Measurements of VHF emissions from PLT Devices

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1. INTRODUCTION

The purpose of this paper is to propose some experiments to assess the possible impact on broadcast reception of recently introduced PLT devices. It is hoped that broadcasters may be able to perform them collaboratively, thereby achieving a greater breadth of results without too daunting a workload for each. With this in mind, some discussion of the experiments before they are made is appropriate.

Why are these experiments needed? Isn't this PLT topic old news? The answer is that PLT devices are changing: commercial/marketing pressure for home-networking products to support higher bit-rate capacity means that much wider total bandwidths are being used. Any emissions of the PLT signal will therefore overlap radio services that were previously unaffected, thus potentially creating new interference threats. It is merely prudent for those potentially affected to assess the situation.

BBC R&D is hoping to be able to make some of these measurements. If any results are available by the time this paper is presented, they will be included in the presentation.

2. BACKGROUND

2.1 What is PLT?

PLT stands for Power Line Telecommunications, a way to convey data signals along electrical power wiring. It is sometimes called Power Line Communication (PLC), or Broadband over Powerline (BPL). It can be used for two different purposes:

- **access** — connecting homes to the outside world (e.g. the internet) using their electric power supply ('mains') connection

- **home networking** — interconnecting devices within the home, possibly in turn connecting them to the internet, whether this is provided by access PLT or some other means, e.g. *x*DSL.

Until recently, only frequencies in the HF range were used, with initial concerns relating to potential interference to HF radio services from *access* PLT systems. *Home networking* PLT now appears to have overtaken access PLT in its likely scale of deployment (certainly so in the UK). Both types of HF PLT have given rise to serious concerns amongst radio users about interference, and arguments about whether, how and to what extent this might be regulated have continued for over a decade without resolution.

2.2 PLT extends to the VHF range

Competition in the marketplace for home-networking products has led to the desire to offer ever higher data capacity. This has led to PLT home-networking devices making use of spectrum above the HF range. Devices are now available which make use of VHF spectrum that overlaps with the Band II and Band III frequencies used for FM and DAB broadcasting respectively. Reception of these forms of radio broadcasting is a popular activity, so any risk of potential interference to it is one potentially affecting a large number of listeners. VHF also represents the core means of delivery for domestic radio broadcasters.

2.3 Emissions are inevitable

The inconvenient truth about using mains cable for data communication is that unwanted emissions, with their propensity to cause interference to radio systems, are inevitable. Mains wiring (cables *and* structure) was designed for power distribution and not for data transmission. Furthermore, PLT devices have to compete in the market with other networking possibilities, leading to a natural desire to be able to advertise a high data capacity. Basic engineering fundamentals tell us that achieving high capacity implies using a high bandwidth, or a high PLT-signal-to-(noise-&-interference ratio) or preferably both. The first implies a wide range of potentially disrupted radio services, and the second implies injecting a high signal level into the mains, in turn maximising the level of any emissions and making them more likely to disturb.

Now, the idea that injecting signals on to the mains causes emissions which can cause disturbance to radio systems is not new. It's been happening ever since electric power tools and appliances, and later electronic equipment, have been available. That's why regulations like those drawn up by CISPR exist. In such cases the signals injected on to the mains are only a by-product of the normal operation of the device. The existence of regulations to limit them obliges designers to reduce them to acceptable limits, whether by fitting filter elements or simply a better design. Manufacturers of appliances lose no functionality by this, but they do incur some costs in both components and design and manufacturing effort.

PLT devices are different, in that they are the only ones where the injection of signals onto the mains is *entirely deliberate*. In order to work at high capacity[2], they must inject signals at higher levels than is permitted for other devices under existing rules. In effect they require to be treated as a *special case*, allowed to inject at a higher level than ordinary appliances, and thus not subject to the emissions limits applied to ordinary appliances.

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[1] This paper was written for BBC R&D under contract and is © BBC 2010.

[2] It may be asked whether this is always necessary. Injection levels could always be traded downwards for lower capacity, while causing less interference.

PLT devices are also different in the way they inject signals on to the mains:

- Non-PLT devices couple their unintentional emissions by whatever accidental mechanism causes them.
- PLT devices tend[3] to inject signal purely differentially between L and N conductors. This partly occurs naturally by the combined use of a coupling capacitor and isolating RF transformer for safety reasons. However, it may also be done in the belief (I believe misguided) that it will reduce emissions, or at least appear to reduce emissions.

The accidental injection (by non-PLT devices) of unintended signals onto the mains is relatively unlikely to be purely differential between L and N. The unintended signals therefore cause at least some common-mode current to flow along the device's power cable (and in turn along part of the house wiring). Common-mode current flowing on wiring will cause radiation, and thus potentially cause radio interference.

PLT devices, intentionally injecting signals differentially between L and N mains connections are very different. If and only if all the mains cable had good balance properties, likewise all devices plugged into the mains network, *and* if there were no stubs, then any radiation would probably be negligible. However, these conditions simply do not occur in practice.

Consider just the case of *stubs*, while everything else remains magically ideally balanced. One type of stub, in this case on the N conductor, would be caused by plugging a device or mains-extension cable into a wall socket that is switched off (by a single-pole switch, as is common in the UK). The RF voltage between N and ground would cause current to flow on this stub, with accompanying radiation. A stub could be formed on the L conductor by the feed to a (single-pole) light switch which is switched off. Current will flow on this stub as a result of the RF voltage between L and ground. In general such stubs will also cause imbalance, so that some common-mode current flows along the mains network as well. Network and stubs will all radiate, but note that the worst common-mode current need not occur at the PLT device, but rather near the stubs. It is even possible to imagine special cases where the balance of the mains network is not disturbed but there is still strong radiation from the stubs — for example if the stubs were to take the form of the arms of a dipole.

Mains wiring has other topological quirks potentially giving rise to radiation, e.g. the wiring to a light switch that is switched on can take the form of a folded monopole.

For all of the above reasons, it is important to consider the potential impact of any radiation from the ensemble of the mains wiring connected to PLT devices.

2.4 What evidence exists already, and what is missing from it?

There is documentary evidence of VHF emissions in the form of a submission to the ITU-R. However it falls short of a definitive indication that PLT devices will or will not cause significant harm. Further work is therefore needed, but a look at what has been done already will help identify what this further work should be.

IRT measurements

These were reported to the ITU-R as Ref. [1]. The measurements, performed by IRT[4] Munich on behalf of NDR/ZDF[5] include results from some PLT devices that only operate at HF, but the part of interest for our present purposes relates to an initial investigation of some devices that were shown to make use of VHF spectrum. Indeed, it was found[6] that these use the spectrum from 50 to 305 MHz, as well as making simultaneous use of the HF spectrum from 2 to 30 MHz. It is also explained that the use of the VHF spectrum depends on the distance between PLT terminals — if the distance is too great, then so too is the attenuation at VHF, and a point is eventually reached where only HF spectrum is used, with an appreciably lower data rate then being supported. This limiting distance in these experiments was reported as approximately 10 metres[7].

Radiated emissions were examined using a network of two PLT devices connected to two notebook computers. Each was connected via a 1.5 m extension cable, these two extension cables being in turn connected via a third in the middle which was plugged in to the local mains supply. The two PLT modems were thus separated by some 3 m of cable in all, with the mains fed in at the middle. Radiated emissions were then measured at a distance of 3 m, with the measuring antenna at a height of 1.5 m. Measurements were made in a bandwidth of 120 kHz, but for convenience using a peak detector rather than a quasi-peak one[8]. Spectral plots are given of the emissions which are described as exceeding CISPR 22 limits.

What is unfortunately not mentioned at all in the paper is the actual impact on broadcast reception in the vicinity.

Ofcom report

The IRT findings are also quoted in a report [2] commissioned by Ofcom. This report draws the conclusion that without mitigation measures, there would be a high probability of interference to broadcast FM reception. It therefore proposes that so-called smart notching should be implemented in this broadcast band. Smart (or dynamic) notching is a concept originally proposed, demonstrated and standardised [3] for the

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[3] There may well be, or have been, exceptions to this.

[4] Institut für Rundfunktechnik GmbH

[5] Norddeutscher Rundfunk, Zweites Deutsches Fernsehen respectively

[6] By means of using a current clamp on the live wire. This doesn't give a calibrated indication of conducted emissions in accordance with any agreed EMC standard but it is entirely adequate to indicate what spectrum is in use by PLT, and its level relative to other 'noise' or ingress on the cable.

[7] Presumably it is the combined effects of attenuation and selectivity of the mains network that 'kill' VHF communication by the PLT devices. We may infer that wiring practice may therefore affect the limiting distance, which might therefore vary from home to home and most particularly between the wiring styles used in different countries.

[8] CISPR 22 radiated emissions measurements specify the use of a quasi-peak detector. Unfortunately this does not lend itself to swept-frequency measurements of acceptable duration. Quasi-peak measurements were originally specified in the days before digital broadcasting; they are supposed to represent better the audible impact on analogue modulation systems.

protection of HF broadcasts. The PLT device senses which channels in the HF broadcast bands are occupied with receivable signals, and notches out those frequencies. It has, however, been reported [4] that this technique can be limited by the effects of intermodulation in the mains network (e.g. from rectifiers in connected appliances) 'filling-in' the notches and thereby reducing their effective depth. Note that no smart-notching implementation has yet been demonstrated for PLT devices using the VHF range.

An urgent need for resolution

We therefore know that emissions occur, and at levels giving cause for concern, since in the reported experiment they exceeded CISPR limits. However, it is not definitively established and demonstrated that they deleteriously affect the reception of FM or DAB radio by the typical listener in a typical situation.

So there is a clear need to perform an experiment directly assessing the impact on radio reception, in which:

- the wanted broadcast field strength is known (by measurement)
  — ideally the site would be chosen having regard to typicality of field strength, as predicted in the customary way for spectrum planning. If we start with a site whose field strength is representative of that which is predicted for a high proportion of locations, then we immediately answer whether we have a big problem. If this site is relatively unaffected, then we should also test another site towards the edge of planned coverage.

- representative portable FM and DAB receivers are used, at representative locations for home usage, both battery powered and mains powered and using their attached antennas

- the PLT network is established over a fair distance inside the home — far enough that the network is needed, and the PLT devices are not running at lowest power because they are immediately adjacent, but not so far that VHF spectrum is no longer used. A good starting point would be upstairs and downstairs rooms, not immediately above one another, for a house, or diagonal extremities for a bungalow or flat.

Other things which are lacking

We don't have any adequate theoretical model which would make it easy to predict the state of affairs without recourse to field trials, and would make it easier to assess and if necessary challenge any regulatory proposals.

A useful start would be to know the required protection ratios for FM or DAB interfered with by the various PLT systems on the market. This should mostly boil down to the number of PLT 'standards'/chip sets on the market, which should at least be a more manageable number than the range of devices themselves. Determination of protection ratios by practical experiment is preferred to a theoretical derivation as in [2], especially in view of the 'new' nature of the interfering signal.

Knowledge of the protection ratio would in turn specify the maximum tolerable PLT-interference field strength at the location of the receiving antenna (either rooftop, for an external antenna, or wherever a portable receiver, with an attached antenna, is situated) for a given wanted broadcast-signal field strength. This would clearly put a sanity check on proposed radiation limits: suppose a limit is set for emissions at say 10 m from the PLT device[9]. If, for example, this emissions field strength exceeded the level acceptable at the receiver antenna it would imply that protection was only given for reception at some distance *greater* than 10 m, which would clearly be unsatisfactory as it would protect neither indoor reception in the same house nor most probably reception in neighbouring houses.

However, it isn't just a question of protection ratio, since interference may well also be caused by direct ingress into the mains connection of mains-powered receivers, which is why it would be good to test reception with both battery and mains operation, since both are widely used by listeners.

Models to describe real mains installations (in the different styles found in different countries) and how they radiate in response to PLT injection are inadequate. Furthermore there is a risk that the test configurations to be prescribed in regulations will bear little relation to real-life situations.

It would also be good to try to confirm the 'notch-filling' caused by intermodulation reported in [4]. In particular it would be helpful to do this at VHF, in order to see whether the use of dynamic notching for the FM broadcast band, as recommended in [2], is actually a practical and sufficient mitigation measure. Unfortunately no existing VHF PLT devices that implement any form of notching in this range are known to the author at the time of writing, so something special would have to be generated for the purpose of the experiment.

3. PROPOSED EXPERIMENTS TO ESTABLISH INTERFERENCE RISK

3.1 Discussion & Preparation

As outlined in the discussion of §2.4, there is clearly some kind of *potential* threat to VHF broadcast reception, FM and DAB, posed by the latest PLT devices that use VHF spectrum, like the one measured in the experiments of Ref. [1].

What we need to establish urgently is whether there will be a widespread issue in practice (once the PLT devices are in common use).

We therefore should repeat the experiments in controlled conditions where we know the broadcast field strength. It would be good to start with a situation in which the field strength is typical — if there were a problem there, we by definition have a serious issue. If this typical situation does not raise issues, then we should repeat the experiment at another location which is within, but near the edge of, a service area. If this too does not have issues, we don't have a significant problem. But assuming it does have issues, then further locations between these extremes would be needed if we wished to quantify by

[9] The choice of 10 m in this example is not a random one; many existing radiated-emissions standards are specified at this distance, or even more. It may be extremely difficult to overturn such precedents even though the reception location we seek to protect is much closer to the mains wiring carrying the PLT signal.

direct experiment what proportion of homes we would predict to have issues. However, this last step may perhaps be avoidable if we can obtain sufficient scientific understanding of the problem to use prediction.

It would be good to start in a laboratory, if only to be well rehearsed in the measurement technique before trying to use people's homes. However, it should be noted that experiments in the laboratory have their own issues, and should indeed be treated more as rehearsal than representative. Laboratories differ from homes in several respects.

Factors possibly reducing PLT impact:

- mains wiring is probably less haphazard than found in typical homes
- mains wiring may be run in ducts or cable trays offering a degree of screening
- field strength of wanted broadcast signals may be *increased* from that expected within homes at locations having the same measured field strength outdoors because of extra height above ground, e.g. if a high floor in a laboratory building were used

Factors possibly increasing PLT impact:

- field strength of wanted broadcast signals may be *reduced* from that expected within homes at locations having the same measured field strength outdoors because of increased screening implicit in the building construction: coated windows, structural metal etc

Factors that merely confuse:

- the technical activities within the laboratory building may increase the general 'noise' level on the mains wiring, thereby making the PLT network have to 'work harder' than typical for the distance in question, or even fail altogether
- the technical activities within the laboratory building may increase the general 'noise' level at RF, thus causing broadcast reception to be unrepresentatively poor, even before any PLT network is established
- the same issue may make any field-strength measurements within the laboratory difficult

Clearly it would be advisable to measure the wanted-signal field strength both *outside*, in the way traditionally done in spectrum planning (e.g. at 10 m for FM), as well as *inside*, so that any unusual penetration-loss effects can be identified.

I take it for granted that the broadcaster will be able to furnish coverage predictions, and to make outdoor field-strength measurements at experimental sites using a measurement van.

A pair of PLT devices — preferably of the same type as used in the experiments of Ref. [1], for ease of comparison with the previous work — should be procured, together with two laptops set up to transfer files between them via the PLT network, with some large files to keep the process busy.

A current clamp of known calibration in the VHF range will be needed, together with means to use it to measure the RF current injected into the mains by a PLT device, without exposing the experimenter to undue hazard. For example, in the past BBC R&D constructed a specific mains breakout box to suit UK practice for this purpose. The L, N & E conductors were brought out to separate double-insulated conductors which were of sufficient length and flexibility that as well as enabling the measurement of RF currents on the conductors individually, they could also be grouped together and passed through the clamp in combinations so as to measure common-mode or differential-mode currents as well. Note however that I propose that an arrangement like this should be used more to check what spectrum is in use than to make any measurements needing serious calibration.

Suitable broadcast receivers should be chosen to be representative of those that might be used by listeners. Ideally both battery and mains powering should be possible. Something reasonably middle-of-the-range in price and performance is perhaps preferred, but it might be worth having something 'cheap-and-nasty' as well, just to make occasional checks whether some listeners unlucky in their purchases are particularly disadvantaged.

3.2 Experiment I — In the Laboratory

All the following steps should be documented with sketches of layout, distances, circuits used and photographs.

- Use a Screened Room to determine the noise floor of the combination of measurement antenna and measuring receiver and/or spectrum analyser that will be used. This value should be clearly quoted in any documentation of results to avoid any false conclusions being drawn about the minimum level of noise 'background' emissions observed.
- Establish a PLT network over as long a run as is convenient within the room available. It might be best to use an extension lead or leads as necessary to provide a mains communication path that is not part of the structured wiring, thus avoiding any undue shielding that may be present in the laboratory, but not in typical homes. Practice transferring files while noting the data rate achieved. Use the breakout box, current clamp and a spectrum analyser to confirm that the VHF spectrum is used — if not, shorten the run until it is.

  If it is found that there is a high level of electrical noise on the laboratory mains supply, such that PLT networking at VHF is either impossible, unreliable or requires an absurdly short distance between PLT modems, give consideration to the use of a mains filter between the experiment and the laboratory mains. However, it should be noted that it may not then be possible to operate from a mains circuit protected by an RCD. This is because the design of a filter intended to provide substantial filtering more or less implies that the leakage current drawn by the capacitors in the filter is then sufficient to trip standard RCDs. It may in that case be necessary to use a circuit (if available) which does not have an RCD **and due care must therefore be taken to ensure safe working!** The performance of the filter at VHF frequencies should be checked; some such items may perhaps only suit HF measurements.

If the PLT network cannot be established in a sensible configuration, abandon Experiment I and go to one of the home locations of Experiment II!

- With the PLT network switched off again, attempt FM and DAB reception with suitable portable receivers at a number of locations in the room.

  If this is not possible because of inadequate field strength or excessive non-PLT interference, abandon Experiment I and go to one of the home locations of Experiment II!

- Establish the wanted-signal field strength outdoors in the customary manner, e.g. using a measurement van. Measure a range of FM transmissions (the spread of signal strengths from various services will in effect model a range of different reception locations for a single service). Repeat for the available DAB Multiplexes. Back these up with field-strength predictions from the broadcaster(s).

- Attempt broadcast reception at a range of locations in the room. At each location, note the subjective[10] quality of reception for a range[11] of FM and DAB services, in every case with the PLT network by turns busy, idle or switched off. If possible also measure the wanted-signal field strength (with PLT off) and the PLT interference field strength[12] at each location using the calibrated antenna in as near as possible the same location as had been occupied by the broadcast receiver. If possible make assessments of broadcast reception when the broadcast receiver is by turns powered by battery and mains.

  It will be clear that this could be a long-drawn-out process, so practice in the laboratory to make it as slick as possible will be a great help before imposing on people's homes.

- Try to make sense of the results obtained from the above, and identify and resolve any difficulties with the measurement techniques before progressing to field measurements. If and only if this can be achieved, proceed to Experiment II.

3.3 Experiment II — In the Field, at a 'Typical' Location

With the assistance of the broadcaster's spectrum planning department, a location which offers a 'typical' field strength for the broadcaster's main radio services should be found at which lives a suitable volunteer who can be persuaded to offer their home, for what is likely to be a day, in order to perform measurements.

What is meant by 'typical' field strength is open to discussion. If the information is available, I suggest either "the field strength which is reached or exceeded at 50% of homes" or the slightly different "the field strength which is reached or exceeded at the homes of 50% of the population". I say "if available" because it may take some deducing: field-strength prediction software can predict field strength in particular locations, having regard to details of the network together with the terrain and clutter surrounding the location. Thus field strength can be related to % locations. However, this has to be combined with knowledge of the population distribution in order to get one or the other of the measures suggested.

The reason for suggesting 50%, and the particular definitions, is simple. If we perform an experiment, and it shows interference occurring, then it would imply that at least 50% of homes or of potential listeners (according to which definition we use) would suffer interference if they had the PLT devices in their homes. This would be a clear indication of major difficulty and the need for action. On the other hand if the experiment does not reveal significant interference, then the potential problem is less serious — more than half of homes or listeners would be untroubled. In this latter case, further experiments would then be needed[13] to scope what % of listeners could be expected to suffer problems.

It would be best if not only were the broadcast field strength typical, but also the home is in some sense typical of listeners' dwellings as well — neither absurdly large nor small, nor of a very unusual form of construction or layout. It will also be necessary to pick sites with access for a measurement van (for the measurement of outdoor field strengths) and also with reasonable access for the indoor experimenters, having regard to the weight and unwieldiness of the test equipment.

As far as possible, the same experiments should be performed here as specified above for the laboratory, with a few significant exceptions or variations:

- The PLT network should be established in a way that is as representative as possible of the way in which such networks are likely to be needed and used. The two ends should be in rooms that are reasonably well separated (within the constraint that a check on the spectrum confirms that VHF is still in use by the PLT network). Remember that PLT devices are at least in part sold as surmounting problems that WiFi is said to suffer from[14], e.g. linking rooms that WiFi won't reach[15]. Use mains extension leads, if at all, only in a way that the domestic

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[10] For DAB it may be possible to add objectivity as well; many receivers can give a 'signal quality indication'.

[11] On the presumption that there will be a range of radio services available, there should be a range of field strengths that with luck will explore conditions from well-served, to typical to edge of coverage scenarios — although there is a serious risk that edge-of-coverage reception may not work inside a laboratory, for the reasons already outlined.

[12] Measurement of the PLT field strength will need to be performed at a clear frequency adjacent to that of the wanted broadcast signal; an on-channel measurement would be confused by the presence of the wanted signal.

[13] Or if, we are lucky, the range of services receivable at this first location may have different field strengths that are able to model this for us.

[14] I can't speak from personal experience of these 'problems' as WiFi B/G (i.e. not even 'the latest and best') serves to interconnect all rooms in my home, as well as the summerhouse at the foot of a long garden.

[15] The 10 m range for high-data-rate VHF PLT networking reported in the IRT experiment is interesting in this context.

user would have found necessary; if the PLT devices can reasonably be plugged directly into a wall socket, do so.

- Measuring antennas on tripods are very unwieldy things to have in someone's home[16]. **Take utmost care** not to damage walls, furniture or bric-a-brac! You will not be able to get the measuring antenna to all the broadcast-receiver locations. Perhaps it will suffice to measure field strengths at some mid-room location where it is safe to deploy the tripod, together with making a broadcast-reception assessment at the same place — as well as any assessments in which the receiver in placed in more domestically-customary positions on shelves or other furniture.

- If an external FM and/or DAB antenna is installed at the premises, then check whether reception using it is affected by PLT operation, for the same selection of broadcasts. If possible, connect it to the spectrum analyser and note the spectrum with and without PLT in operation. Note whether the house is supplied with electricity by overhead or underground cabling.

- Try to establish the nature of the electrical installation, noting anything unusual. If time permits, investigate whether PLT interference levels vary with the sort of changes to the mains configuration that arise in everyday usage, e.g. switching lights on and off (especially 2-way switched circuits); plugging in an extension lead, switching it on and off at the wall socket[17] outlet; switching on and off at the wall socket any domestic items that are already plugged in.

3.4 Experiments III-on — In the Field, at Other Locations

These will be less urgently needed if the location of Experiment II is well-chosen: it should give an indication of the interference potential to broadcast signals of a typical planned field strength, and thus tell us directly whether widespread problems are likely. With luck, as well as being typical in relation to the target radio network, there may also have been some other radio services whose field strength is higher or lower than typical. If that is the case, then some estimation of the proportion of listeners potentially affected by PLT interference may be possible without further experiment.

If not, then it will be necessary to try further locations, choosing them to ensure that a range of expected wanted-signal field strengths is explored.

In any case, if resources permit, it would be good to try multiple dwellings. Different housing construction and different wiring layout could affect the results. If a significant issue with PLT is located it would be good to have a larger body of evidence that this is so, in order to increase the strength of the broadcaster's argument.

4. FURTHER EXPERIMENTAL WORK

The experiments just outlined in §3 should suffice to determine whether the emissions at VHF of the latest PLT devices present a serious risk of interfering with reception of broadcasting by FM and/or DAB.

If they show there is an issue which needs to be dealt with then it will be necessary to make proposals how such emissions can be *regulated*.

Regulations have to be expressed in terms of repeatable experiments; such experiments of necessity represent a more or less artificial situation. The choice of this artificial situation will determine whether the regulation (if adhered to) ensures freedom from interference for the majority of listeners. To influence this choice, further work will be needed in order to relate the real-world experience that has been gained to the type of measurement that it is feasible to make in the controlled, artificial conditions of a conformance test. It will be important to ensure that the conformance test does indeed test something relevant.

No attempt will be made to specify further experimental work here — we need the results of the first round of tests first. Note however that if smart notching is intended to form part of the regulatory solution it will be necessary to study further the effects of intermodulation.

5. CONCLUSIONS

Recently introduced variants of home-networking PLT products have been found to make use of VHF spectrum (in addition to HF), and therefore bring the risk that they might cause interference to reception of FM and DAB radio broadcasting. This paper has discussed what experiments might be performed by broadcasters in order to determine the seriousness or otherwise of this potential interference threat. If the experiments reveal serious issues, then broadcasters will need to participate actively in the process of specifying suitable regulatory measures.

It is hoped that some experimental results may be available in time for the spoken presentation.

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7. GLOSSARY

CISPR *Comité International Spécial des Perturbations Radioélectriques*, or Special international committee on radio interference
DAB Digital Audio Broadcasting
DSL Digital Subscriber Line (the family of standards used to provide internet connections to homes using their telephone-wire connection)

[16] This might be a very good reason to avoid dwellings which have unusually small rooms, as well as grand ones full of breakable valuables!

[17] Switched wall sockets in the UK commonly have single-pole switching in the Live connection, thus leaving a stub on the Neutral when the socket is switched off. Lighting circuits can cause stubs on the Live.

FM Frequency Modulation (as used for domestic sound broadcasting worldwide, in which case further subcarrier(s) provide stereo etc)
HF High Frequency (refers to the spectrum range also described as Short Wave, officially 3 to 30 MHz but often interpreted as 1.6 to 30 MHz)
ITU International Telecommunication Union
PLT Power Line Telecommunications
RCD Residual-Current Device
VHF Very High Frequency (refers to the spectrum range 30 to 300 MHz)

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"Jonathan Stott joined BBC R&D after graduation from Cambridge University in 1972. He worked mostly on the application of digital techniques to broadcasting, and in particular in latter years on the development of three major digital broadcasting standards: DVB-T (digital terrestrial TV), Digital Radio Mondiale (DRM, a system for radio broadcasting at frequencies below 30MHz) and finally DVB-T2 (second-generation digital terrestrial TV, with more features and higher efficiency). He is the author of several patents relevant to these standards, mostly on receiver techniques.

The initial threat from PLT to the reception of HF broadcasting (and thus also the nascent DRM) over a decade ago drew him into Spectrum Protection work in parallel, in relation to which he has attended more committees than he cares to remember. Jonathan retired from the BBC at the end of 2009, but continues to perform some consultancy activities, including the work for BBC R&D reported in this paper."

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