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Research & Development
BRITISH BROADCASTING CORPORATION

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DO EMC LIMITS PROTECT BROADCASTING AS INTENDED?

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Abstract: Broadcasting below 30 MHz is under threat from emissions from new broadband telecommunications systems exploiting existing mains and telephone wiring. Protection requirements for radio reception are derived and compared with the protection afforded by various emissions-limit proposals. A suitable limit is described; most other proposals are shown not to satisfy the intention of the EMC Directive to allow radio to "operate as intended".

1. Introduction

There is currently much interest in establishing broadband communications by all means possible, especially those which are easily and cheaply installed. Systems using telephone lines for access to homes and businesses (*x*DSL) are one example, while others, which use mains wiring (Power Line Telecommunications or Communications, PLT/PLC), are the subject of this Workshop. PLC can be used for both access and home-networking.

Re-using existing infrastructure (the mains wiring) to provide a new PLC broadband access service is thus politically and financially very attractive. It does not require new cables to be laid, potentially speeding rollout, and enables electricity-supply companies to develop a new revenue stream using infrastructure that is already paid for by the power-supply business. Within homes, in-home networking using PLC brings plug-and-play simplicity for the consumer.

But there is a big snag: the existing mains wiring was never designed to support high-speed communications. On the one hand this brings design challenges to PLC-system designers, but on the other it means that the PLC signals transmitted over the mains wiring are not wholly contained within the wiring. A significant proportion of the signal energy is radiated, and thus has the potential to interfere with radio services. At present the greatest threat appears to be to services operating below 30 MHz, on which this paper will mainly concentrate, in particular on the reception of broadcasting.

In principle, EMC Regulations are supposed to control emissions so that radio reception is not unduly impaired by interference. Various proposals to govern emissions from PLC systems are under consideration at the time of writing and some will be discussed in this paper.

2. The imperatives to protect radio

The use of radio is governed by the ITU-R Radio Regulations, which have the status of a treaty between states. Operators of radio services have an obligation not to cause interference to each other. For this reason, there is much activity to determine appropriate protection ratios (see Section 3.4 below) and planning procedures. Indeed many frequency bands are subject to detailed planning at World or Regional Conferences. Any changes to established services (e.g. a change in the frequency allocation table) are phased in over a substantial period in recognition of the financial investment in radio systems.

The Radio Regulations go further, in recognising that radio systems are not the only sources of interference. Article S15.12 requires Administrations to 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, … does not cause harmful interference to a radiocommunication service".

Within the EU, Article 4 of the EMC Directive 89/336/EEC sets out that "the apparatus … shall be so constructed that … the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended…". Furthermore, Annex III sets out an illustrative list of apparatus whose operation should not be hindered, with "domestic radio and TV receivers" at the head of the list.

So, clearly, radio services, and broadcasting in particular, are intended to be protected against interference from non-radio apparatus and installations — by force of law.

3. Broadcasting below 30 MHz

3.1 What is it used for?

Broadcasting in this frequency range has been going on for some 80 years. Historically, it has always used simple double-sideband Amplitude Modulation (AM) and the corresponding frequency bands are sometimes described as the 'AM bands'. The bands can be divided into the long- and medium-wave bands (LW & MW) below 1.6 MHz and the short wave bands (SW) above 1.6 MHz.

It is often thought that there is a simple split in the usage: LW & MW normally used for broadcasting *within* countries, and SW for broadcasting *between* countries, i.e. international broadcasting. This is an over-simplification. What all these bands have in common is that large-area coverage can be achieved without needing dense networks of transmitters — *a property unique to these frequency bands*. At the lower frequencies ground-wave propagation is the key mechanism, making both LW and MW very useful for coverage from local to national. At the higher frequencies, sky wave propagation takes place via refraction in the ionosphere. This makes SW, and to a lesser extent also MW, useful for international broadcasting. However, it should not be forgotten that larger countries, and countries of any size in the Tropics, make extensive use of SW for local and national broadcasting using Near Vertical Incidence Skywave propagation (NVIS) from a single transmitter site.

MW/SW are thus crucial for international broadcasting. They enable broadcast signals to reach distant coverage

areas independent of any gatekeeper or of infrastructure in the target country, unlike satellite broadcasting or indeed the internet.

Because of the favourable propagation characteristics of the bands below 30 MHz, many broadcasters and manufacturers have worked together in the Digital Radio Mondiale (DRM) consortium [1] to develop a digital system [2] for broadcasting at these frequencies. It is an ETSI Standard and has been Recommended by the ITU.

The 'AM bands' are heavily used. Millions of people listen to LW/MW broadcasts in the UK alone, while there is considerable pressure within ITU-R to increase the spectrum allocated to SW broadcasting.

3.2 Frequencies

The frequencies allocated to broadcasting are agreed internationally by the Radiocommunications Sector of the International Telecommunications Union (ITU-R). Precise details vary in different parts of the world. In Europe the LW ranges from 148.5 to 283.5 kHz, while the MW ranges from 526.5 to 1606.5 kHz, with all carrier frequencies lying on a 9 kHz grid. (The Americas do not have LW, but have an extended MW with a 10 kHz grid.)

Similarly there are variations in SW, but Table 1 indicates the bands in which broadcasting is authorised in some parts of the world at least, albeit with temporary restrictions applicable to some more recently allocated bands. Some further operation outside internationally agreed bands is authorised by the Administrations of some countries. Noting that listeners to SW bands are in many cases listening to international broadcasts directed to them from other countries, it is the frequencies authorised in the *originating* countries that are important to the listeners.

Table 1: SW broadcasting bands

Frequency range, kHz	
2300-2498	Tropical band *
3200-3400	Tropical band *
3900-4000	
4750-4995	Tropical band *
5005-5060	Tropical band *
5900-6200	
7100-7350	
9400-9900	
11600-12100	
13570-13800	
15100-15800	
17480-17900	
18900-19020	
21450-21850	
25670-26100	

* Tropical bands are in principle reserved for use in countries in a defined Tropical Zone.

3.3 Typical reception scenario

With modern radios being available in a range of styles and sizes, reception takes place anywhere it is physically possible, including in cars or while jogging! However, a very great deal of AM reception takes place within the home, most commonly using a portable receiver which can be carried from place to place to accompany the listener as they perform various domestic tasks — note that radio is more suited to this than television. Or the listener will sit down purely to listen to the radio. The key points to note are:

- reception can be anywhere in the house
- reception uses the built-in antenna of the portable radio

This means that the built-in receiving antenna is never very far away from mains or phone wiring, at least in the rooms of modest size that are found in most dwellings.

Built-in antennas of portable radios are usually ferrite rods for LW/MW and short telescopic whips for SW. Ferrite rods respond to the magnetic (H) field of both signals and interference, while whip antennas respond to the electric (E) field.

A very few listeners use more sophisticated installations with antennas situated outdoors, e.g. in a garden. This represents a negligible proportion of the audience: few are able to erect external antennas, irrespective of price, and cheap receivers tend not to perform well when an external antenna is connected.

3.4 Protection requirements

A very great deal of effort is devoted in the ITU-R to ensuring that radio signals do not interfere with each other. In order to promote efficient use of the spectrum, many signals (of the same or different services) will share (i.e. reuse) the same frequency many times over throughout the world. This works because it is well thought-out and controlled. A *protection ratio* (PR) is determined for each pair of signal types that may interfere; it is the ratio between the strengths of the wanted signal and the interfering signal that is necessary to ensure that the impairment of the wanted signal is limited to an agreed level. PR values for wanted/interfering-signal combinations that are of interest (or have been in the past) are documented in ITU-R Recommendations or the Proceedings of Planning Conferences. Once the PR is known, steps are taken in planning so that the ratio wanted/interfering-signal exceeds the PR wherever reception of the 'wanted' signal is intended and the strength of the wanted signal exceeds a planned minimum field strength.

Suggested minimum field strengths for AM broadcasting are given in ITU-R Rec. BS 703. They are: 66 dBμV/m (LW), 60 dBμV/m (MW) and 40 dBμV/m (SW). Of course, reception is often possible at much lower field strengths in places where interference is absent.

The ITU-R does not as yet tabulate any PRs for the situation where the interfering signal comes from *x*DSL/PLC systems. This is for several reasons: the threat is a new one; *x*DSL/PLC systems are not radio services; and for PLC in particular there appear to be a wide variety of proprietary systems whose signal characteristics are unpublished.

However, we can make some estimates. ADSL, VDSL and perhaps some PLC systems produce interference that is essentially noise-like. This means that the necessary *radio*-frequency signal-to-noise ratio (RF SNR) for adequate reception is also the PR for such noise-like interferers. A value of 34 dB can be deduced for SW from the reasoning in Annex 4 of ITU-R Rec. BS 560-4. A slightly greater value, 40 dB, then appears reasonable for LW and MW where entertainment-quality reception is expected. Note that these are not unreasonable 'hi-fi' standards — the noise is clearly audible at these SNRs. Note also that these SNRs are expressed as (mean carrier power)/(mean noise power).

4. Why the interference threat is different

Emissions limits have been drawn up in the past for many types of domestic and non-domestic appliances. In many ways the nature of the threat to radio posed by PLC systems is rather different in character.

It will be clear that items like hairdryers, electric drills, food mixers etc., when used in the domestic environment, are used only intermittently. They are not in widespread simultaneous use. Furthermore, their emissions would be

very much incidental to their operation — motor commutators can be suppressed without preventing the motor from working. Other items of a more electronic nature may emit only in localised parts of the frequency spectrum, e.g. local oscillators, or clock-frequency harmonics. Once again the emissions are incidental — although the internal oscillators are absolutely necessary, there is no need for these signals to leave the equipment.

It is therefore reasonable to include a certain element of statistics in the setting of limits for such devices. The likelihood that any given receiver will be affected is limited by the need for near-coincidence in place, time and frequency before interference can arise. Furthermore, as the emissions are incidental in nature their levels are likely to be subject to a spread in production. If a manufacturer takes steps to ensure that the majority of items produced meet an emissions limit, then the typical emissions may well lie well below the limit. Taking all these factors together, existing emissions limits for such items do not therefore provide an absolute guarantee that interference will not occur to a receiver tuned to a given frequency, at a given place, at a given time — but the likelihood of interference may nevertheless be reduced to reasonable levels.

*x*DSL/PLC systems are very different. They intentionally transmit signals along wires as a fundamental necessity of their operation. The signals they transmit are broadband in nature (thus affecting a large part of the spectrum simultaneously) and may well also be continually present (note the marketing of many internet-access systems as "always-on"). The wires along which they are transmitted run throughout dwellings so that indoor reception is inescapably in close proximity to them. Furthermore, being part of the infrastructure, it is not feasible to upgrade them to reduce emissions in the way that, say, a computer-printer cable could be replaced by one of better quality, having e.g. a better screen.

A further difference is the degree of user control. If, as a listener, you suffer interference while using an electric drill, you know that the interference will stop when you finish using it. Indeed, in this example the interference may not matter much, as the *acoustic* noise probably is even more important! If you are unlucky enough to suffer interference from your neighbour's electric drill, then you have a reasonable expectation that it will not last long. If you have an ADSL service, then signals will be present on your telephone line if the ADSL modem is switched on. If you switch off the modem, the signals (and any resulting interference) disappear. You might have preferred to be able to listen to the radio *and* browse the internet simultaneously, but if interference occurs, you may have to make a choice — at least you can do so. A PLC access system sends signals along all the mains wiring served by the same substation transformer. Thus if any households in your immediate area take up a PLC service, some level of PLC signals will be present in your home, whether you subscribe to the service or not. If these signals are sufficient in level to interfere with radio reception there is very little you can do about it.

5. Emissions limits

Harmonised standards for the emissions from telecommunications networks are now being considered in Europe, as a result of European Commission Mandate M 313. The work has been entrusted to a CENELEC/ETSI Joint Working Group (JWG). Prior to this various national limits had been proposed. One of these has become something of a benchmark in discussions: a German limit commonly known as NB 30. Radio users favour limits which are *tighter* by more than 20 dB, while PLC proponents favour limits which are *slacker* by more than 20 dB, and at the time of writing this whole gamut of limits is under consideration by the JWG.

5.1 The German NB 30 limit

This limit is supposed to be applied to measurements made at 3 m from a cable carrying the telecommunications signal. The H field is measured using a loop with a measuring receiver which is set to use a peak detector. For the frequency range of interest here, the measurement bandwidth is 9 kHz. The limit is expressed in terms of the equivalent E field as:

$$E \le 40 - 20\ \mathrm{Log}_{10}[f_{\mathrm{MHz}}]\ \mathrm{dB\mu V/m},\ 0.15 < f_{\mathrm{MHz}} < 1,$$

$$E \le 40 - 8.8\ \mathrm{Log}_{10}[f_{\mathrm{MHz}}]\ \mathrm{dB\mu V/m},\ 1 < f_{\mathrm{MHz}} < 30 \qquad (1).$$

5.2 EBU/BBC proposal

While it would, in principle, be perfectly possible to derive individual limits to protect all the different users of radio services, each derived from their individual reception scenarios and protection requirements, this would not be very helpful in making progress towards a harmonised standard.

What is, however, fairly clear is that all radio services have to cope with the present-day noise floor. The various radio services and systems have different SNR requirements, but in practice these are achieved by the transmit powers in use evolving to ensure the various SNR requirements are satisfied, with some modest margin. To use vastly more transmit power than necessary is costly and is therefore mostly avoided. It follows that all services are similarly affected if the noise floor is increased by a new source of interference, such as PLC.

The author therefore picked up on the idea of deriving a limit from the concept of limiting the increase in the noise floor. Both EBU (European Broadcasting Union) and NATO representatives had suggested the idea of a small increase in the noise floor, say 0.5 dB. Now it would be impracticable to relate this to the noise floor at every particular location, so the author therefore proposed deriving a limit from a *reference scenario*, with the intention that the limit would be appropriate for the majority of radio services, not just broadcasting.

The reference scenario was taken as reception using an outdoor dipole antenna, 10 m from the cable under consideration. It was further assumed that the noise floor was intermediate between the 'Rural' and 'Quiet Rural' cases documented in ITU-R Rec. P 370. This was considered to be representative of the situation available to radio amateurs and some professional users — measurements by the Radio Society of Great Britain, the BBC and others confirm that the proposed existing-noise model is, despite the names, representative of suburban gardens in the UK. The emissions level which would increase this reference noise level by 0.5 dB was then calculated.

The resulting level was then converted to the corresponding level which would be found closer to the cable, at a distance of 1 m, under the assumption that the field varied inversely with distance, an assumption supported by measurements made by the UK Radiocommunications Agency. The distance of 1 m was chosen for several reasons:

- it makes the interference field which is to be measured stronger, so the measurement is easier to make without equipment-sensitivity problems
- if measurements are to be made indoors, a greater distance is not practicable in most dwellings
- it matched the distance used in the UK MPT 1570 standard
- it is representative of typical indoor broadcast reception

It must be stressed that the increase in the noise floor, at a distance of 1 m, is in general *very much greater than 0.5 dB* — in other words, a significant compromise is made for indoor broadcast reception.

The detailed derivation is set out in [3]; the proposed limit, measured with a loop at 1 m distance, using 9 kHz bandwidth and a peak detector is an equivalent E field strength

given by:

$E \leq 21.8 - 8.15 \, \mathrm{Log}_{10}[f_{\mathrm{MHz}}]$ dBμV/m, $0.15 < f_{\mathrm{MHz}} < 30$ (2).

This limit was proposed to CEPT SE35 (another committee considering the subject) and received support from the EBU (representing broadcasters), NATO, civil aviation and radio amateurs. It thus achieved its aim of finding a common position for radio services.

6. Protection afforded by various limit proposals

Now we consider the protection given by various proposals to domestic reception of broadcasting. For simplicity we consider only the SW band and two limits: NB 30 and the EBU/BBC proposal. Other limits currently under discussion can be simply related to NB30.

We consider that the wanted broadcast signal is at the minimum protected field strength identified in Section 3.4, namely 40 dBμV/m, and that reception takes place at a distance of 1 m from the cable. Noting the size of rooms on typical dwellings, the layout of the wiring and the use of portable receivers around the home, not just in the main room, it is hard to see that any larger distance is practicable. The radio has to be placed somewhere, and shelves (and often other items of furniture) are adjacent to walls, where the cables usually run. And if the radio is mains-powered the distance shrinks to zero!

The procedure followed is as in [4]. We calculate the emissions at 1 m, when the NB30 limit is supposed to be respected at the 3 m, assuming the field varies inversely with distance. This means we can directly compare the two proposals. Both proposals specify a peak detector. If we assume the interference is noise-like it is reasonable to assume the mean 'noise' power is 10 dB less than the peak-detected value, so we subtract 10 dB from the interference levels. Finally, we then calculate the RF ratio of wanted signal to interference that each proposal permits, for comparison with our target value of 34 dB. See Fig. 1.

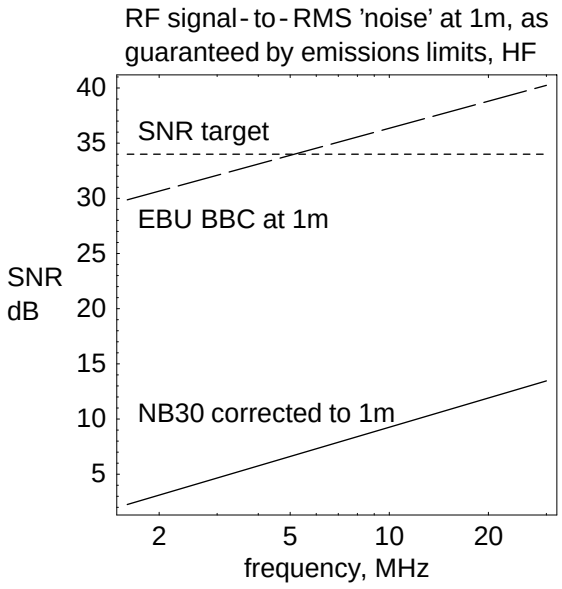


Fig. 1: Ratio of signal to noise-like interference guaranteed by NB30 & EBU/BBC proposals for reception at 1 m

We can see that, as previously noted, the EBU/BBC proposal is already a compromise for indoor reception. At the low-frequency end of SW, it does not guarantee that the modest protection target is fully achieved. However, the NB 30 limit is grossly inadequate: the very low signal-to-noise-like-interference ratio it assures is insufficient for even intelligibility of the radio programme. Ref. [4] shows that LW/MW are also badly affected. Levels of interference substantially greater than NB 30, as demanded by many PLC proponents, will lead to *negative* SNRs — the presence of the radio signal will be completely undetectable beneath the interference.

It is important to note that the situation will be no rosier for future digital broadcasting using the DRM standard.

7. The purpose of EMC regulation

A prime purpose of harmonised EMC standards is to enable radio receivers etc. to "operate as intended" (as in Article 4 of the EMC Directive). One has to question whether a standard that did not even ensure a positive SNR under normal reception conditions for most of the time could be claimed to serve any purpose at all.

In seeking to justify even slacker limits than NB 30, it has been argued that limits for telecommunications networks must be consistent with (i.e. no more stringent than) other product standards — despite the fact that the scenario of operation is very difficult. As explained in Section 4, occasional interference from appliances, while regrettable, may be tolerable if the probability of it occurring is relatively low. Losing radio reception throughout your home, for 100% of the time is clearly not! Noting that sending signals along the mains wiring is an intentional and necessary part of PLC, it seems likely that emissions will frequently reach any limit that is agreed. There is every incentive for this to happen — the greater the strength of the signal transmitted, the greater the capacity (in Mbit/s) that can be achieved, according to Shannon's oft-quoted theorem.

If any other existing product standards can be shown not to achieve reasonable protection (a low probability of interference) then perhaps it is time to review them too.

If limits do not protect broadcasting below 30 MHz, then a precedent is set for all radio services to be unprotected.

8. Conclusions

The bands below 30 MHz are a valuable resource for broadcasting (and other radio applications) as they have beneficial long-distance propagation characteristics which are equally useful to national and international broadcasters.

Broadband telecommunications networks using the mains or phone wiring — wiring never designed to carry high-speed communications — has the potential to cause emissions which will interfere with reception of radio services, including broadcasting. This is admitted, in effect, by the system proponents asking for emission limits to be set at very high levels.

A limit has been developed, on a technical basis, with the intention of providing reasonable protection to most types of radio services. This BBC proposal was endorsed by the EBU and supported by other radio users including NATO and civil aviation. Even this limit represents a compromise as far as indoor reception of broadcasting is concerned.

The NB30 limit is inadequate to protect indoor reception of broadcasting. It, and the even slacker limits demanded by PLC proponents, cannot be claimed to fulfil the intentions of Article 4 of the EMC Directive.

9. References

[1] http://www.drm.org

[2] J.H. Stott, "DRM – Key Technical Features", *EBU Tech. Rev.*, Mar. 2001. http://www.ebu.ch/trev_286-stott.pdf

[3] J.H. Stott, "Emission limits", BBC Research and Development Dept. White Paper WHP013, Nov. 2001. *

[4] J.H. Stott, "AM broadcasting and emissions from *x*DSL/PLT", BBC Research and Development Dept. White Paper WHP012, Nov. 2001. *

* These papers are available from the BBC R&D web site, http://www.bbc.co.uk/rd/pubs/whp/index.html See also White Paper WHP 004.

Do EMC limits protect broadcasting as intended?

Jonathan Stott
19 February 2003
Power Line Communications Workshop
EMC Zurich '03

Relationship of broadcasting and broadband

- BBC is a major broadcaster – our core business
- BBC also operates largest content website in Europe
  - so improvements in broadband access very welcome
  - streaming is a welcome supplementary delivery method
- But streaming does not replace 'over-air' RF delivery
  - streaming is very expensive for the broadcaster
  - impractical to serve >150 million BBC World Service audience
  - streaming is very expensive for the listener
    - beyond the means of majority of BBC World Service target audience
  - streaming does not reach 'closed' societies
- So while the BBC welcomes wider access to broadband, it has to be sure that it can continue to reach the majority audience by 'over-air' RF means
  - investing in DRM to bring MF/HF into digital age

Unique resource of spectrum below 30MHz

- The radio spectrum below 30 MHz is uniquely valuable because long-distance propagation is possible
  - special mention in Art. S4.11 of International Radio Regulations
    - "Member States recognize … bands between 5 MHz and 30 MHz are particularly useful for long-distance communications; they agree to make every possible effort to reserve these bands for such communications…"
  - any many radio users rely on exploiting it

- MF/HF extremely valuable for broadcasting of all types
  - International (e.g. BBC World Service)
    - reaches other countries from 'outside'
  - National – only affordable method for some developing countries

Digital Radio Mondiale — DRM

- DRM consortium formed 1996-98, with members from around the world:
  - broadcasters
  - transmitter and receiver manufacturers
  - research institutes
- Strong and active European representation
- Has developed digital system for broadcasting below 30 MHz
  - Standardised by both ETSI and IEC
  - Recommended by ITU-R
- Brings new features and increased quality to 'AM'-band broadcasting

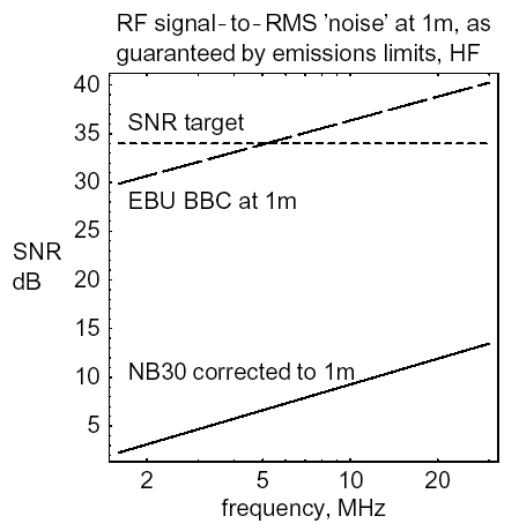
Radio services are supposed to be protected

- Many radio services share the spectrum
  - it works because there are rules – the ITU-R Radio Regulations
  - rules/planning so that radio users do not interfere with each other
- Radio users also should be protected from other interferers
  - RR Art S 15.12 requires Administrations "to 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, … does not cause harmful interference to a radiocommunications service"
  - and this principle also underlies the "emissions" part of the EMC Directive, Art. 4: "apparatus … shall be so constructed that … the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment … to operate as intended"
- How real is the protection?

Emission limits don't seem to provide solution

- PLC signals sent along mains cables 'leak' – emissions
- one way to protect radio services: setting a limit to emissions
- difficulty is agreeing on level
  - PLC operators ask for as much as 60 dB greater than radio users!
  - Radio users need low emission levels to continue to operate services
  - PLC operators need high levels in order to offer any worthwhile throughput
- NB30 is a benchmark compromise in the middle (dB scale)
  - unfortunately satisfies neither radio users nor PLC operators
- BBC/EBU proposal tries to protect all radio users
  - see printed paper for details

Protection of broadcasting by two proposals



- Plot shows SNR for a receiver at 1 m, assuming that EBU and NB30 limits just reached at respective distances (1 m or 3 m)
- EBU/BBC is not over-protective
- NB30 offers only a very low signal-'noise'-ratio that is not adequate for broadcast reception

Put into context — audio demonstration

- simulated interference recorded at various levels
  - compare these values to limit proposals
  - assumes receiver at 1 m from cable (indoor reception)
  - wanted signal at minimum protected field strength

track		C/(Ipk)
1	11	–32.7 dB
2	12	–22.7 dB
3	13	–12.7 dB
4	14	–2.7 dB
5	15	7.3 dB
6	16	17.3 dB
7	17	27.3 dB
8	18	37.3 dB
9	19	47.3 dB
10		clean

← NB30 + 20 dB @ 6 MHz

← NB30 @ 6 MHz

← NB30 – 20 dB @ 6 MHz

1-9 simulate one type of PLT, 11-19 are noise-like (ADSL, VDSL & some PLT)

Other arguable features of emission limits

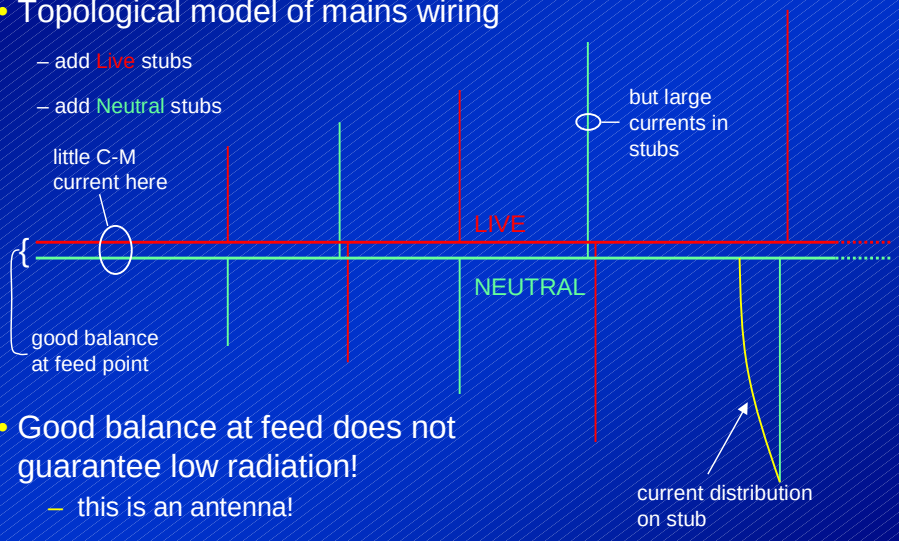
- Measurement distance
  - receivers need protecting where they are normally used – indoors
  - indoors, it is difficult to get away from mains wiring
  - hence BBC/EBU proposal (and UK MPT 1570) measures at 1 m
    - avoids argument about roll-off with distance, by measuring at the location to be protected
    - also avoids problems of sensitivity
  - JWG has followed NB30 example, and specifies 3 m
    - so can't make the measurement in most rooms anyway
    - leads to claims that radio-users' limits are not measurable
  - indoors, typically surrounded by wiring so what is the distance?
- Compliance or enforcement?
- Would they apply *everywhere?*
  - important thing for broadcasters is to protect receivers in homes

Alternative: conducted-current limits

- Signal current flowing in wires causes emissions
- For 'reasonable' cables, only common-mode current matters
- So limit on common-mode current controls emissions
- Normally tested with a 'dummy-load' fixture
  - accounts for LCL (imbalance) of cable
- But is this approach valid or relevant for PLC?
  - correctly describes C-M current at outlet of PLC modem
    - assuming test fixture is representative of home mains wiring
  - but what of currents elsewhere in the home?
  - home mains wiring has unbalanced terminations attached as stubs
    - wiring to light-switches (Live stub)
    - appliances plugged in, but switched off at the wall socket (Neutral stub)
      - switched appliance outlets very common in UK
    - appliances themselves? (No requirement on them to be balanced)

Good balance, efficient radiator

- Topological model of mains wiring
  - add Live stubs
  - add Neutral stubs



- Good balance at feed does not guarantee low radiation!
  - this is an antenna!

Way forward — collaboration

- Pursuing limits in public is clearly not leading to consensus
- Neither emissions limits nor current limits likely to produce solutions satisfactory to radio users and PLC operators
  - will lead to 'either/or' (or even *neither*) outcome
  - expensive and drawn-out legal action?
- Way forward is for PLC operators and Radio Users to collaborate to seek novel and mutually acceptable solutions away from public arena
- Suggest collaboration in EC Sixth Framework programme to achieve this
  - BBC has been strongly encouraged by EC to find partners

Conclusions

- Broadcasters see value in broadband roll-out
  - but it supplements and cannot replace 'over-air' delivery
- Spectrum below 30 MHz is a unique resource
  - long-distance propagation of great value to broadcasters & others
  - broadcasters active in development of digital system for it – DRM
- Radio services protected by International Radio Regulations
- Emissions from PLC systems can interfere with radio
  - protection needed but simple limits on emissions or conducted current cannot satisfy both camps — so consensus unlikely
- Stalemate is damaging to all
- Collaborative search for novel solutions is way forward

The End

Thank you for listening

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