1.0, April 2008; Version 2.0, July 2009; available from **http://circa.europa.eu/Public/irc/enterprise/emccbnb/library**

BT Vision; the radio interference iceberg

By Richard Marshall MA, CEng. FIEE, FInstP, FIET, Richard Marshall Limited

Overview

Some people say that interference to radio services from power-line telecommunications cannot be a serious problem because relatively few complaints have been documented.

This article examines this proposition, asking – and answering - the question "how many victims are close enough to a culprit for interference to be expected?"

This examination has been made possible by the marketing in the UK of BT Vision. This is a consumer service which includes as part of its package Power Line Adaptors (PLAs) that use the technology PLT (Power Line Telecommunications, also known in other countries as PLC or BPL) to communicate between the telephone line interface and the user's TV. This technology [Ref. 1] generates conducted interference upon domestic mains wiring at a power level a thousand times that which would be reasonable for any other domestic appliance, and does so twenty-four hours a day, seven days a week, simultaneously across almost the whole of the short-wave radio spectrum.

We will show that, despite the quite large numbers of both culprit BT Vision installations and victim radio users, geographical separation and the motivation and mechanics of the complaint process have so-far limited the registration of complaints.

However, complaints are proliferating with enhanced victim awareness, and this trend will accelerate with increased market-penetration of culprit and me-to products.

The balance between innovation in business and environmental loss to the wider community can only be managed successfully by conformance to a consistent set of EMC Standards, and it is important that all attempts to destroy this consistency should be resisted.

Introduction

Norms for interference emission for domestic appliances and IT products, as exemplified by refs. 2 and 3, are based upon a conceptual "protection distance" of 10 metres. By this is meant that product emission is allowed up to a level that should not interfere seriously with the reception 10 metres away – that is, on an adjoining property - of a radio transmission whose strength puts it within its "service area" as defined by the International Telecommunications Union [ref. 4]. There are many uncertainties in real-life situations, but the practical experience of Administrations and Radio Users over the last eighty years has confirmed that this protection distance sets a sensible statistical compromise between the cost of appropriate design of domestic products and the cost of transmission power for the delivery of radio services.

Broadband PLT technology, by virtue of the wider spread of its thousand-fold excess interference emission power, predicates a protection distance that is larger by the square root of a thousand. Accordingly, radio receivers may expect trouble if they are located anywhere within 310 metres of a culprit, rather than just within 10 metres.

It is important to distinguish between the various flavours of PLT. Low-speed communication for metering and control of the mains network was standardised many years ago [Ref. 5]. It is widely used and being kept in technically-competent hands has caused few problems. Broadband PLT uses higher powers over a much wider and higher-frequency band and has been let loose onto the consumer market. The broadband power-line adapter used for BT Vision is supplied by Comtrend and uses the DS2 chipset. Uniquely, this chipset radiates prolifically even when no data is being transmitted: The rival "Homeplug" hardware emits only occasional "ticks" when in the standby state.

In more technical detail, this Comtrend device emits from its mains terminals an interference signal that is about 30dB greater than the customary Class B conducted limit [Refs.2 and 3] for mains terminals over the range 2 to 26.6MHz, except that some (but not all) amateur bands are "notched" down to that limit. (It has been noted that these notched bands, and other parts of the wider spectrum, can never-the-less experience interference when PLT emissions are frequency-shifted by inter-modulation that is caused by rectifiers elsewhere in the supply network, or by adventitious "rusty rectifiers" such as iron guttering and clothes lines.) In the scaling calculation above we have used a "far field" calculation and absorbed the inherent errors [ref. 6] of such an approximation into the general statistical uncertainties of EMC prediction.

So a large number of devices have been placed on the market that can be shown by quite simple mathematics to have the potential to cause interference to short-wave users within a radius of a few hundred metres. They have provided a unique opportunity to check interference theory against practice - and it will be shown below that the agreement is good.

First we estimate how often culprit and victim will be sufficiently close to each other for BT Vision to be a problem.

How many potential victims are there?

There are "professional" victims in aviation, shipping, military, security and emergency services as well as devices for the disabled, but these do not yet appear in Ofcom statistics.

There are 65,000 Amateur Transmitting licences issued in the UK. Some amateurs hold two licences, some are interested only in vhf and microwaves, some are quite dormant. We can estimate that 20,000 are active within the HF band that is open to interference from PLT.

There must be 200,000 short-wave listeners with varying degrees of interest. Some 22,000 of these are committed enough to buy the specialist magazines "Radio User" and "Practical Wireless". Some were born outside the UK and to these people the link with their homeland may be regarded as a basic human right.

All the above are potential victims, but if they do suffer interference they will only appear in complaint statistics if they can cross two barriers;

* The first problem for all the above would be recognising the source of interference. The noise PLT makes is rather featureless (but listen to the examples that may be found by searching for "radio interference" on Youtube.co.uk), and the straightforward technique of switching off each possible source in turn is not usually practicable. However such identification is easier for the more-technical Amateurs than for the broadcast listeners. This is probably why about two-thirds of the complaints in Ofcom's statistics are from Amateurs despite the much larger population of broadcast listeners. Maybe one half of the 20,000 Amateurs and one-fortieth of the 200,000 Listeners would be able to recognise the source of any problem - that is 15,000 in all.

* Next the victim must be sufficiently motivated to do something. We British are lethargic and not natural whingers. To whom should one complain? BT may have supplied the offending item but the victim is not usually BT's customer and so there is no straightforward way to contact them. Trading Standards pass the issue to Ofcom, whose website page http://www.ofcom.org.uk/complain/inter/radio/293505/?itemid=300133 is very helpful but does mention the possibility of a £50 charge.

If we reckon that only 20% of potential victims cross these two hurdles then in the UK there are 3,000 people who, if they were exposed to interference from PLT, would complain. *Out of a total population of 60 million some 220,000 people - 1 in 270 - might suffer the problem, but of these only 3,000 - 1 in 20,000 – would make an official complaint that would appear in the statistics.*

How likely is it that there is a potential victim within range of a BT Vision Culprit?

National statistics provide the following population and land area figures from which an average distance between people can be calculated. There is of course a very wide variation in people/km^2 between different regions;

Region	Population	Area km²	people/km²	average distance between individuals
Whole UK	60,000,000	242,000	248	64 metres
Greater London	7,513,000	1,579	4,758	14.5 metres

The above analysis is quite robust because of the square-rooting that is inherent in the calculation of average distance.

Since both the above protection distance calculation and an informal analysis of reported complainants shows that victims are typically up to 150 metres from BT Vision users, we may conclude that, on average in the UK, *whenever a BT Vision customer has a near-neighbour who is a short wave user, actual interference will result.*

Arguably such a customer will have 4 to 20 near-neighbours. We will assume 10 as a round-figure average.

How many Culprits are there?

BT have formally stated [Ref. 7] that *"The take-up of BT Vision accelerated during the year. By the end of March 2009 we had 423,000 customers"* Sources within BT, acknowledging that some sales are not currently installed and others have had the Comtrend PLT components replaced by a wired connection, accept that there are probably 300,000 active installations using PLT.

Complaint Prediction

Above, we postulate that there are now 300,000 culprits, each of whom has 10 near-neighbours, there being a 1 in 20,000 chance of each such neighbour having a life style that leads to their suffering interference , recognising it and doing something about it. This ought to produce 300,000 x 10 /20,000 = 150 complaints.

At the time of writing, Ofcom has reported a total of 143 complaints. There is of course a strong element of chance in this close agreement. However, *the point is that the logged complaints represent a near 100% complaint rate from relevant neighbours, and is held at what some may consider a manageable level only by the sparse distribution of the victims and by the difficulties of identifying the culprit and recording a complaint.*

The future

Service Engineers for electrical and electronic products generally expect a "bathtub" complaint profile, with most failures due to workmanship or component failure at the beginning of life, a trouble-free middle age, and gradually increasing failures due to wear-out as the end of life nears. In contrast, interference complaints result from *design* failure, and so are equally likely at any time in the working life: They will happen when an affected radio user recognises the problem.

The overall rate of complaint should be largely dependent upon the total field population *times* user awareness of the problem. The effect of user awareness can be clearly seen in the Ofcom statistics plotted in the chart together with the BT Vision population figures.

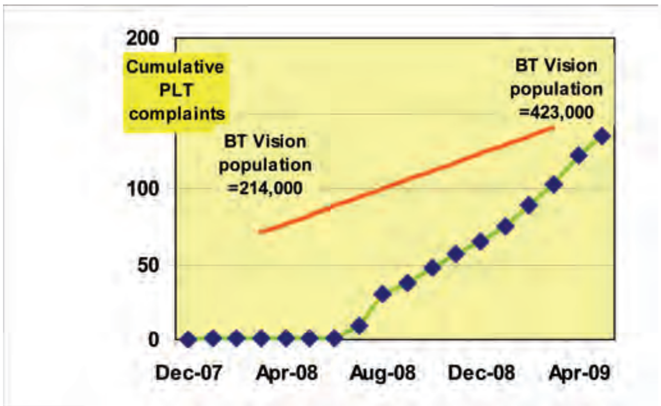

Chart: This shows the growth of complaints (Courtesy Ofcom) and the related subscriber numbers for BT Vision [Refs. 7 and 8]

Despite the field population of 214,000 units at 31st March 2008 [Ref. 8] virtually *no* complaints were logged before August 2008, at which time the activities of the UKQRM group, the various postings on Youtube and reports in the press of a question at BT's AGM raised awareness of the problem and of how to deal with it.

There remains considerable scope for increased user awareness to push up the complaint rate. An increase by a factor of 220,000/3,000 = 73 is conceivable.

Dan Marks, CEO of BT Vision until June 2009, has stated [Ref. 9] that BT's objective is 3 million subscribers by 2010. That 7-fold increase on the March 2009 claim would, at the present level of public awareness, lead to a complaint rate of about 100 per month. However, one article in the *Daily Mail* could increase awareness sufficiently to overwhelm the resources of Ofcom and BT. How many complaints are needed to make the authorities, the marketeers, and the product designers to go back to basics?

The declared UK and EC policy of "facilitating deployment of PLC, whilst retaining a regulatory influence on any undesirable side effects" [Ref. 10] clearly cannot work given the limited efficiency of a complaints-driven process that is without focus or motivation. A complaints-driven process is equivalent to shutting the stable door once the horse has bolted.

Furthermore, the time delay inherent in such a process is incompatible with twenty-first century design and marketing time-scales. We have to implement a better process for managing the electromagnetic environment.

Postscript

In addition to the local problems discussed above, there is a long-distance-interference problem due to ionospheric reflection carrying PLT interference around the globe. This causes a general increase in the HF noise floor, to which the logical counter-response will be the environmentally undesirable use of higher radio transmitter powers. This will become a serious issue if PLT is widely deployed since it renders impossible the avoidance of interference by the separation of culprit and victim. This "Cumulative Interference" is an inevitable result of the laws of physics, and was demonstrated in practice for analogue cordless phones many years ago. It is intended to return to this problem in a future issue of *The EMC Journal*.

The writer acknowledges the contribution of Robert Barden to the brainstorming of the structure of some of the calculations in this article.

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[2] *"Electromagnetic Compatibility – Requirements for household appliances, electric tools and similar apparatus. Part 1: Emission"* CISPR14-1
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RF Emissions of Powerline Ethernet adaptors

By Tim Williams, Elmac Services

A previous article [1] discussed the issues raised by PLT (Power Line Telecommunications) in the context of EMC. In passing, it mentioned the BT Vision in-home entertainment system. Since that was published, the author has had the opportunity of making some emissions measurements on a pair of Comtrend PowerGrid 902 Powerline Ethernet adaptors, as supplied with every BT Vision package. This article reports the results and discusses their implications.

The BT Vision PLT component

The BT Vision package [2] is a system provided to a residential customer by which streaming video can be sent down an ADSL (broadband) line and circulated around the customer's house to allow a choice of TV programmes and other video content in each room. The communication around the house is provided by a local area network, and this can be implemented either by wired Ethernet, or wireless networking, or by using a pair or more of adaptors to convert the Ethernet data to a signal that can be passed across the mains power wiring in the house.

The adaptor uses a form of modulation which spreads the data across a spectrum extending from 2MHz up to 26.5MHz and applies this spectrum as a differential signal between live and neutral of a standard 13A mains plug. It can be plugged in to any available mains socket, and a mating adaptor elsewhere on the ring main then re-converts the received data to Ethernet format. As supplied, the adaptors are "plug-and-play", that is they will negotiate a link automatically as soon as they are switched on and need no further attention once set up.

The approach is a very convenient and easy-to-implement way of passing broadband data around a house, especially in situations where wireless networking is impossible or inadequate. But unlike other wired and wireless methods, it raises substantial concerns of interference to innocent third-party users of the radio spectrum in the neighbourhood and perhaps beyond. These were discussed in some depth in [1], and here we will concentrate on the performance of the adaptors as actually supplied.

Measurements on the Comtrend adaptors

Two adaptors taken from a supplied BT Vision package have been measured in a standard CISPR conducted emissions measurement set-up. The configuration used is shown in Figure 1 and is compliant with the usual CE test as described in CISPR22/EN55022 and familiar to all EMC test labs. In order to ensure a clear communication channel the two units were plugged into a single multi-socket strip which was itself plugged into the LISN (CISPR 50 ohm/50µH V-network) via a 1m cable length. This should give the most favourable conditions for the devices, since there is virtually no path loss, no interference, and a flat, defined differential mode impedance of 100 ohms. The Ethernet port of one unit was connected to a battery-powered laptop via a short (50cm) UTP cable, located next to the test units; that of the other unit was connected to the local Ethernet router via a 2m UTP cable. File transfer could be initiated across the Ethernet link to test the adaptors' emissions in standby mode or when communicating continuous data.

The measuring instrument was an Advantest R4131B spectrum analyser. The measurement method was exactly as described in CISPR22:2005, that is, the voltage levels across Live to Earth and across Neutral to Earth were measured separately and the maximum value at each frequency taken. The significance of this will become clear later.

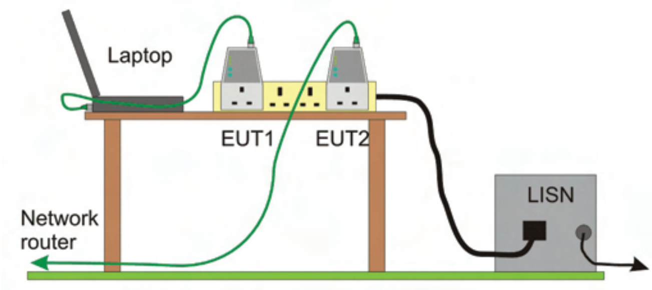

Figure 1 Schematic of the measurement set-up

The results compared against the class B (residential) QP limits are shown in Figure 2, and those compared against the Class B average limits are shown in Figure 3. Measurements were made beyond the CE top frequency of 30MHz, to see if there were any emissions that might fall into the radiated frequency band, although radiated emissions testing was not performed. Three sets of data are shown in each plot; with the units plugged in but switched off (the STATUS LED showing red), labelled "quiescent"; with the units in standby, i.e. with all LEDs showing green but not transferring data; and with continuous file transfer taking place across the link. Quasi-peak measurements were made at spot frequencies, as is typical test house practice, shown by diamonds on the plots.

To check the effect of the test set-up, the Ethernet links were separately disconnected in standby mode and the laptop was moved relative to the test ground plane. No effect on the measured levels was seen, showing that these were generated across the Live and Neutral terminals with no reference to the Ethernet port or to the ground plane. This was confirmed by using the LISN diagnostically to show that the emissions were largely in differential mode (L – N) rather than in common mode (LN – E). Values at all frequencies were essentially identical on both Live and Neutral lines.

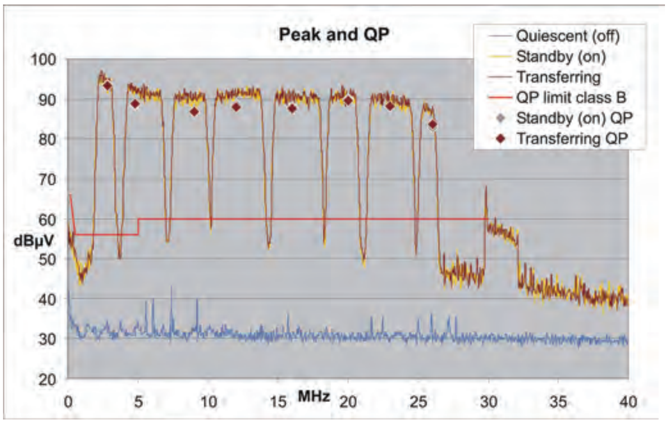

Figure 2 Conducted emissions: peak and quasi-peak

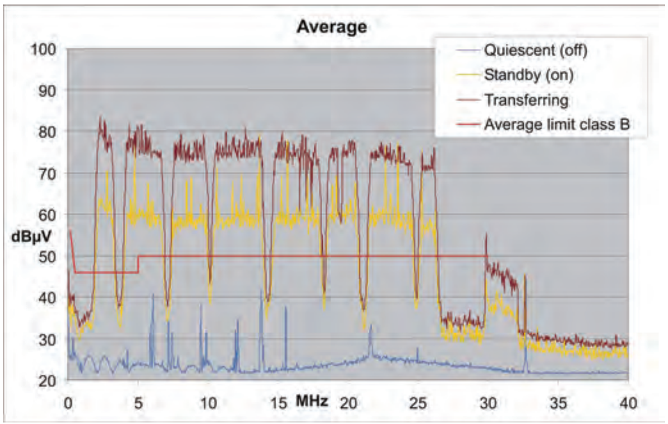

Figure 3 Conducted emissions: average
NB spikes visible on the quiescent trace are local ambients, not caused by the adaptor

The headline result here is that for both average and quasi-peak limits, the system is approximately 30dB over the CISPR limit, not at isolated frequencies but over large swathes of the conducted emissions range, with notches to below the limit at certain frequencies. When not transferring data the average level drops, though still well above the limit, but in QP there is essentially no difference as to whether the unit is transferring or not. Unless the user deliberately switches the units off – in which case the products are comfortably compliant, illustrated by the "quiescent" trace – they will be putting out the full signal level 24 hours a day.

Notches

The notches in the emitted spectrum fall below the limit at frequencies which roughly correspond to the UK amateur bands at 3.5MHz, 7MHz, 14MHz, 18MHz and 21MHz. These are shown in Figure 4.

These notches are as supplied from the factory and cannot be changed; also as supplied, by default there is a specific exclusion for the frequency range 26.5-28MHz which is to prevent interference to wireless mouse connections, which use the 27.12MHz free radiation frequency. This can be disabled via the unit's web user interface, in which case the emissions extend up to 28MHz, and this has indeed been found experimentally to interfere with a wireless mouse in the vicinity. It is also possible to insert extra custom notches via this interface, with a concomitant reduction in data transfer rate. Whilst a technically able user could do this in order to mitigate a case of interference at a specific frequency, it would be unreasonable to suggest this as a default method of interference control in the hands of a naïve user.

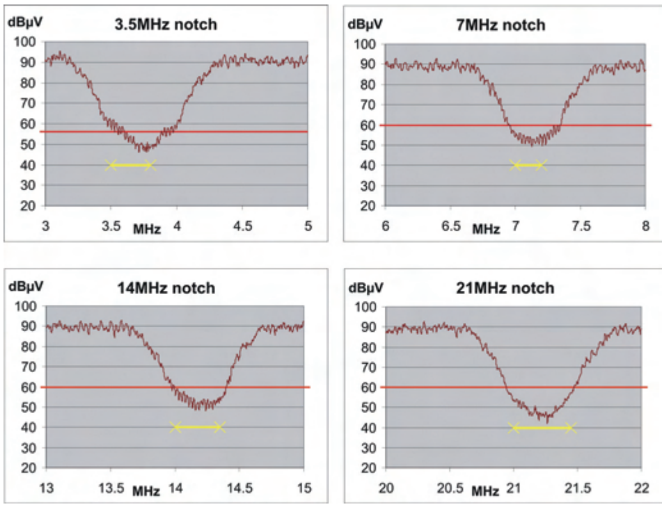

Figure 4 Notches at various frequencies
The yellow lines correspond to the UK amateur bands

The web user interface also shows that power control is enabled on both units as supplied, but there is no indication that the power level is being adjusted in real time to minimise the amount of RF passed into the mains.

The use of notches creates a further issue of concern, which is intermodulation. The plots in the figures above were taken without a transient limiter in circuit in the LISN. Figure 5 below shows the effect of switching in a limiter, as may be standard practice in some test labs to protect the front end of the measuring instrument. In the measurement system shown, the limiter is a pair of back-to-back silicon diodes preceded by a few dB of attenuation, which imply a clipping threshold of around 1V at the measurement point. The effect of a limiter in general EMC testing was discussed in [3]. In Figure 5, it can be seen that the limiter raises the apparent noise floor of the measurement to 70dBµV and "fills in" the notches. This is because the intermodulation generated by the non-linearity of the limiter creates frequency components that were not present in the original signal; if the original signal is broadband, the intermodulation will cover all frequencies that were notched, including those above the source spectrum, as is evident in Figure 5.

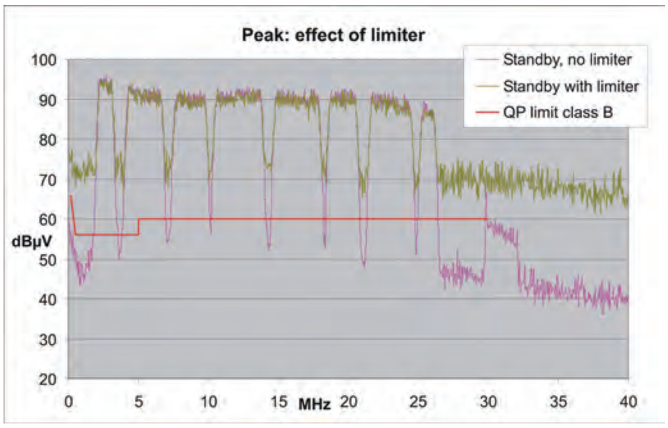

Figure 5 The effect of intermodulation from a transient limiter

This is an artefact of the measurement system; the total peak amplitude of hundreds of mV is quite sufficient to push a standard limiter into non-linearity. However, it is relevant to a PLT installation since any mains network is likely to include a variety of non-linear devices, principally the rectifier diodes at the input of any connected electronic apparatus or the triacs in, for instance, lighting dimmers. So that, although intermodulation should be guarded against in the measurement set-up, it is dangerous to rely on notches to protect any part of the radio spectrum since in real life, and depending on the individual installation, the unavoidable non-linearities will defeat their purpose.

Discussion

These measurements lead to the unavoidable conclusion that the Comtrend PG902 adaptor exceeds the allowable limits in CISPR 22/EN 55022 by a factor of 30dB, continuously, over the majority of the frequency range. Any reputable manufacturer of electronic equipment would not market such a device until it had been redesigned and brought into compliance. Yet, British Telecom are supplying these units in their hundreds of thousands to BT Vision subscribers, and in October 2008 extended their contract with Comtrend to continue supplying them for a second year [4]. The adaptors are CE Marked, implying that their manufacturer believes that they are compliant with the appropriate European Directives. How can this discrepancy be explained?

A clue lies in the declaration of conformity that Comtrend place in their user guide for the PowerGrid 902 model [5]. Within this DoC we find the following:

(reference to EN 55022:2006)

Other specifications and Technical Documentation:

CIS/I/89/CD Amendment to CISPR 22: Clarification of its application to telecommunication system on the method of disturbance measurement at ports used for PLC (Power Line Communication)

PowerGrid 902 TCF Technical Construction File of PowerGrid 902 ref. PG902CTTCF0508v1

This Certificate is guarantee by the following support documentation:
…
CISPR I/89/CD Test Report IE_ICEM_COM080101-IN issued by ENAC accredited laboratory 190/LE1113-4 ITACA and therefore complies with the essential requirements and provisions of the EMC and LV Directives

CISPR/I/89/CD

The reference to CISPR/I/89/CD is significant. This was a draft document [6] circulated for comment in November 2003 by CISPR in an attempt to create a mechanism within CISPR 22 that would allow PLT devices to comply directly with it. It was withdrawn before being developed further; as discussed in [1], later developments included a new document, CISPR/I/257/CD, which has also been rejected in turn. As is usual with draft documents, CISPR/I/89/CD includes the standard warning "THIS DOCUMENT IS STILL UNDER STUDY AND SUBJECT TO CHANGE. IT SHOULD NOT BE USED FOR REFERENCE PURPOSES." Nevertheless, some Competent (now Notified) bodies in Europe have used it as the basis for an opinion, and this is clearly the case here: ITACA is an accredited EMC test lab (although, to be clear, not accredited against CISPR/I/89/CD, and therefore referring to them as an "ENAC accredited laboratory" in this context is irrelevant) in Valencia, Spain who have apparently taken this approach in agreeing Comtrend's Technical Construction File.

The method proposed in CISPR/I/89/CD relied on the balance of the mains supply when used for RF broadband communication. Its introductory note stated that

The current document is based on the principle that PLC equipment must have a positive signal to noise ratio in order to function, and therefore must be allowed higher signal levels on the power mains. The interference potential at the multi purpose port is thus measured twice:

1) in its function as a power consumer (i.e. communication function disabled) using the familiar V-network and limits in tables 1 and 2 of CISPR 22 and;

2) in its function as telecom device using the T-network specified within this document and applying the limits in tables 3 and 4 of CISPR 22.

National committees are advised that this application of separate limits for the different functions is a new approach in CISPR/I and are asked to comment on this approach.

The first sentence was highly controversial and most probably contributed to the document's failure, but in the context of the PG902 adaptor the technical basis was also unacceptable. Clearly, if the device is disabled but still consuming power it satisfies case 1) above and, as can be seen from the plots shown earlier, it easily meets the normal limits of CISPR 22. But for the PG902 the distinction between "disabled" and "standby" is vital; when turned on, the unit operates 24 hours a day in standby mode and is putting out its full spectrum signal even though it is not transferring data. The "communication function disabled" state is irrelevant in the real world.

Case 2) refers to "the T-network specified within this document" and this is a network with a flat longitudinal conversion loss (LCL) of 30 ±6dB (see [1] for an explanation of LCL). This author has not been able to measure the samples with this network to see if they meet the limits referred to in case 2). Because no published standard has specified such a network it is not commercially available, although an enterprising test lab could undoubtedly construct one. But given that the signal is applied differentially between live and neutral, emissions which appear at the levels shown in the plots above when measured with a normal LISN could indeed just about meet the telecom port limits when measured with a T-network of LCL 30 ±6dB. Therefore, taking CISPR/I/89/CD at face value as a contribution to an EMC Technical Assessment according to the EMC Directive, it is possible that the PG902 could be shown to comply with it.

But CISPR/I/89/CD cannot be taken at face value. Apart from being withdrawn by CISPR, it included a statement which effectively torpedoes even what limited merit it may have had. Describing the specification for the T-network, it states (and the sentiment is repeated in the introductory note)

This ISN is only representative for low voltage distribution networks where the two conductors, usually Phase and Neutral, that are being symmetrically driven by the PLC equipment are cabled together. This ISN is not appropriate for representing networks where one of the driven *conductors is run independently of the other driven conductor as may be the case in some remotely switched circuits.*

Such independently run mains wiring is commonplace, at least in the UK, where for instance the live wire can be run away from its neutral return to a light switch or other switching circuit, and back again. This effectively unbalances the phase and neutral conductors and negates the assumption of a 30dB LCL. So any measurements to CISPR/I/89/CD cannot be used to offer a justification for compliance of a product that is used in UK residential properties. Again, this would have been a reason for rejection of the document within CISPR/I.

Consequence of excessive emissions

What are the consequences for such an egregious disregard for limits accepted as mandatory by all other manufacturers of electrical and electronic equipment, especially when the unit in question is supplied in volume by the largest telecom utility in the UK?

Firstly, is there an actual interference problem? Continuously exceeding the limits by 30dB suggests this might be expected, and indeed it is easy to demonstrate that HF broadcast reception is seriously affected by the operation of the adaptors (audio recordings of this interference can be found at the Elmac Services website, **www.elmac.co.uk**). But more than this, the spread of BT Vision has given rise to a protest group, UKQRM, whose reported discussions with Ofcom, the regulator, can be found on their website [7]. Their on-line petition calling for an immediate ban on power line adaptors of the type currently supplied by BT has attracted 3,500 signatures, suggesting that experience of interference problems is indeed widespread.

Secondly, what kind of message does this give about official attitudes to the EMC Directive? Make no mistake, BT wields very considerable clout in CISPR, and is no stranger to the EMC world. Most of the readers of the EMC Journal will be compliance engineers in companies that have elected to make sure their products comply with the pan-European standards harmonised for the EMC Directive. This is because there is a legal requirement on them to do so. EMC is not a lightweight discipline; considerable effort and cost is needed in both design and testing to confirm that the standards are indeed met. If BT appear to be able to ignore these standards, in placing on the market to the end user a high-volume product which clearly does not meet them, what is the worth of other companies continuing to make these efforts?

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Headroom for PLT: is it necessary?

Signal/Noise ratio considerations for PLT

By Richard Marshall, MA, CEng., FIEE, FIET, FInstP, Richard Marshall Limited

1) Introduction

It is commonplace to hear it stated that ***"Of course, PLT needs some headroom to operate, therefore the service must be allowed an interference level xxdB above that allowed for other products"***

This contribution examines this proposition from both practical and experimental viewpoints and concludes that useful PLT products could be designed within the limits already standardised in CISPR22 for mains ports. The headline data rate and working range would of course be lower – but still sufficient to be very useful.

2) An everyday view

The interference already found on the mains network is unpredictable in time and in frequency, although mandatory EMC standards should limit the amplitude. In the frequency dimension there are substantial bands of low amplitude interference as may be seen from any conducted emission test plot. **Figure 1** below is expanded into the time dimension to show that here too there are substantial gaps for PLT to operate. We have illustrated time-continuous interference at 7 and 10MHz, and isolated emissions at 22MHz.

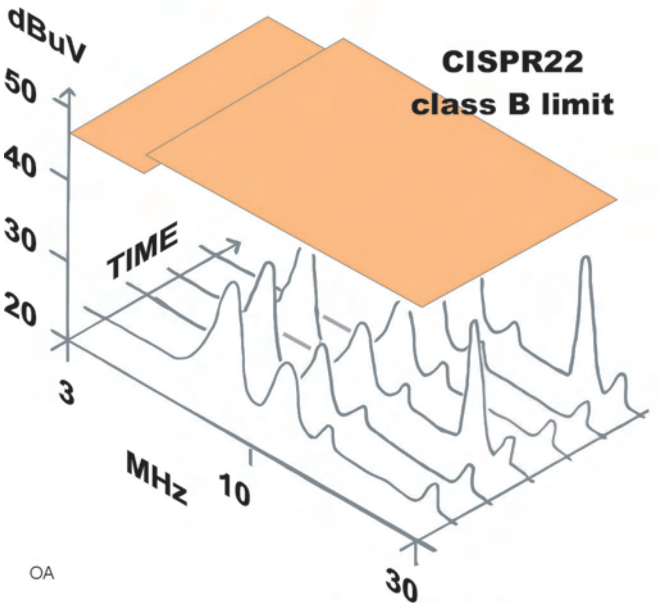

Figure 1. Conventional interference sources approach the limits only rarely across the range of frequency and time.

Data transmission coding algorithms are always designed to give maximum resilience with a specific data rate and interference profile. Those used by PLT must be chosen to exploit the gaps in frequency and time. These algorithms have been improved over the years and the benefit taken in increased data rate. Homeplug 1.0 claimed a physical layer data rate of 13.78 Mb/sec in 2001, and in 2005 Homeplug AV claimed 200Mb/s. **The designers could have chosen to take the benefit of an improved algorithm as improved conformance to CISPR22; but they chose instead to take all of the technology benefit as a higher headline data rate.**

3) Theoretical background

The Shannon-Hartley Theorem established the theoretical maximum data rate ***C*** for a signal of amplitude ***S*** in a communication channel of bandwidth ***B*** in the presence of white noise of amplitude ***N*** as;

$$C = B \times Log_2 (1+S/N)$$

This relationship is plotted with parameters appropriate to PLT by the solid curve in **Figure 2**.

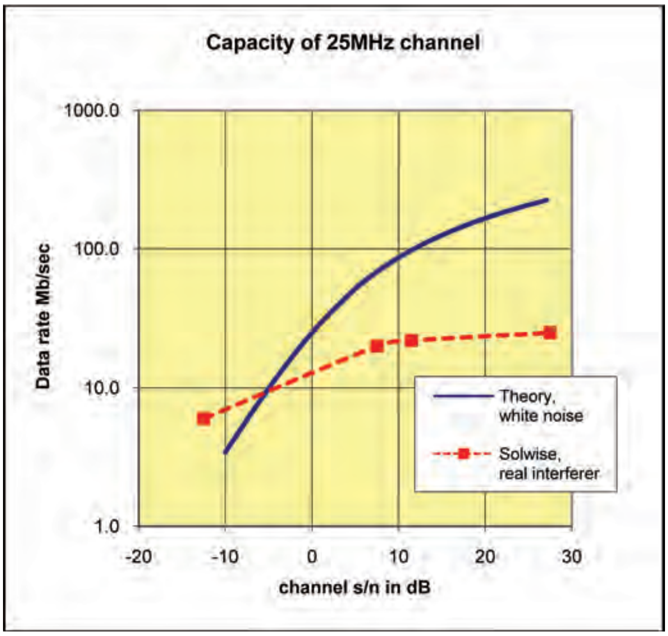

Figure 2. The capacity of a communication channel in the presence of interference.

This theory will *substantially understate* the available data rate for PLT since, as stated in Para. 2) above, the interference in a mains cable is not "white noise": It will have a much lower effective level than the "white" equivalent assumed in the Shannon-Hartley Theorem because of the substantial frequency and amplitude gaps between the peaks of emission from a continuous source, and the gaps in time between emissions of a discontinuous source.

This is emphasised by the dotted red plot of the throughput achieved by a pair of Solwise PL-85PE PLT modems in the presence of a "real interferer" adapted as necessary to give three different values of signal/noise ratio. Practical performance is considered further in the next section, but for comparison with theory note that for negative dB values of s/n the practical product out-performs simple theory because of the gaps discussed above. For positive values of s/n the practical performance is limited to well below the "sales specification" of 85Mb/s by protocol overheads and possibly by the inability of the associated computer hardware to handle very high data rates.

However the chart does illustrate that whilst higher data rates are available with higher signal power, **a significant data rate is available at zero or negative dB signal/noise ratio even with a "white noise" interferer.**

4) A practical demonstration

A number of "Grey Import" computer power supplies are being marketed in the UK which, although CE marked, have key EMC related components omitted. Trading Standards have been informed – but that is another story. These PSUs are very useful as sources to explore the capability of indoor PLT to tolerate interference, because they can be fitted with external filters crafted to produce any desired level of conducted emissions. By this means we can model the performance that would be achieved by a CISPR22-conforming PLT system by raising the interference environment to restore parity with the PLT modems.

External filters were used to establish the dotted red curve in **Figure 2**. For this test the sending and receiving modems and the interferer PSU were all plugged in to the same socket strip, which was powered via a CISPR16 LISN to provide a defined circuit impedance and isolation from any remote interferers.

The QP emission spectrum of the "Xpower" ATX-400TD PSU with external filter "C" is 20dB above that expected from a product compliant with the CISPR22 Class B limit within the PLT band of 3 to 30MHz, as may be seen in **Figure 3** below.

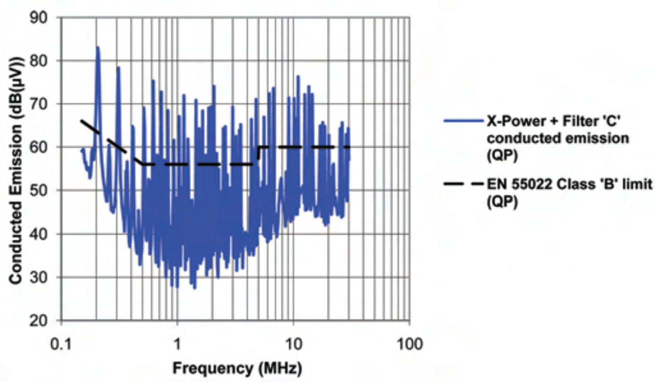

Figure 3. The mains conducted emission of a "20dB above CISPR22 class B" power supply feeding a 168 watt load.

A typical domestic PLT installation was set up to transmit a video file from a laptop via an adjacent PLT modem in an upstairs room to a desk-top computer with its adjacent modem in a ground-floor study. These two areas were served by different ring-mains connected to different mcbs in a single distribution board. The interferer was plugged into another socket in the same ground-floor study. When this was switched on the video throughput fell from 18 to 13 Mb/sec., as shown by the Netmeter plot in **Figure 4 below**.

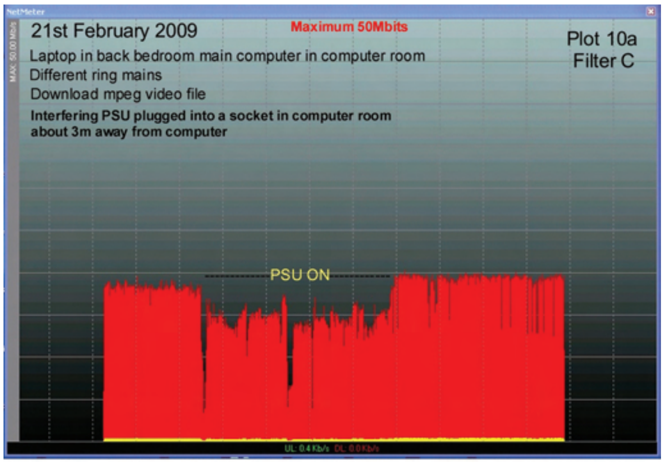

Figure 4. Turning on a local interferer reduced the throughput from 18Mb/sec to 13Mb/sec.

Under these conditions the PLT circuit is operating at a substantial negative signal/interference ratio, whilst producing an useful data rate for present-day applications. Moving the interferer to a third location elsewhere in the building increased the data rate to 16Mb/sec. Note that this quite-useful performance is achieved with a PLT data coding system that has not been optimised for low s/n ratio operation.

5) Conclusions

The development of power line telecommunications has been seriously handicapped by a tactic of leaving conformity to EMC standards to the last, rather than considering it at the earliest design stage.

This paper has presented theoretical and practical evidence that the technology could provide a useful function within the existing CISPR22 limits and without damage to radio services. It just needs properly-directed coding algorithm design within appropriate power limits and realistic headline data capacity.

6) Acknowledgements

The version of the Shannon-Hartley Theorem quoted here was given by K T Foster in the BT Technical Journal, 2008.

The QP figures and plot given above have been provided by Dr. D Lauder of the Department of Electronic Engineering, University of Hertfordshire.

The practical network testing and Netmeter data throughput figures are by R Page-Jones, MIET.

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Why broadband PLT is bad for EMC

By Tim Williams, Elmac Services

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.

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 or campus, to deliver the data connection from the service provider;
- Networking within the individual home or larger building, for data interconnection between mains-connected devices.

Although an ETSI document (TS 101 867 [11]) exists to attempt to create co-existence between access and in-home systems, it has been largely ignored and there are several proprietary implementations using some or all of the frequency range between 1.6 and 30MHz. Coding schemes, spectral distribution and signal levels differ between systems and detailed data is not published. For a variety of reasons access systems are not widely implemented in Europe, although they are being actively pursued in other parts of the world.

On the other hand there is an established specification for the HomePlug network system which is in use in the US and elsewhere for in-home networking. The version 1 specification 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. A more recent specification is called HomePlug AV, which is stated to give an information rate of 150 Mbps. In the UK, BT is marketing its BT Vision package, which includes a mechanism similar but not identical to HomePlug for passing broadband data in the range 3–30MHz around the mains wiring.

In round numbers, and bearing in mind that the technology is now sophisticated enough that quoting a fixed level might be misleading, 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 impedance 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 between each phase and earth – one hundred times lower.

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:

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

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

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

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).

Notching and power management

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; 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. This issue, as we shall see later, is at the heart of the approach being taken by standards committees.

The technique of notching raises a further question, 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 or prevalence.
Another technique which can be applied in PLT modems is power management. Widely used in the GSM mobile phone context, it simply means that the system intelligently uses only the minimum power needed over a given part of the spectrum to achieve reliable communication. Thus although a figure can be quoted as above for the power level needed for adequate operation in all kinds of mains environments, in practice this can be adjusted downwards in any given spectrum sub-band depending on the noise level that the modem finds, in real time, in that sub-band.

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, access PLT in particular has been 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 [10] 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 member states saw the potential RF interference dangers of this technology early [2], 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 former 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 [3] 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 Recommendation [5] which included the following uncompromising statement:

> *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. … 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 network which is made up of equipment compliant with the Directive and used for its intended purpose … and which is installed and operated according to good engineering practices… (emphasis added)*

* An early version used the word "remaining"

The text goes on to talk about procedures for "If a system is deemed compliant but is nevertheless creating harmful interference, the competent authorities of the Member States should take special measures according to Article 6 of the EMC Directive, with a view to resolving such interference", but such procedures are bound to be time-consuming, and meanwhile the interference damage is being done. It is, though, interesting that the Commission clearly envisages a separation between "compliance" of a PLT system and its capacity to cause interference.

As it happens, the economics of access PLT systems have meant that the application of the Commission's Recommendation has been somewhat muted. But by comparison, in-home systems have quickly become popular, and it is to these that most attention is now given.

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. An increasing number of short-range devices using for instance 13.56MHz, such as RFID readers and alarms, are installed in homes and offices. 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].

One such stakeholder is the Radio Society of Great Britain (RSGB), which represents the UK's radio amateurs. A couple of years ago, the RSGB made a complaint regarding non-compliance of a PLT product that was declared compliant in Germany. Ofcom finally responded in 2008, implying that they would not take enforcement action in the UK. The RSGB's view, expressed in a public letter to Ofcom from its President, is that "this delay, attributed to restructuring, is frankly deplorable, unprofessional and certainly does not reflect well on the neutrality of the administration or the stated Statutory Duty of 'Ensuring the optimal use of the electro-magnetic spectrum'."[9] The evident frustration of radio amateurs at the lack of interest shown in the problem by some authorities is not limited to the UK.

Ofcom took over the duties of the disbanded Radiocommunications Agency at the beginning of 2004. Since their remit also includes "ensuring that a wide range of communications services – including high speed data services – is available throughout the UK", it may be thought that when it comes to enforcing regulations against a form of broadband delivery on behalf of radio users, there is more than a hint of conflict of interest in the air.

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 particularly important to broadcasters. 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.

To overcome some of the admitted reception quality issues with conventional AM broadcasting, a new digital service has been launched by a consortium of broadcasters, including the BBC and Deutsche Welle, known as DRM (Digital Radio Mondiale, see www.drm.org). An increase in the local HF noise floor due to PLT, with its continuous, broadband nature, would have the potential to seriously compromise the effectiveness of this service.

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 can be 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 (2004/108/EC), whose first essential requirement is that apparatus shall only be placed on the market or taken into service if

> *The electromagnetic disturbance it generates does not exceed a level above which radio and telecommunications equipment or other equipment cannot 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 have been 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 within Europe through the operation of the EMC Directive to anything that is likely to cause such interference. Designers of mains-connected equipment are by now familiar with these requirements, which constitute an extra but necessary burden on their designs.

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 unintentionally as is the case with other sources such as fluorescent light inverters or computer power supplies. From access-PLT systems, the interference could affect all households being supplied from a substation in a PLT-active zone, whether they are a subscriber or not. In-home systems can interfere with other parties connected to the same electricity supply point or in nearby properties; the electricity supply meter is not designed to attenuate HF signals.

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.

One problem with determining the extent of actual interference problems is that non-technical radio users may have no idea that the interference they are experiencing is in fact due to a PLT source, since they will never have heard anything like it before. However the rapidly growing number of BT Vision installations, which appear to create a continuous signal even when not passing data, has already provoked a protest group which can be found via the YouTube website.

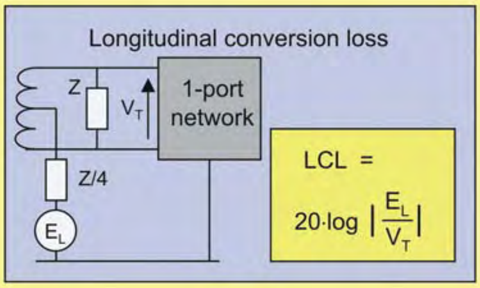
Dependence on quality of wiring

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 and frequency coverage of the signal must be 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 degree of unintentional radiated emissions that a wired network 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 should 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 good 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 (phone-connected) broadband into the home.

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, but note the reliance of the measurement on a meaningful ground connection):



It is not true of mains wiring. The most important aspect of cable design which affects LCL is the physical balance of the wire pairs which make up the cable. Each conductor must be tightly coupled to the other in the pair 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. Data cables are tightly twisted in a controlled way to achieve this. The interfaces at either end of the cable must be equally well specified.

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, computers, 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. In fact, the UK's protective multiple earth (PME) wiring system is inherently unbalanced at the service entrance by the connection of Neutral and Earth conductors.

The IT emissions standard (CISPR 22 [6], published in Europe as EN 55022) gives a figure of 55dB for low-frequency LCL of Category 3 data cable (rarely used now in new installations) and 65dB for Category 5, degrading by 7dB at 10MHz. By contrast, work under the aegis of the COST 286 programme [14] has suggested a "mains symmetry factor" (comparable to, but not the same as, LCL) of around 7.5dB for same-phase measurements. In other words, mains cable could be up to 58dB or nearly a thousand times worse than the most commonly installed data cable at controlling unwanted radiation.

In fact, because of the inherently unbalanced nature of typical installations, it is arguable whether LCL is a suitable parameter with which to characterise mains wiring networks anyway. It is also the case that the specification of LCL depends on a knowledge of both common-mode and differential-mode impedances, and on a reference connection to an external earth. Since these are generally not available for mains networks, the use of a different measurement such as the mains symmetry factor proposed in the COST 286 paper appears to be a better way forward.

Is PLT the same as other interferers?

PLT supporters base their proposals for a relaxation of the emissions compliance requirements that a PLT system has to meet on those already 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 localised interferer is possible.
- PLT may be always on. CISPR limits incorporate a relaxation which takes into account the probability of non-coincidence in time of source and victim – for instance, no one uses a vacuum cleaner 24 hours a day. For PLT, this factor should be unity.
- 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. Such products are typically only near the limit at one or two frequencies; PLT covers the whole band as a matter of design. If CISPR limits do indeed protect HF reception, this factor should not be overlooked.

In fact, PLT modems seem to be unable to operate anywhere near the mains conducted emissions limits in force in CISPR at the moment.

Radiated or conducted?

It has been 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 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 would be reflected from the ionosphere and illuminate 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 former 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. 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 Recommendation 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 the level of RF voltage that is 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? Until recently, the only alternative available to their manufacturers was the Technical Construction File (TCF) route, according to Article 10.2 of the first edition EMC Directive. This required the case for compliance to be submitted to a Competent Body, who provided a certificate stating that compliance with the essential requirements was actually achieved without recourse to standards. It is understood that all PLT modems on the EU market in the early days did actually use such a TCF route for their CE marking, implying that there was a Competent Body somewhere in Europe who believed that such a case could be made.

Because of the difficulty in justifying it, both the EC Association of Competent Bodies and the UK EMC Test Laboratories Association 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. (EMCTLA [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. (ECACB [20])*

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

The position changed with the adoption of the second edition of the EMC Directive, and the publication of a new guidance note from the ECANB [21]. This advises the use of the emissions measurement and limits according to the draft document CISPR/I/257/CD (see later), along with mitigation measures as proposed in the companion CISPR document (adaptive notching, also discussed later). But CISPR/I has already (within a few months of its circulation) rejected the method of CISPR/I/257/CD. This leaves the unsatisfactory position that EU Notified Bodies are being advised in the ECANB guidance to use an inadequate method for giving a compliance opinion.

The alternative, now available to manufacturers under the second edition EMC Directive, is to perform their own "EMC Assessment" without seeking the opinion of a Notified Body and without fully applying EN 55022. This leaves them open to a greater risk of challenge to their compliance statement; but given the lengthy process and uncertain outcome of such a challenge, some manufacturers might opt for this approach.
The fifth edition of CISPR 22/EN 55022, published in 2006 and harmonised with a date of withdrawal of older editions of 1st October 2009, has caused further upset to PLT manufacturers. This is because it includes a flowchart (Figure C.10) which determines the appropriate method for testing a telecommunication port. If this port is defined as a "mains" type (i.e., a PLT modem) then it insists that the test should be done according to the standard method applied to all types of mains-powered equipment. This has removed any lingering hopes that an alternative procedure that allowed the device to pass, could be applied – unless and until CISPR 22 is amended further.

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, its signals must be greater than this minimum noise level, and so it must breach these limits, almost by definition. As we have seen, this is indeed so, by several tens of dB. Yet all other mains-connected equipment, such as ITE, medical and 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 technology alone is granted exemption? If PLT can flagrantly flout the limits and still protect the radio spectrum, 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. To mix metaphors 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/I is looking at ways to adapt CISPR 22 to apply in a meaningful way to PLT. The PLT project team 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 for a PLT modem as "A port connecting to power lines supporting data transfer and telecommunications". 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. 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 (not the standard mains LISN – a decision which has itself provoked controversy) which applies a defined degree of longitudinal conversion loss (LCL).

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 an early draft (CISPR/I/89/CD) was 30dB across the whole frequency range. But this figure was decidedly optimistic, and it was revised down to 24dB in the later draft, CISPR/I/257/CD [22]. Even this is too high to be acceptable to the majority of CISPR, and 6dB was to be the next proposal, tying in with the 7.5dB mains symmetry factor offered by the COST 286 work. But it appears that there is a practical difficulty in constructing a network that would both create a 6dB LCL and pass the wanted data signal – the standard CISPR mains LISN, used for conducted emissions tests for many years, actually gives an effective 6dB conversion between differential and common mode, since it measures half the differential signal on each line with respect to earth, but it deliberately blocks the wanted signal.

So, having gone around in several circles, the project team is now heading back towards specifying a higher LCL but with a different set of limits. In doing that, as a result of a higher-level decision within CISPR, it will have to verify that any new set of limits it comes up with are adequate to protect the radio spectrum.

Notching to the rescue

Having repeatedly run into the buffers on the question of measurement and limits, the CISPR/I project team has turned its attention to other technical fixes. The one that is causing most interest is adaptive notching. The way this works is described in CISPR/I/258/CD [23] as follows:

> *Adaptive Notching is a new technique in an advanced state of development in industry and in ETSI. It aims to protect in-house short wave broadcast reception and avoids static notching of all broadcast bands at all times, which would result in substantial permanent performance loss. Laboratory and field tests jointly with the EBU have successfully demonstrated this technique. Adaptive Notching is a powerful mitigation technique for PLT devices.*
>
> *Adaptive notching operates autonomously. The modems sense the radio frequency spectrum, detect the broadcast channels received* ***with usable quality*** *at the site and at the time and notch out these channels in the transmitted signal. The loss of throughput of a PLT system due to adaptive notching is very low.* ***Only the few broadcast channels which offer useful indoor reception at a given time are notched.*** *(my emphasis)*

The status of CISPR/I/258/CD is not entirely clear; it seems to be meant as no more than a report, but there is pressure to implement it as a standard requirement, and as said earlier, it is already viewed in this light by the ECANB guidance. This would be an entirely new development in the history of radio spectrum protection. It is clearly intended to address the powerful broadcasting lobby which has been a major stumbling block to the acceptance of PLT within CISPR, and there is every likelihood that if the technique is made mandatory within CISPR 22, it will neuter the objections of this group. What are the implications of this?

Note the emphasis in the above quotation. It is *the PLT modem itself* which judges what broadcast signals are received "with usable quality" and only these frequencies are notched – the rest of the spectrum is blotted out. So what becomes of the specialist user of the HF bands: the short-wave listener, the seeker of interesting but low-level broadcasts, the DX-er, the radio astronomer, and other uses such as long-distance aircraft communications? Such users clearly do not have any influence on the PLT modem to represent their interests. This is possibly the first time that an interference control agency has proposed to cede its authority so comprehensively not just to a third party, and not even to another authority, but to the whim of an autonomous piece of electronics in somebody's home. The phrase "driving a horse and cart through the principles of interference control" has already been used in this article. If CISPR/I actively votes this amendment into being, those principles are clearly being re-invented wholesale.

Aside from the issue of principle, some unanswered questions remain. Firstly, will it work even within its own remit? There appears to be no acknowledgement within CISPR that intermodulation could undo the effect of the notches and "fill in" the holes carefully left in the spectrum for the few privileged broadcast frequencies that are deemed to be usable. Laboratory and field trials will not answer this question – only experience.

Secondly, how would the operation of a modem using adaptive notching be tested and verified? Accurate standardized EMC emissions measurements are notoriously difficult to achieve even assuming a static interference source. How long would it take to develop and validate a new test method for such a device within CISPR, and what would the PLT industry be doing meanwhile?

Third, where does it leave the mainstream of electronic products that are not PLT modems? If an enterprising switchmode power supply designer were to create a power supply that was able to dynamically and adaptively notch its switching frequency emissions (admittedly unlikely with the present state of the art), would it benefit from the same waiver in emissions limits? If not, why not? More importantly, if the principle of uniform emissions limits is breached in this special case, there will surely be many other special cases to follow. CISPR must realise the nature of the Pandora's box it seems intent on opening.

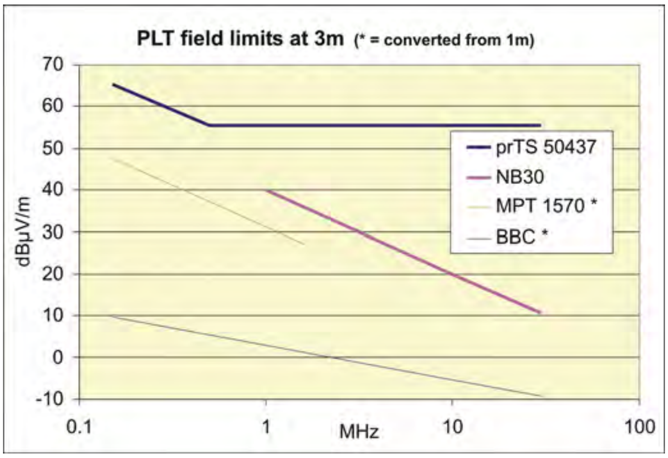
Another mitigation technique that could prove more beneficial is adaptive power management, briefly mentioned at the beginning of this paper. Reducing the power output to the minimum necessary to communicate might, in favourable circumstances, allow a PLT modem to operate at levels compatible with existing limits. But as with notching, this would be at the expense of delivered bit-rate; and it would limit the possible size of installations that the technology could address, since a large distributed system (think of a hotel, for instance) would still need high power levels just to cover the required distance.

Attempts to write a PLT systems standard

Meanwhile, acting in parallel, the CENELEC/ETSI Joint Working Group (JWG) produced in 2004 a draft of its Technical Specification (NB: not a standard) for the measurement of emissions from an operating PLT *network* [4]. This was restricted to limits and methods of measurement for electromagnetic emissions emanating from access powerline communications networks; in other words it didn't apply to in-home networks. Over the frequency range from 0.5 to 30MHz, it applied 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 thought that such a value was about 40dB too high.

In a presentation to the EC's October 2003 workshop on PLC, the chairman of the JWG 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 was never published, and in the end, in 2006 the JWG agreed to stop work on the project. It fell short of returning its Mandate to the European Commission, which would effectively have been an admission that PLT networks were incompatible with radio reception; it carried on work in other areas, in the hope that the networks standard could "resume some time in the future when new technology was in place". Because the EC Mandate was still active, this had the effect of preventing national authorities from introducing national regulations on their own initiative for the conformance of networks. In fact, with the advent of the mitigation methods referred to earlier, work has indeed resumed, but at the time of writing there is still no published specification.

Meanwhile, an Australian radio amateur has developed a prediction program [24] for determining the level of local interference that can be expected from a system which just meets the limits that were suggested in the original TS, 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 and adaptive 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 or a re-definition of what is meant by protection of the radio spectrum;
- 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 radio protection.

From the point of view of radio users, PLT is a technology too far.

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This is a substantial revision of a paper first published in 2005 at **http://www.elmac.co.uk**

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PLT and broadcasting — can they co-exist?

By Jonathan Stott, BBC Research and Development

INTRODUCTION

PLT, Power-Line Transmission (or Telecommunication) is a means of transmitting data using existing mains-electricity cables. This is clearly an attractive proposition since there is no need to install new cabling, and in principle it can therefore be literally 'plug and play' for the consumer. It can be used for two purposes:

- *access* to the home, that is, to connect the home to the Internet
- *in-home networking*, e.g. to network home computer(s) and peripherals, or to interconnect home-entertainment devices

In practice an access-PLT system may combine both functions, since an external Internet connection is only useful if it reaches the customer's home computer(s).

Note that various names are used for this technology: it is also known as PLC, Power-Line Communications; DPL, Digital Power Line; and BPL, Broadband over Power Line.

So far, so good. PLT constitutes another way to provide communication. In particular, telecommunications regulators view access-PLT favourably because it is a way to have competition in the market for providing 'Broadband to the Home'. They hope this will make domestic broadband access both cheaper and more readily available, which is indeed a worthy aim, and one that the BBC (with a major web presence at www.bbc.co.uk) strongly supports.

But there is a snag. The mains-electricity wiring infrastructure was never designed to carry high-speed data. On the one hand, this means that it is technically challenging for PLT designers to achieve the capacity and reliability they wish. On the other hand there is the difficulty for radio-system users that the signals PLT injects do not simply travel from point to point along the wiring, they also escape as *radiated emissions*, and these undesired emissions can interfere with radio services.

This interference question has given rise to much heated debate, and to attempts to put regulations in place to favour the cause of PLT, or radio, or, in effect, neither. At the time of writing no satisfactory outcome appears in prospect.

This paper outlines the nature of the problem, presents evidence of actual interference, and postulates a possible way forward.

RADIO SERVICES' ENTITLEMENT TO PROTECTION

Importance of radio spectrum

The radio spectrum is important because it provides a way to communicate in almost every conceivable scenario — on the move, by land, sea or air; over distances large and small — and is in many cases the *only* possible means for communication. This was recognised very early on and has led to the organisation and protection of radio services by legal sanction.

Internationally recognised principle

The key instrument at the international level is the Radio Regulations (RR), produced by the Radiocommunication Sector of the International Telecommunication Union (ITU-R). This has the status of a Treaty between States. It both establishes general principles and sets out detailed procedures for planning and operating radio services. Article S15 of the RR deals with every aspect of "Interferences" and in particular Article S15.12 covers interference to radio services from non-radio systems (emphasis added by present author):

"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."

So it is clear that Administrations are required by the RR to ensure that PLT — a telecommunication service using the power network — does not interfere with radio services.

Similarly, the European EMC Directive (89/336/EEC and subsequent amendments) sets out its over-riding principle in its Article 4 (emphasis added by present author):

"The apparatus referred to in Article 2 shall be so constructed that:

(a) the *electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment* and other apparatus ***to operate as intended***; …"

How radio services protect each other

Now, as soon as two radio systems operate in the same part of the frequency spectrum, there is potential for mutual interference. If each part of the spectrum were used only once, there would be no interference but the use of spectrum would be very severely curtailed indeed. So radio services have for a long time had to deal with this by agreeing how much interference can be tolerated and then planning the radio systems and networks so that it is sufficiently improbable that this level will be exceeded. In this way frequencies can be re-used.

Often the potential interference is of the same type as the wanted signal (e.g. in those bands allocated exclusively to one type of radio service). Some bands are allocated by the RR to be shared between different types of services, in which case more combinations of wanted and interfering signals have to be considered. For each combination a *protection ratio* (PR) is established; it is the minimum ratio of wanted and interfering signals that ensures satisfactory reception of the wanted signal. Radio services are then planned so that the necessary PR will be achieved with an agreed high probability. In this way it is possible to invest in substantial communication or broadcasting networks with confidence.

Note that protection is normally only given to receiving locations where the wanted signal is received at or above a certain minimum field strength. E.g. for AM broadcasts in the HF band this minimum protected field strength is taken as 40 dBμV/m for the purposes of this paper. This is derived from ITU-R Rec. BS.703 [1].

Glossary

AAC	Advanced Audio Coding
ADSL	Asymmetric Digital Subscriber Line/Loop
AM	Amplitude Modulation
BPL	Broadband Power Line
CELP	Code Excited Linear Prediction
Cenelec	European Committee for Electrotechnical Standardization
COFDM	Coded Orthogonal Frequency-Division Multiplex
DRM	Digital Radio Mondiale
DVB-T	Digital Video Broadcasting (Terrestrial)
ETSI	European Telecommunications Standards Institute
HF	High Frequency
HFCC	High Frequency Coordination Committee
HVXC	Harmonic Vector Excitation Coding
ITU	International Telecommunication Union
JWG	Joint Working Group
LAN	Local Area Network
LF	Low Frequency
MF	Medium Frequency
MLC	Multi-level Coding
NVIS	Near-Vertical-Incidence Sky-wave
PLC	Power Line Communication
PLT	Power Line Transmission/ Telecommunication
PR	Protection Ratio

BROADCASTING AND THE RADIO SPECTRUM

An important radio service

Broadcasting is one of the radio services recognised by the ITU-R and will be well known to all! It has allocations in many parts of the frequency spectrum ranging from the low frequencies of Long Wave to the microwave frequencies used for satellite broadcasting. Particular allocations can be used for radio or for television, and will suit applications from small-scale local broadcasting to international broadcasting.

At the time of writing, most PLT systems of which the author is aware use spectrum in the range below 30 MHz, which, amongst other radio services, contains the LF/MF/HF broadcasting allocations (also known as Long- Medium- and Short-wave bands). Furthermore, most PLT systems also seem to avoid the LF/MF bands, so the potential threat at the moment is chiefly to reception of HF broadcasting. HF is therefore the focus of this paper, but with a clear note that other frequency bands used for broadcasting also require careful consideration.

Broadcasting below 30 MHz

Radio (i.e. sound) broadcasting began in this part of the spectrum in the early part of the 20th century, and is still going strong. It is used for all types of broadcasting from local to international. Amplitude Modulation (AM) was used from the beginning, but see below for a description of a digital replacement.

The spectrum below 30 MHz is unique in that it has propagation mechanisms that can support long-distance communication and as such it is important to broadcasters and other radio users alike.

Medium wave (and Long wave in Europe) can cover a large area by ground-wave propagation (especially so at the lower frequencies). Thus a single LF transmitter is often sufficient to cover a whole country; perhaps a network of a few is needed to do the same at MF. At night-time, sky-wave propagation occurs, bringing an increase in range (and an increase in mutual interference which has to be planned for). Some international broadcasting takes place to neighbouring countries in these bands. At the other extreme, low-power MF transmitters are also used to provide local services, the reduced range of low-power transmissions enabling frequency re-use even within a country.

Short-wave broadcasting normally makes use of sky-wave propagation, which enables an *international* broadcaster to reach a target country without needing any transmitter within the target area. It is in many cases the *only* practicable means to serve a target country, since the few technically-feasible alternatives[1] require the cooperation of third parties — which may not be forthcoming.

Short wave is also used for *national* broadcasting, especially for countries that are large, are in the Tropics or have a scattered population in difficult terrain. All of these factors make short-wave broadcasting advantageous. A single transmitter of modest power can cover a large area using Near-Vertical-Incidence Sky-wave (NVIS) propagation. This is of sufficient importance that the RR reserve certain broadcasting bands for use in the Tropical Zone defined by ITU-R.

[1] E.g. local relays, satellite broadcasting, Internet. (Local relays are also unlikely to cover a large area).

Digital Radio Mondiale (DRM™)

As explained, spectrum below 30 MHz is uniquely valuable for broadcasting, to both international and certain national broadcasters, because of its long-range possibilities. There is a snag, which is that using the analogue AM technique in conjunction with 9 or 10 kHz RF channelling means that the audio bandwidth is low. Taken together with the multipath nature of sky-wave propagation, this means that the audio quality of AM reception is not up to modern expectations — not unreasonable for a technology that is more than 80 years old.

But there is a way to eat our cake and have it. The DRM Consortium [2] (of broadcasters, manufacturers and research institutes) has developed a digital system [3] (also called DRM) which can be used in this frequency range instead of AM, and which delivers much-improved audio quality. This involves two processes. First it uses modern audio-coding techniques so that a low bit-rate is sufficient to describe the audio signal adequately. Depending on the application and bit rate available, the broadcaster can choose between a waveform coder (AACplus or AAC) and a speech-only coder (CELP or HVXC). This low bit-rate information is then sent using a modulation and channel-coding system that combines COFDM (Coded Orthogonal Frequency-Division Multiplex) and MLC (Multi-level Coding). The result is that good-quality audio can be received, even over a short-wave channel that would sound very poor using analogue AM.

Note that DRM is designed to meet the needs of all kinds of broadcasters, small and large, from local to international, long wave to short wave, to which end it has a number of options that broadcasters can set to match it to their situation. Receivers recognise the appropriate mode in which to work without any intervention from the user. Indeed the system contains other features intended to make the receivers much easier to use, so that, for example, having to pick frequencies from a daily schedule list becomes a thing of the past.

The DRM system was officially launched in June 2003 (coincident with a World Radio Conference) and is expected to be widely taken up in the next few years. Many DRM transmissions are made every day by a number of broadcasters.

The Protection Broadcasting Needs

Simply put, broadcasting needs the level of interference at the listener's antenna to be 'small enough' in relation to the strength of the wanted broadcast signal. More scientifically, we require that the signal-to-interference ratio, S/I, exceeds the relevant *protection ratio*, PR. The necessary PR has to be determined for every relevant combination of wanted and interfering signal types. Thus, for example, the necessary PRs have been established for broadcast signals receiving interference from other broadcasts on the same and on adjacent channels, as a necessary prelude to planning the use of broadcast bands.

When it comes to considering a PLT system as an interferer, the necessary PRs have not yet all been determined. Indeed, in the absence of definitive accessible specifications for many PLT systems, this would be difficult to achieve. It is easy to make some estimates. If the PLT signal were reasonably noise-like (as appears to be the case for ADSL systems[2], at least in the part of the spectrum that is actually carrying traffic) then the PR could be deduced from the known behaviour of the broadcast signal in the presence of thermal noise. Real PLT systems vary in character but generally appear to be slightly more annoying, at the same level, than white noise when they interfere with an AM signal, so we can deduce that the necessary PR is as least as great as that for white noise/ADSL, and perhaps somewhat greater. When the wanted signal is digital it is perhaps unwise to speculate, and the PR really should be determined by laboratory experiments.

Whatever the fine details, one generalisation is safe: the PR for interference to either AM or DRM from broadband interferers will always be substantially positive when expressed in dB, where the interfering power is measured in the same bandwidth as the AM/DRM channel width. In other words the interfering power in the channel must be significantly less than that of the wanted broadcast signal.

REGULATION OF INTERFERENCE

Approaches

When interference (of whatever origin) spoils a radio listener's enjoyment of their favourite radio programme, they do not care about what caused the problem, they just wish it had not occurred, and maybe start looking for someone to blame. The regulatory process is different; it makes a distinction between sources of interference.

Interference between (legitimate) radio services is handled within the radio community. Generally there is some form of planning based on propagation models and the application of appropriate PRs. This can take the form of very rigid and long-lived plans established by a major World Radio Conference (common in most broadcasting bands except HF) or a more informal seasonal approach as is taken for HF broadcasting through the HF Coordination Committee, HFCC.

Interference from non-radio systems to radio services is treated quite differently. As we have seen, there are instruments (internationally, the RR, and in Europe, the EMC Directive) that set out the general principle that radio services should be protected from interference. But the way to turn this into practice is where difficulty can start.

Interference from appliances and apparatus is dealt with under EMC regulations. In principle these should do a similar job to the way that radio services protect each other: determine the protection strictly necessary, and then apply whatever relaxation is reasonable considering the likelihood that the item in question will cause problems. E.g. an item only used in large factories will always be much farther away from a domestic radio than items commonly used in the home. It makes a difference whether interference occurs sporadically and briefly, or is continuous in nature. Emissions templates drawn up to set a limit on say clock-frequency leakage will have taken into account that only a few spectral components will be present. They do not imply that broadband interference will also be acceptable if it just does not exceed this template. A simple example will make this clear. The COFDM system used in several types of broadcasting is very tolerant to isolated narrow-band interferers

[2] Asymmetric Digital Subscriber Line, a popular means of connecting homes to the Internet using *phone* wiring.

that in effect knock out just one, or very few, of the OFDM carriers it uses [4]. In this way, DVB-T digital television can accept surprisingly high amounts of co-channel interference from analogue TV signals (where a high proportion of the signal power is concentrated at the vision and sound carriers). In contrast, co-channel interference from another DVB-T transmission would have to be at a significantly lower level to be acceptable. This is recognised in the different PRs applied in planning for these two cases. Interference from any other type of broadband interferer would have to be treated in the same way.

Interference from PLT is a bit of a special case that does not fit comfortably within existing procedures. The interfering emissions actually come from mains wiring (a passive item). They occur because signals are injected on to the wiring by PLT modems, and unlike other apparatus potentially causing incidental interference (e.g. electric drills, fluorescent lamps) the signals are injected deliberately, even if the radiation is unintended. The interference from access-PLT systems at least will occur more-or-less continually and will potentially affect all households receiving mains supply from a sub-station in an equipped area, whether they subscribe to the service or not.

Some previous proposals

The author has witnessed the evolution of proposals to regulate PLT emissions for many years. Right from the start there was debate whether to apply a 'flat' limit or to have 'chimneys'. (The 'flat' limit would not necessarily be literally flat; it might have a slope across the band to a degree matching the trend of the noise floor. 'Chimneys' were parts of the spectrum where greater emissions would be permitted; they would be the complement to notches). There was resistance to 'chimneys' on various grounds:

- radio users felt they would give a degree of legitimacy to interference, supplanting the RR
- the prerogative of World Radio Conferences to allocate and re-allocate frequencies would be diluted or bypassed
- the radio user(s) in whose spectrum allocation any chimney would fall would be justifiably aggrieved

So a general preference for a 'flat or slowly varying' limit was established quite early. Initially Administrations took the lead (exercising their responsibility under the RR).

NB 30

A typical and often-quoted example is the German 'NB 30' proposal. This was described as a compromise between radio users and PLT operators. Unfortunately the gulf between what the two wanted was large (many 10s of dB) so establishing a compromise in the middle satisfied no one. PLT systems either could not meet the limit or would have to reduce performance substantially to do so. Meanwhile this limit demonstrably [5, 6] fails to protect broadcast reception in the home. NB 30 is specified over a wide frequency range; in the MF/HF range, 1 to 30 MHz, measurements are to be made at a distance of 3 m using a loop antenna. The equivalent *E*-field limit, measured in a 10 kHz bandwidth with a peak detector, is given by the following formula:

$$E \leq 40 - 20\,\mathrm{Log}_{10}\left[f_{MHz}\right],\ \mathrm{dB\mu V/m}$$

BBC/EBU

Many types of radio services use the HF band. You might therefore think that an attempt to protect them all from first principles, using their individual wanted-signal levels and different protection ratios, would lead to a limit that was far from flat or smoothly varying with frequency. However, this neglects the fact that the different wanted-signal levels have all evolved driven by the same thing — the general noise floor.

The present author therefore derived [7] a limit proposal that was, as required, 'flat or smoothly varying' and which sought to provide appropriate protection for all LF/MF/HF services in their different situations. It was based on accepting a limited degradation of the existing noise floor for outdoor reception, and if anything, it made the greatest compromise in its level of protection for indoor reception of broadcasting[3]. The measurement in this case would be made with a loop antenna at a distance of 1 m, and applies to the frequency range 150 kHz to 30 MHz. The equivalent *E*-field limit, measured in a 10 kHz bandwidth with a peak detector, is given by the following formula:

$$E \leq 21.8 - 8.15\,\mathrm{Log}_{10}\left[f_{MHz}\right],\ \mathrm{dB\mu V/m}$$

We immediately face a difficulty that this proposal is not directly comparable with NB 30 as the measurement distance is different. The author chose 1 m for good reasons:

- it increases the level of the unwanted emissions, making them easier to measure
- it is not possible in most homes to find anywhere that is 3 m from all mains cables
- 1 m is representative of the likely distance that a battery-powered receiver will be from mains cables in the home, so the limit can be mapped onto the real problem

This limit was taken up by the European Broadcasting Union and also received wide support from other radio users; unfortunately it found little support amongst Administrations.

'Joint Working Group' proposals

The European Commission issued a mandate (M313) to a Joint Working Group of ETSI/Cenelec to produce a harmonised standard for emissions from networks (including PLT). After protracted debate it became clear that agreement within this group was unlikely, and instead three proposals were prepared and put out to National Standards Organisations for voting. The three proposals were:

- conducted-emissions limit derived from product standards
- radiated-emissions limit, equivalent-*E* 55.5 dBµV/m quasi-pk in 9 kHz at 3 m

[3] A limit based strictly on the concept of (minimum protected FS less PR) for AM broadcast reception would give a limit that is tighter still, for all the international broadcasting bands at 6 MHz and above.

- radiated-emissions limit, essentially NB 30

NB 30 is the tightest of these, but even that is quite inadequate to protect broadcast reception. Unfortunately the slacker second option seems to be currently favoured. The author considers that setting an emissions limit that, like this proposal, permits emissions that are very substantially *stronger* at the point of reception than the wanted signals (when the converse is clearly necessary for reception) simply brings EMC activity into disrepute.

The conducted-emissions limit has the benefit of being linked to other product standards, but also raises questions. There is no allowance for the broadband and continual nature of the interference. The currently-favoured, second-option radiated-emissions limit is essentially derived from it. The tests for conducted emissions assume that common-mode current is worst at the injection point under specified test conditions (a test-fixture provides the load). This neglects the fact that the structure of mains wiring, with its many one-legged stubs (for light-switches, extension cables plugged into wall sockets which are switched off, etc) will convert a differential input into a common-mode current *elsewhere* [8].

EXAMPLES OF EXISTING PLT SYSTEMS

In this section we discuss some example PLT systems of which BBC R&D has had some experience, albeit in some cases limited. We have paid two visits to Crieff in Scotland, where Scottish and Southern Electricity (SSE) have deployed access PLT from three manufacturers. On the first visit in 2002 (reported in detail in [9]) we saw systems by Main.Net and Ascom, and on a second visit in 2004 we saw a system by DS2. We have also acquired on the open market some home-networking PLT devices to the HomePlug specification, from two manufacturers, that we have studied in the laboratory.

Main.net access PLT

System

Available information about the Main.Net system is very scarce. Their web site [10] gives no insight into how the system works (in terms of what signal is fed onto the mains). It does explain that it makes use of repeaters, and that the concept includes home-networking as well as access.

We were informed that it uses direct-sequence spread-spectrum, although the observable characteristics rather support the notion that it is frequency-hopping spread-spectrum. We noted that the in-home terminals communicate directly with the outside world, whether that is the modem at the sub-station or a repeater located somewhere on the way.

Observed behaviour

The system observed in Crieff affected the spectral range from roughly 4.5 to 13 MHz. We were not able to turn the PLT system fully off, but we could specially contrive a 'quiescent' state in which there was no deliberate traffic. In this condition reception of any broadcast channel in the frequency range was affected by brief regular clicks. Once the traffic was restored continual interference could then be heard. This is best appreciated by listening to it (all the audio samples from the 2002 Crieff visit, identified as items 1 to 31, are available from the BBC web site [11]). Nevertheless, Fig. 1 conveys it graphically with a display of the audio waveform, recorded using a normal portable radio tuned to an HF broadcast in the 12 MHz band which was chosen to be representative of a signal at the minimum protected field strength of 40 dBμV/m. At the left of the Figure the modem is quiescent and the programme audio can be seen, with small clicks from the PLT, and then once the modem is busy (right of Figure) the programme audio is submerged below the interference.

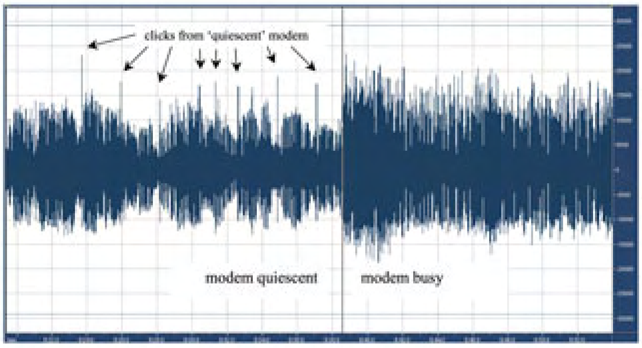

Fig. 1. The recorded audio waveform at the boundary between items 9 and 10. This shows how the audio is 'submerged' under PLT interference as the modem becomes busy, and also shows that the 'quiescent' Main.Net modem introduces visible (and audible) regular clicks.

The interfering field strength was measured indoors using a calibrated loop antenna and measuring receiver. For example, at 5820 kHz (chosen as a clear frequency near to a broadcasting band) the equivalent *E*-field strength in a 10 kHz bandwidth was 64 dBμV/m (with a small fluctuation above and below) using a peak detector, whether the modem was busy or quiescent. The distance of the loop from the wiring carrying the emissions cannot be stated precisely; the loop was simply erected on its tripod where it could be in the close confines of the room where the measurement was made. Assuming the relevant wiring was in the walls or ceiling, the distance was of the rough order of 1 m. This reinforces a point: rooms in most people's homes are not large enough to give them the option of moving a radio very far away from mains cables (even supposing that the radio is battery-powered, as ours was for the recordings). If we walked about with the portable radio, the impairment remained similar.

We were fortunate to have the opportunity to make a brief visit to the neighbour's house. This was the adjoining house in the same terrace, and thus is representative of the situation where houses are in terraces or are semi-detached. This neighbour did not have the PLT service — but he still suffered the interference[4]! Once again we recorded a broadcast of representative field strength, which was significantly impaired (listen to items 12 and 13 from the web site [11]).

[4] The brevity of the visit meant that we merely established that interference indeed occurred in this situation, and might reasonably be expected to happen to other neighbours of PLT subscribers. What could not be conclusively determined without a more prolonged experiment is whether the interference was received by radiation from the PLT-equipped house, or by radiation within the victim's house of the conducted PLT signal. However, interference was also found to be widespread in the street, tending to suggest that more than the immediate neighbour might also be affected.

Ascom access PLT

System

The Ascom system is more fully described in public sources, e.g. Ascom's website [12], than Main.Net.

The Ascom system uses different parts of the spectrum for *access* and *internal networking*, conforming to the common convention of using lower HF for access and higher HF indoors.

The frequencies used for *access* are four bands, centred on 2.4, 4.8, 8.4 and 10.8 MHz. We believe that any particular installation only uses three out of these four. Ascom claims a capacity of 2.25 to 4.5 Mbit/s for each system. The frequencies used for *indoor networking* are bands centred on roughly 19.8, 22.4 and 24.6 MHz (there are minor inconsistencies about the precise details).

We were told that the system nominally uses 1 MHz blocks of spectrum centred on the above frequencies. If these were tightly constrained to this width they would represent a good choice as far as broadcasters are concerned, since there would be no overlap with any HF bands currently used for international broadcasting[5]. So it appears that the designers have made a commendable effort in their choice. However, it also appears that each band carries data using a simple single-carrier modulation scheme; the intrinsic roll-off is shallow and is supplemented (if at all) by relatively gentle filtering. So, sadly, significant interaction with broadcasting can still occur.

The bridge between these internal and external systems is provided by the *outdoor access point* (OAP). This was connected to the supply side of the electricity meter in both premises we visited, so that the higher-frequency indoor-band signals had to pass through the meter to reach the indoor modem, which was situated adjacent to the computer. This can be seen in Fig. 2, which depicts the outdoor meter cupboard at one of the premises. As the indoor frequencies are injected/received by the OAP on the supply side of the meter it is clear that interference could occur between households if OAPs are too close together.

The system uses time-division multiplexing on each carrier.

Fig. 2. The Ascom Outdoor Access Point, installed in an outdoor meter cupboard. The OAP is the unit in the lower right of the picture, and, as can be seen, was connected to the supply side of the electricity meter. (At the other Ascom-equipped premises visited there was an electrically similar arrangement, but in that case the meter and OAP were housed indoors.)

Observed behaviour

The time-division-multiplex nature of this system was audibly apparent, and can be seen in Fig. 3, which is derived from a zero-span spectrum analyser plot, with a resolution bandwidth of 10 kHz.

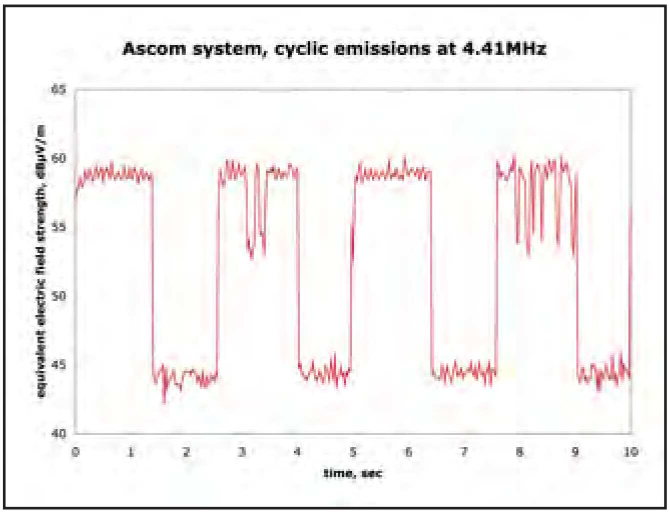

Fig. 3. The cyclic nature of Ascom-system emissions at 4.41 MHz.

5 The bands centred on 2.4 and 4.8 MHz clash with the so-called Tropical Bands used for national broadcasting in the Tropical Zone defined by the ITU-R. If SSE are right in asserting that the highest indoor band is centred on 25.2 MHz (instead of 24.6), then that would overlap the lower part of the 26 MHz band.

Despite the designers' apparently careful choice of frequency bands, the impact on broadcast reception was still enough to be disturbing at certain broadcast frequencies, e.g. listen to recorded items 30 and 31 from the website [11].

Further details of emissions measurements can be read in [9].

DS2 access PLT

System

The publicly-available technical information about the DS2 system is limited [13]. It is based on OFDM technology. It uses different bands for upstream and downstream, and for indoors and access, and all can be programmed — there is no single defined range. There is some facility for introducing notches to reduce emissions in specific bands.

Observed behaviour

Our second field trip to Crieff, in June 2004 was intended to enable us to compare the DS2 system directly with the Ascom and Main.Net systems we had already seen and measured. DS2 gives the impression that its later-generation system has somehow solved many interference issues of those earlier systems. Unfortunately, however, DS2 representatives would not allow us to make measurements inside subscriber's homes and so we cannot make any valid comparisons between DS2 and the other systems, nor can we describe reliably what the experience of a DS2 user trying to receive radio indoors would be like. All our measurements on this visit were made either *outside* two houses served by the system, or outside the sub-station, or on the road.

We were able to confirm the multi-carrier nature of the system by observing its spectrum. The spectrum has regular narrow peaks spaced at roughly 1.1 kHz, although every 4^{th} appears to be missing, giving another periodicity at 4.4 kHz. Without further information it cannot be deduced whether the OFDM carrier spacing is actually 1.1 kHz, or 4.4 kHz with sideband artefacts, perhaps from pilot information. However, the regularity means that an AM radio receiver reproduces a 1.1 kHz tone, wherever it is tuned in the relevant frequency range.

A report detailing our measurement results is in course of preparation at the time of writing this present paper. We can however note that measurements *outside* an equipped house gave interference field strengths[6] in the range 40 to 50 dBµV/m (i.e. at or above the minimum broadcast field strength). So it seems very likely that significant interference to broadcasting would have been experienced indoors. It was certainly obvious on a recording made outdoors at some 3 m from the house. This may also be indicative of what a neighbour in an attached house might suffer.

HomePlug home-networking PLT

System

This system was developed by a consortium, the HomePlug Powerline Alliance, and there is an agreed specification to which many vendors make apparatus.

It is intended to provide networking in the home similar to Ethernet or WiFi, but through the medium of the mains wiring. It is OFDM-based and uses the spectral range from 4 to 21 MHz. It appears to have been designed with some radio users in mind, in that its spectral mask is specified with fixed notches to a depth 30 dB below the maximum level. These notch frequency ranges correspond to the bands allocated in the USA to Radio Amateurs[7], the so-called 160, 80, 40, 30, 20, 17, 15, 12 and 10 metre bands. Each device uses the full frequency range (less notches) to transmit Ethernet packets.

Observed behaviour

We have examined devices from two suppliers, Corinex and Devolo. They appear to be interoperable without problems, confirming the expected benefit of the existence of a common specification.

We were able to confirm that the notches were implemented as required by the specification. This was checked using a wide-band transformer arrangement[8] to examine the differential RF voltage between Live and Neutral, see resulting plot, Fig. 4. All devices checked had very similar results. The specification indicates that relevant OFDM carriers in the notches are never transmitted; however, it is easy to calculate the spectrum of the specified OFDM waveform, accounting for its pulse shape and the omitted carriers, and note that this is wholly insufficient to produce the required notch depth. We therefore deduce that further digital filtering must be used.

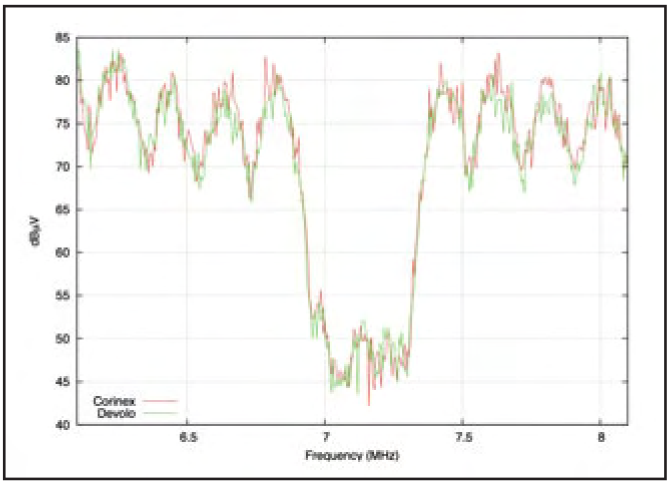

Fig. 4. Spectrum of HomePlug PLT, showing the 7-7.3 MHz notch and the ripples in the rest of the spectrum, which correspond to the HomePlug OFDM carriers. These ripples are pronounced because the cyclic prefix is relatively long. (Measured using differential transformer and spectrum analyser with 3 kHz resolution bandwidth and 'max hold').

Unfortunately for broadcasters, the notches do not protect most of the parts of the spectrum they use. It was easy to show that operation of a Homeplug network caused disruption of reception of both AM and DRM HF signals, see Fig 5.

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[6] Equivalent-*E*-field measured with loop and spectrum analyser using max-hold and 10 kHz bandwidth, an essentially comparable technique to the 2002 results, which used a measuring receiver.

[7] Since the USA allocations are in some cases broader than those in the rest of the world, radio amateurs everywhere take benefit from this.

[8] With appropriately rated safety arrangements, including isolating capacitors!

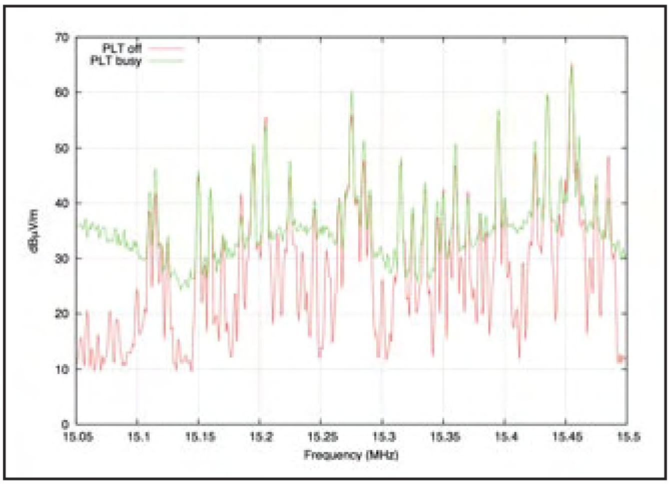

Fig. 5. Spectrum of the 15 MHz broadcast band, measured using a loop antenna and spectrum analyser with 1 kHz resolution bandwidth and 'max hold'. The red trace shows that many broadcast signals can be discerned when the HomePlug PLT system is off, but when it is active (green trace) the 'noise floor' is raised significantly, to a level such that broadcast signals exceeding 40 dBμV/m would be badly impaired. The 'noise floor' varies cyclically, corresponding to the HomePlug OFDM carriers.

A further experiment graphically demonstrated that PLT signals are radiated. 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[9], see Fig. 6. 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.

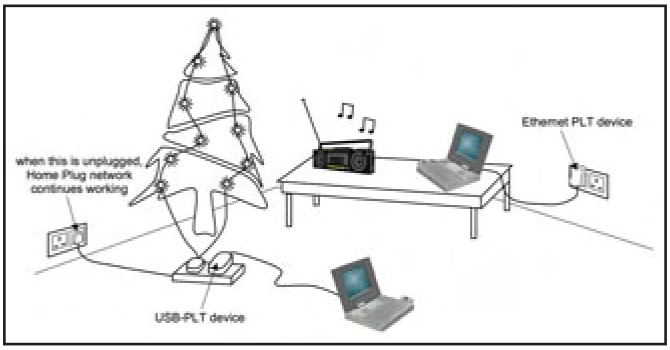

Fig. 6. Arrangement by which a home-networking PLT system can be shown to operate as a wireless network. When the mains extension cable is unplugged from the wall the PLT network continues to operate, despite there being no (wired) connection any more. The broadcast receiver suffers interference when the PLT system is operating, whether 'wired' or 'wireless'.

POSSIBLE APPROACHES TO CO-EXISTENCE

Simple limits will fail

Emissions from all PLT systems discussed here are at a level that will disturb broadcast radio reception in the immediate vicinity, if the wanted signal is in the same part of the spectrum as is being used for (or occupied by) PLT. It seems likely that this will continue to be true, for all PLT systems having a worthwhile capacity. Hence attempts to set a simple emissions limit will never be a solution. A level high enough to permit PLT operation offers no protection to reception of broadcasting. A level low enough to protect reception of broadcasting will prevent PLT operation.

So the key to possible co-existence has to be more complicated. We can say that it is possible, but broadcasting and PLT must not try to use the same spectrum at the same time at the same place.

In effect this has been partly recognised already. The Ascom system appears to have bands chosen trying to avoid most broadcasting and amateur bands (even though the implementation does not deliver the desired result). The DS2 system has some notching ability and the HomePlug system has fixed notches corresponding to the radio-amateur bands.

Notches may be the answer, but…

The European Commission and others make much of the idea that PLT operators can notch out interference on a specific frequency after interference has arisen and been reported. Unfortunately "the devil is in the detail". In principle, if the interfering signal is removed from the part of the spectrum in which a listener's chosen programme is located, the problem is solved. But much more has to be done before this can be quoted as the simple answer:

1. The technology to notch the interference adequately has to be demonstrated (We cannot confirm at present that the DS2 notches are adequate. However, we have been demonstrated an early prototype of a home-networking PLT system by another company which did implement very flexible notch facilities that appeared to be of adequate depth, although there was no time to confirm this by detailed measurement).

2. There have to be guarantees that notches would be operated to protect listeners whenever the latter need it. Since providing the notch reduces the PLT operators' capacity, it is unlikely that this will happen unless there is regulatory pressure to do so.

3. How would this be operated in respect of broadcasting? Listeners to international broadcasting have a wide range of possible stations to choose from, on a constantly varying transmission schedule. They fill many broadcasting bands to bursting point — albeit not all at once, since the ionospheric propagation varies, favouring different frequencies on a diurnal, seasonal and 11-yearly cycle. Who would decide which channels or bands would be protected and when? We presume PLT operators have no intention of protecting the entirety of

[9] The author is deeply indebted to Dr. Markus Wehr of RBT in Germany who first proposed this scenario and reported its behaviour.

all the broadcast bands, all the time[10] — nor do they need to. There is a risk that the PLT operators are perhaps to assume the mantle of *censor* — you can listen to stations they choose to protect, but not to others.

This is very dangerous, and would be an absolute gift to the regimes of the many countries in the world where freedom of expression and uncensored access to the Internet is non-existent. At present international broadcasters from Europe, such as the BBC World Service, can broadcast to these countries, and their citizens can listen, even if this is disapproved of. Such countries (say country X) may choose to jam the broadcasts, with varying success, and in contravention of the ITU Radio Regulations. At present, European countries are in a position to complain to X about this, and sometimes these complaints have effect. However, once radio reception in Europe becomes 'censored', albeit in an unofficial way by PLT providers, then there are no longer valid grounds for complaint. Note that this 'reciprocal' argument obliges us to protect even a radio programme broadcast to Europe by country X to which maybe no one actually cares to listen in Europe, and thus there is no listener who will complain about its loss.

The only obvious way to avoid this argument (and a lot of bureaucracy and resulting costs) is for PLT equipment to be operated in a way that it senses the use of the radio spectrum by radio services (during intentionally inserted 'silent' periods in the PLT network's transmissions) and avoids all parts of the spectrum[11] in which it finds radio services currently operating. This would ensure that no censorship was deemed to take place — and would maximise the PLT capacity, under the constraint that interference from PLT to indoor radio reception was minimised.

Some statements by the European Commission clearly recognise the possibility of this method[12], although they might be misinterpreted as implying that systems like this are already available. To the best of our knowledge this is not the case, and indeed seems very unlikely to be unless there is some regulatory pressure to encourage their development. We have made a brief experiment to see if it might be feasible.

Experiment in using mains as sensing antenna

What we need is for the PLT modem to be able to detect whether there is a receivable signal in each part of the spectrum. Wherever one is found the PLT system must not operate, i.e. it places a notch. It may not be practicable to provide the PLT modem with a separate antenna for this purpose, so we tried using the mains itself. We tried two ways. In one we used the previously mentioned transformer that sensed the differential voltage between Live and Neutral; in the other we placed a current clamp around a convenient mains cable (actually that feeding our spectrum analyser).

We also placed a (calibrated) loop antenna outside and at a distance of 11 m from the building in which we were experimenting. This was used as a reference, so we knew what RF signals were potentially available for reception, and their signal strengths. The challenge was to see if by examining the signal from the mains we could identify all the receivable transmissions. Fig. 7 shows part of the spectrum, with traces for the signal received outside and that obtained from the mains, in this case using the wideband transformer. Results with the current clamp are similar. 'Eye-balling' these traces suggests that it should indeed be possible to devise an algorithm that would identify the channels occupied by receivable signals. Some simple algorithms were tried, with good results. Further work along these lines is strongly recommended.

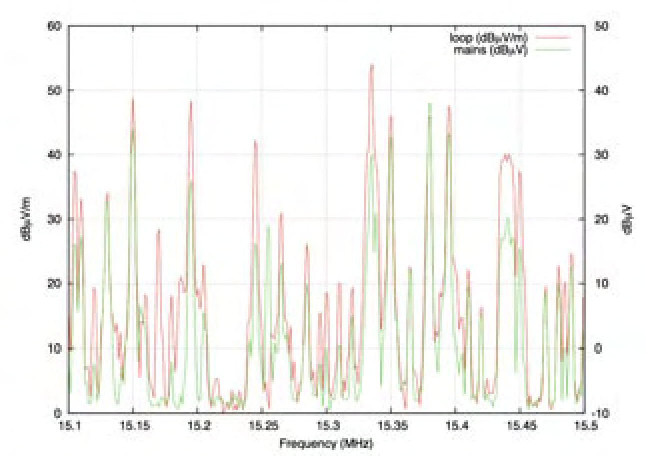

Fig. 7. Spectrum traces (1 kHz resolution bandwidth) of the 15 MHz broadcast band, comparing the broadcast-signal field strength received by an outdoor antenna (red trace, dBμV/m scale on left), with the differential voltage sensed across the mains (green trace, dBμV scale on right). The peaks correspond well — although not always dB-for-dB. This could suggest that the loop and the mains wiring have different directional characteristics; however, it could also be a consequence of the traces being recorded sequentially when signals were subject to fading.

CONCLUSIONS

Radio services are entitled to protection from interference under the terms of the International Radio Regulations and the European EMC Directive.

The radio spectrum below 30 MHz is a unique resource of special value to radio users because of its long-distance propagation properties which, in the case of broadcasting, are essential to international broadcasters and are also of very great value for national broadcasting where countries are large, poor, have scattered populations or are in the Tropics.

Broadcasting below 30 MHz is in the process of being transformed by the introduction of DRM to replace AM, bringing greater audio quality and ease of use — an all-round improvement of the listening experience.

[10] And even doing this requires programmability of the notches. Spectrum allocations under the ITU-R Radio Regulations evolve over time, for example realignment of the amateur and broadcasting bands around 7 MHz is currently under discussion. Thus fixed notches, as implemented by HomePlug, are not a solution.

[11] The protection could perhaps be limited to internationally allocated broadcasting and radio-amateur bands, i.e. those for which home reception is intended. It would have to be verified in this case that other radio users' services (with receiving antennas situated away from home environments) did not suffer undue interference either. The author has registered concern that *cumulative interference* from a very large deployment might have a significant impact on aeronautical radio services in particular, which should be assessed further [14].

[12] E.g. the statement "Advanced mitigation techniques such as the ability to put spectral notches in real time will facilitate interference resolution", from [15].

Mains wiring acts as an antenna at HF and therefore has the potential to radiate and receive electromagnetic fields.

Power-Line Transmission has the potential to cause substantial interference to reception of broadcasting in listener's homes. This potential has been confirmed by the recording and measurement of actual interference from all the PLT systems examined.

Proposals by Administrations or the European Commission for the regulation of emissions do not adequately protect broadcasting. In one case the gulf is of the order of 60 dB. Proposals like this just bring EMC regulation into disrepute.

A limit that did protect broadcasting and other radio services would have the effect of outlawing PLT and other similar broadband services. This is probably politically untenable, however, it may not be necessary.

What is needed is for interference to be prevented. It appears that this can only be achieved if PLT does not operate at the same time, at the same frequency and in the same place as broadcast reception is taking place. 'Notching' of the PLT system is proposed as the way to achieve this.

Notching alone is not enough. It has to be verified that sufficiently deep notches can be achieved. They have to be flexibly allocated whenever and wherever needed. A human system for doing this would be costly, slow to respond to need and would raise difficult ethical questions over censorship.

A possible method has been suggested whereby the PLT system might itself determine automatically which parts of the spectrum are occupied by radio signals and avoid them. An experiment suggests that this should be feasible.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the generous help he has received from: his BBC colleagues John Salter and Susannah Fleming, in performing field measurements and laboratory experiments; Scottish and Southern Electricity, in facilitating measurements at Crieff; others participating in those measurements, especially Colin Wooff of RTCG and Robin Page-Jones of RSGB; and finally the householders whose homes in Crieff we visited.

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