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EUROPEAN BROADCASTING UNION

IMPACT ON BROADCASTING OF VARIOUS EMISSION LIMITS FOR DSL/PLT

BPN 061

October 2003

Impact on Broadcasting of Various Emission Limits for DSL/PLT

Executive Summary

Systems which re-use mains or phone wiring for communications purposes (such as xDSL, PLT or home-networking systems) are currently of interest. As well as their obvious benefits they have the potential to cause interference to radio systems, especially to receivers in the immediate vicinity.

Various limits to the emissions from these systems have already been proposed. One is already law in Germany, and covers a wide range of frequencies. Another, covering the LF/MF range, is agreed and in the process of becoming law in the UK. A CEPT Working Group, CEPT SE35, has been considering the issue and has nearly completed its task of drafting an ERC Report. Furthermore, the European Commission has mandated a Joint Working Group of Cenelec/ETSI to produce a standard for Europe.

In Part 1, this report considers the various proposals for limits that are under discussion. It also describes the development of an alternative proposal based on limiting the increase in the noise floor, and shows how a practicably applicable limit can be logically developed from this very justifiable starting principle.

Part 2 determines the degree of protection that the various limits offer to reception of broadcasting services in the general vicinity of the data-carrying cables. It is shown that the proposed limit provides reasonable protection to outdoor reception for all radio services. Some compromise in performance has to be accepted by listeners using antennas indoors for reception — this applies primarily to broadcast reception
However, the conclusion is that neither of the limits that have already gained legal status in Germany and the UK offers adequate protection to broadcast reception.

Regulators are urged to ensure that any emissions limits they bring forward provide a level of protection to radio services which is at least equal to that offered by the proposal presented here. Anything less stringent cannot be claimed to protect radio users — even the alternative proposal involves some compromise on the part of listeners.

1.1 PART 1: The Limits

Three sets of limits are discussed below

1.1 German NB 30

A regulation has been passed into law in Germany; it is generally known by the abbreviation NB 30. It covers the whole AM broadcasting range of frequencies (0.15 to 30 MHz) — as well as frequencies below and above that. It is based on the measurement of magnetic field strength at a distance of 3 m from the data-carrying cable, using a peak-reading measurement receiver with 9 kHz bandwidth. The equivalent E-field limits in the frequency range of interest, measured in dBμV/m, are:

$$E \le 40 - 20\,\mathrm{Log}_{10}[f_{MHz}], \qquad 0.15 < f_{MHz} < 1$$

$$E \le 40 - 8.8\,\mathrm{Log}_{10}[f_{MHz}], \qquad 1 < f_{MHz} < 30$$

1.2 United Kingdom MPT 1570

The UK has determined the limits it will apply for frequencies up to 1.6MHz. These are set out in a document named MPT 1570 and are in the process of passing into law at the time of writing. Limits for higher frequencies are under discussion. The limits for the LW/MW range apply for magnetic-field measurements at a distance of 1 m, using a peak-reading measurement receiver with 9 kHz bandwidth. The equivalent E-field limits in the frequency range of interest, measured in dBμV/m, are:

$$E \le 50 - 20\,\mathrm{Log}_{10}[f_{MHz}], \qquad 0.15 < f_{MHz} < 1.6$$

A subtle point to note is that the field is measured with a *spacing* of 1m between the CISPR loop antenna (diameter 0.6m) and the wire. This means that the field is in effect measured at a distance of 1.3 m (the distance from the wire to the centre of the loop). This nice distinction is neglected for the rest of this document. In this scenario the *H* field varies rapidly with distance, and thus varies over the area of the loop. Nevertheless, it can be shown that the field value obtained is very close to that which is actually present at the centre of the loop..

1.3 EBU proposal

1.3.1 Introduction

In CEPT SE35, papers and presentations from both NATO and the EBU[1] have suggested another way to protect radio services from unwanted interference caused by emissions from cable systems. It is similar to that already applied in many circumstances to govern interference between radio systems sharing the same spectrum, where the interference is

[1] This is based on work carried out by the BBC R&D dept.

treated as noise, and is allowed to raise a receiving system's noise floor (often expressed as noise temperature, especially for satellite systems) by some small amount (0.25 dB is sometimes used).

However, before going any further, we must bear in mind that there is a fundamental practical difficulty. If it is required that the noise floor at the radio user's receiving antenna may be increased only slightly by the emissions from the PLT/xDSL/etc cable system, then the emissions *at that location* will be difficult to measure. If the permitted increase is any value less than 3 dB, then the emissions limit will be smaller than the pre-existing noise level and thus may be difficult to measure for regulatory enforcement purposes. Nevertheless, the concept of allowing only a small increase, say 0.5 dB, remains a perfectly proper, reasonable and defensible requirement. This paper proposes a possible way forward which maintains the principle of a 'limited increase' in the noise floor, applies a reasonable compromise to the protection afforded to different classes of receiver, and leads to a limit which is also measurable and enforceable.

1.3.2. The principle

Applying the principle of permitting an *x* dB increase in the noise floor of any radio system strictly would be somewhat unworkable. It would require knowledge of the (different) noise floor of every receiving installation — which would mean that would-be cable-system operators would not have a known general target to try to meet. For enforcement purposes, it would become necessary to measure 'before and after' noise-floor levels — to a great accuracy, if the permitted increase were indeed small. So we must do something different. We start by assuming that we can categorise present noise floors by some formula, which can then be applied universally. Noting that the new sources of interference will be essentially continuous, it will be reasonable to use the well-known man-made-noise curves from ITU-R Recommendation P.372.

This ITU-R Recommendation gives curves based on simple formulas for the median man-made noise. They are given for four cases: "Business", "Residential", "Rural" and "Quiet rural", sometimes labelled A to D. It should be noted that measurements made in the UK by BBC, RA, RSGB and MoD suggest that the curves somewhat overestimate noise levels in the UK, e.g. the gardens of suburban houses are found to have *overall* noise levels lying between the "Rural" and "Quiet rural" cases.

We therefore follow a suggestion made earlier by the EBU, and adopt a curve mid-way between the "Rural" and "Quiet rural" cases of Rec. P.372. Call this curve 'M' for the purposes of this paper. We suppose that this is indeed representative of the noise floor of the sorts of installations likely to be found in residential gardens and of other similarly located installations (e.g. radio amateurs, enthusiastic broadcast listeners with external antennas, aeronautical engineers on call from home…). We then require the emissions at this point — which we take to be 10 m from the nearest potentially-emitting cable — to be no more than would cause say a 0.5 dB increase in this level.

As already noted, such a level would be difficult to measure, so we scale it according to the common assumption that magnetic field (which is what we would measure) varies as (*1/r*) and define a new curve giving the corresponding level at say 1m. This becomes the distance used for enforcement measurement. As the level is 20 dB higher, it now becomes measurable.

Of course, this means that indoor reception would be correspondingly less well protected, and this is where a distinct compromise is made. If however, we accept that existing *indoor* noise levels will in some cases be higher than curve 'M', it will be seen that the principle of limited increase to the actual noise floor is, to a limited extent, respected (see examples presented later).

On the other hand, serious professional monitoring stations may have noise floors right down at the ITU-R 'Quiet rural' or below — and thus below our hypothetical curve M. But such stations will presumably be located at a greater distance than 10 m from the nearest potentially-emitting cable so that they too suffer only a limited increase in their noise floor as a result of that cable. (Note however that such 'sensitive' stations may nevertheless be affected by cumulative interference [1]. The limit proposed here has not yet been assessed for its cumulative effects). So much for principles, the following section spells out some details.

1.3.3. Details

1.3.3.1. The starting point for the proposal — the ITU curves and the derived curve 'M'

1.1.1 ITU Definitions

The curves are defined in ITU-R Rec. P.372-6. In fact the published curves define the *external noise figure* F_a . The equivalent (RMS) electric field strength can be calculated from this using a formula, which depends on the type of antenna. For reception using a half-wave dipole, the formula is given as:

$$E_n(\text{dB}\,\mu\text{V/m}) = F_a + 20\,\text{Log}_{10}[f_{MHz}] + B - 99.0$$

where B = 10Log$_{10}$ [(bandwidth in Hz in which E_n is measured)].

A simple formula is defined for the median man-made noise:

$$F_{am} = c - d\,\text{Log}_{10}[f_{MHz}]$$

where the constants c and d are tabulated for four environments, Business (A), Residential (B), Rural (C) and Quiet rural (D):

Environment	*c*	*d*
A : Business	76.8	27.7
B : Residential	72.5	27.7
C : Rural	67.2	27.7
D : Quiet rural	53.6	28.6

Combining the two equations we get a simple formula for the median RMS field strength measured in a 9kHz bandwidth, using a dipole antenna:

E_n (dBμV/m in 9 kHz, λ/2 dipole) = $c' - d' \text{ Log}_{10} [f_{MHz}]$

where *c'* and *d'* are tabulated below:

Environment	*c'*	*d'*
A : Business	17.34	7.7
B : Residential	13.04	7.7
C : Rural	7.74	7.7
D : Quiet rural	-5.86	8.6

Definition of curve 'M'

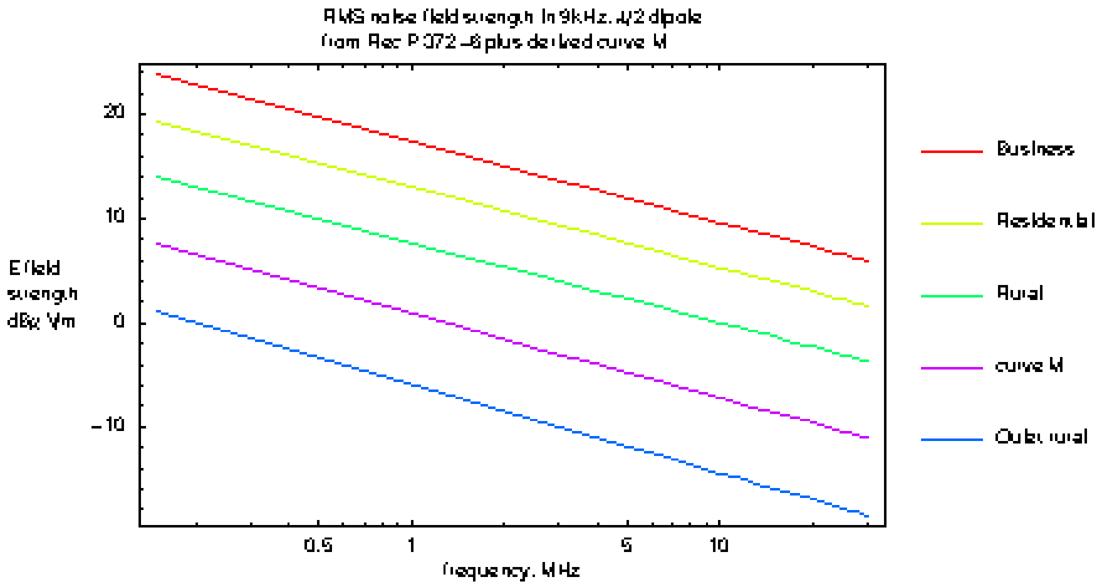
Following the previous EBU suggestion, we take the mean of curves C and D. Curve M is thus defined by:

E_n (dBμV/m in 9 kHz, λ/2 dipole) = $0.94 - 8.15 \text{ Log}_{10} [f_{MHz}]$

We take this as representative of the (pre-existing) RMS noise floor at a distance of 10 m. It is this level that we propose may be increased by no more than 0.5 dB when emissions from the cable are added.

Plot of RMS noise field strength according to ITU curves

Curves A to D and our derived curve M (mean of C and D) are plotted below.



1.3.3.2. The emissions level notionally permitted at 10 m

The basis of the proposal is that the noise floor defined by curve M may be increased by *x* dB as a result of emissions from a cable which is 10 m away. This ensures that reception using outdoor antennas in such locations is protected. It follows that the permitted (RMS) level of emissions (at 10 m) is less than curve M, having a level relative to it of:

$$10 \text{ Log}_{10} [10^{x/10} - 1] \text{ dB.}$$

We choose to limit the noise-floor increase *x* to 0.5 dB, with the result that the RMS level of emissions (at 10 m) must be 9.14 dB *less* than curve M.

1.3.3.3. The proposed enforcement limit at 1 m

We propose to measure much closer to the potentially-emitting cable, for two reasons:

- it makes the field much easier to measure, as it is stronger
- it makes it easier to be sure from which cable the measured emissions emanate

Existing proposals measure at either 3 m or 1 m. The UK emissions limit MPT1570 specifies a distance of 1 m for emissions in the LF and MF range. This distance is particularly appropriate in this range since it correlates directly to the likely achievable distance for indoor reception. It also ensures that the field strengths are more easily measurable.

Practical objections seem as likely to arise for either distance — obstructions may sometimes make it difficult to get as close to a cable as 1 m, but equally, small rooms may not permit measurements to be made as far away as 3 m.

Note that the MPT 1570 uses a slightly strange definition of ‘ 1 m distance’: it requires the *nearest part* of the measurement loop to be at 1 m distance from the cable. Given that the standard measuring loop is of 0.6 m diameter, this means that the magnetic field is actually measured at a distance of 1.3 m from the cable.

A measurement distance of 1 m *to the centre of the measuring antenna* is therefore proposed. We assume that the magnetic field will actually be measured, but express it as the equivalent electric field strength. To account for measurement at 1 m we increase the '10 m' value by 20dB. In order to express it as a value applicable when a *peak* detector is used (as specified in previous proposals) we add a further 10 dB, making 30 dB in all.
The proposed equivalent-electric-field strength limit is thus:

E_n (dBμV/m in 9 kHz, peak) = *curve M* – 9.14 +10 + 20
= 21.8 – 8.15 $\text{Log}_{10}\,[f_{MHz}]$

The corresponding magnetic field (which is what is measured, and is thus the definitive proposal) is obtained by subtracting the familiar factor of 51.5 dB for the impedance of free space:

H_n (dB V/m in 9 kHz, peak) = – 29.7 – 8.15 $\text{Log}_{10}\,[f_{MHz}]$

1.2 PART 2: The Implications to broadcasting

2.1 What protection does broadcasting need?

2.1.1 Minimum field strengths for broadcasting

When planning broadcast services it is necessary to ensure that the broadcasting stations do not interfere with each other. This is done by arranging the assignment of frequencies and powers to the stations so that the strength of the wanted received signal exceeds that of interfering stations by a defined *protection rati*o. Different protection ratios are applied for co- and adjacent channels. They are set out in ITU-R documents but different values sometimes may be applied by mutual agreement. A common feature is that protection is only afforded to a wanted signal if its signal is above a certain *minimum field strengt*h. There is a small degree of inconsistency in the ITU-R texts, but the following values from ITU-R Rec. BS 703 will be taken as representative:

Band	**Minimum Field Strength, dBmV/m**
LF	66
MF	60
HF	40

Of course, some listeners will live at places within the coverage area which receive stronger signals; equally, some listeners may live outside the coverage area but get satisfactory reception because it so happens that the level of interference is low — they are not strictly 'protected', but if they are nevertheless used to receiving a good signal they will complain if they lose it.

2.1.2 Signal-to-noise ratio

Interference from data-carrying cables can be treated in a similar way to that from other radio services, i.e. a protection ratio could be determined for each potential interferer. For the purpose of this paper we assume, however, that the interference is sufficiently noise-like that we can treat it as noise and examine the signal-to-'noise' ratio. (The validity of this assumption will depend on the modulation scheme, energy dispersal and so on of the data-carrying system. It is believed to be valid for some xDSL systems, at least). Note that it is always possible that some system with an audibly more offensive character could be introduced for which the assumption could be false.

A good starting point therefore is the RF signal-to-noise ratio currently considered applicable to broadcasting. This is difficult to identify from ITU-R texts, perhaps for two reasons. One may be that AM broadcasting has been going on for so long that the signal strengths that have been in use for decades are simply known to work. In any event, the main focus in any ongoing planning issues is the mutual interference between stations — which is unaffected by the general level of transmission powers. Another complication is the 'analogue' nature of AM: just-intelligible reception of (well-compressed) speech is possible at quite low RF SNR (order of 10 dB), while a further increase of more than 40 dB is needed before background hiss becomes essentially inaudible.

A minimum guide can be taken from the derivation of minimum field strength indicated in ITU-R Rec. BS 560. It clearly indicates that the minimum field strength for one HF planning scenario was chosen in order to ensure the RF SNR was 34 dB. Noting that generally less stringent standards are normally applied for HF, we might expect a higher value of SNR to be appropriate for the entertainment-quality reception intended for LF/MF broadcasting, say at least 40dB RF SNR.

If we compare the minimum field strengths tabulated above with the ITU-R man-made noise curves of ITU-R Rec. P 372-6, we see that the resulting LF/MF RF SNR exceeds 40 dB, *even for the industrial-area noise curve*.

Note that the RF SNRs just discussed are

$$RF\ \ SNR = \frac{mean\ carrier\ \ power}{mean\ noise\ \ power}$$

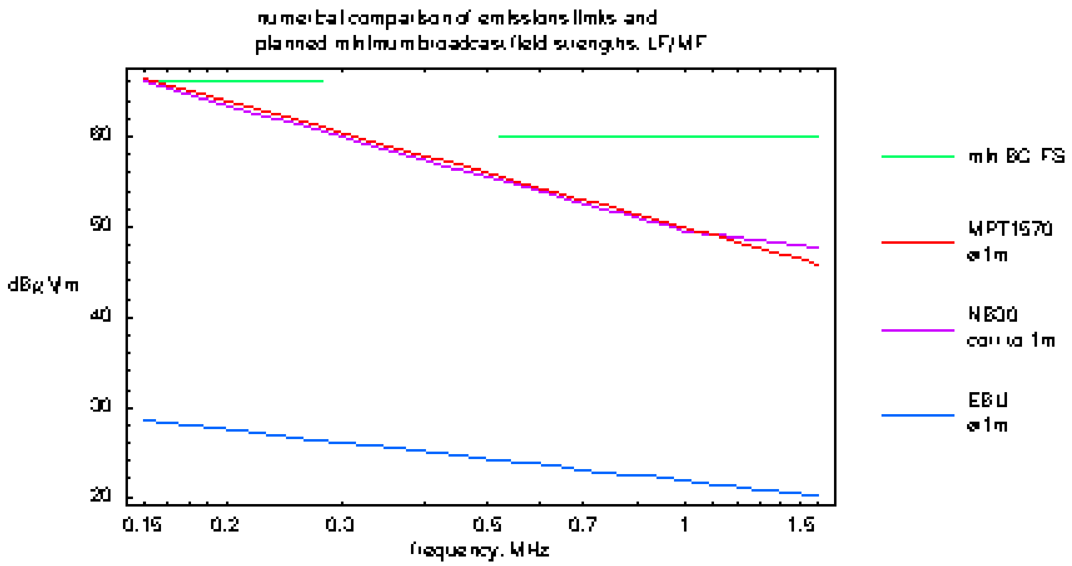
whereas proposed emission limits mostly relate to measurements of noise using a *peak* (not RMS or mean) detector. We may take it as a good approximation that the RMS noise level (for genuinely noise-like signals) is 10 dB less than the peak indication on the measuring receiver.

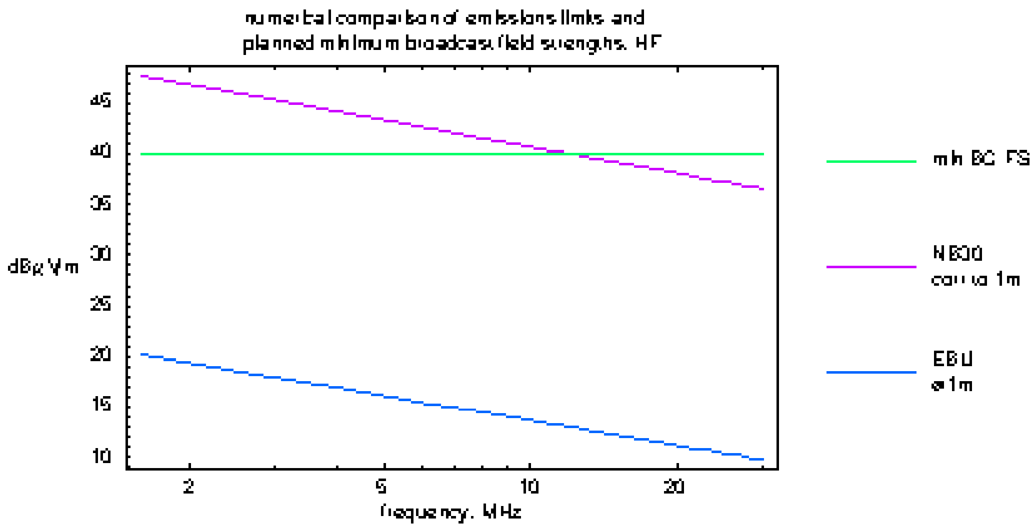
2.2 The 'protection' given to LF/MF broadcasting by the proposals

It is now instructive to compare the degree of protection that the various proposals afford to broadcasting.

2.2.1 Plots of limits and minimum protected broadcast field strength

We could simply plot the numerical field-strength values as given. However, this could be misleading. The NB30 limit is specified at a distance of 3m, whereas the other two are specified at 1m. It is customary to assume that the field falls off as (1/*r*), whereupon a correction of $20\,\mathrm{Log}_{10}[3] \approx 9.54\ \mathrm{dB}$ is appropriate to convert from one distance to the other. This is done in the following graphs:





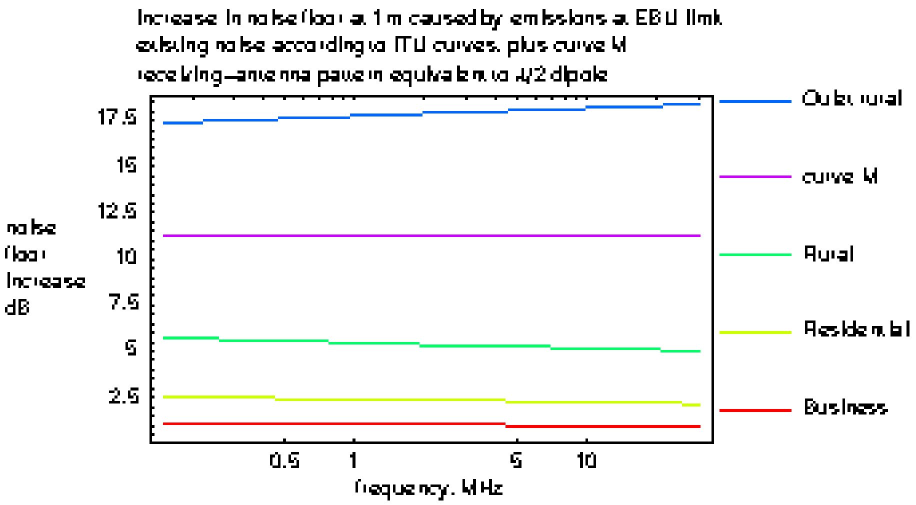
This now enables the protection given by the various limits at the distance of 1 m (representative of indoor listening) to be compared properly. However in assessing the *absolute* level of protection we must also take account of the fact that all the limits specify the use of a *peak detector* when making the measurement.

2.2.2. Impact on the existing noise floor

We have chosen the limit so that the noise level at 10 m distance is increased by 0.5 dB as a result of emissions at the limit — if the existing noise floor corresponds to our hybrid curve M. We shall now look at the impact at our measurement distance of 1 m. What is the impact if the existing noise level is different? The following graph shows the increase in noise level at a distance of 10 m, where the existing noise accords with the various ITU-R curves (as shown in § 1.3.3.1).

Note that the emissions are converted to RMS quantities in order to combine properly with the ITU-R noise-curve values.

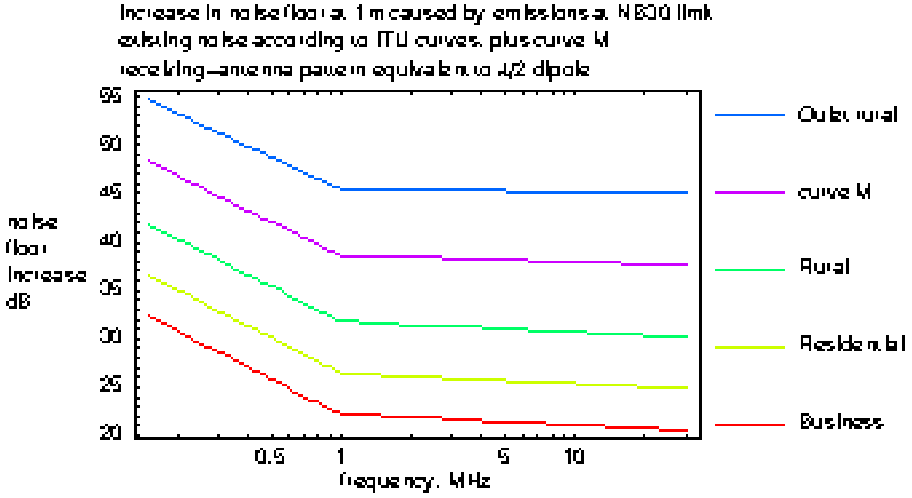
2.2.2.1. Proposed EBU limit



At 1 m, the increase is greater than would be the case at a distance of 10 m. The increase is greatest where the existing noise floor is lowest (i.e. ITU-R “Quiet rural”). For other areas, where the existing noise level is worse, the increase is less great but even in “Business” areas it is about 1 dB. The compromise inherent in the new proposal is now clear: those locations where pre-existing noise levels indoors remain low will be very significantly affected. Note that this compromise will primarily be made by broadcasting, since it is the radio service in this frequency range for which indoor reception is most used and expected.

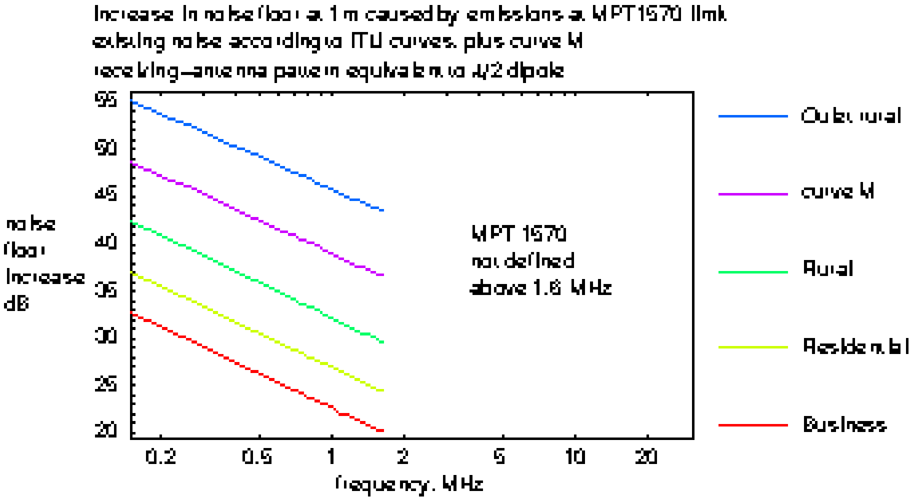
2.2.2.2. NB30 Limit

Here we do the same but assuming the NB30 limit applies. The following graph shows the result of doing this, for reception at 1m.



The *smallest* noise-floor increase (arising where the existing indoor noise corresponds to ITU-R “Business”) is 20 to 33dB. Other regions suffer even greater noise-floor increases, up to 55 dB! In comparison, the plot presented in § 2.2.2.1. shows that the new proposal causes *at most* an increase of about 18 dB at 1m.

2.2.2.3. MPT 1570 Limit



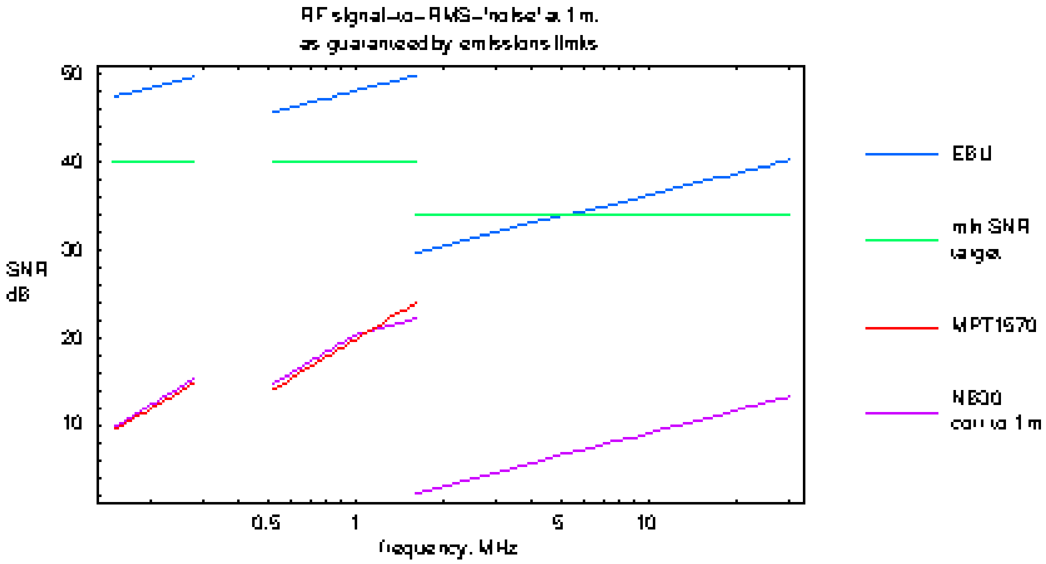
This is very similar to the NB30 case.

2.2.3. Plot of effective signal-to-‘noise’ ratio that is guaranteed

If we subtract a limit from the minimum protected broadcast-signal field-strength we get the minimum signal-to-‘noise’ ratio that the limit ensures would be achieved, assuming that the wanted broadcast signal never falls below the minimum protected level. *In practice, of course, the actual signal - to- noise value, with interference at the limiting value, will be less than this, owing to the existence of other noise*.

We include a correction factor of 10 dB under the assumption that the interference from xDSL/PLT/etc is Gaussian-noise-like in nature, for which the RMS value is about 10dB less than the peak — which is what is regulated by the proposed limits.

The resulting RF signal-to-RMS-‘noise’ values are plotted below[2]:



Noting that a reasonable RF SNR target for LF/MF broadcasting is 40 dB, as identified earlier, we see that that the NB30 and MPT1570 limits fall very far short indeed of the protection needed, especially at LF. An RF SNR of 10 dB would leave a signal of no entertainment value whatsoever. (Even an outdoor antenna at 10 m, giving a 20 dB improvement, would not achieve the target).

Similarly, for HF, taking an RF signal-to-RMS-‘noise’ ratio of 34 dB as our target in this case we see that NB30 does not protect listeners at all, while, even with the EBU proposal, some degree of compromise is required by the listeners using the very bottom of the HF band.

3. Possible impact of a change from AM to DRM

Broadcasting in the bands below 30 MHz has always used AM — Amplitude Modulation. A standard has recently been defined for digital broadcasting in these bands — DRM, Digital Radio Mondiale. As a digital system it is affected differently by noise. Whereas AM has a more-or-less continuous variation of audio quality over a wide range of SNR, and thus necessitates a high SNR to achieve good quality, DRM has the typical ‘near-cliff-edge’ behaviour of a digital system: when the SNR is high enough it works and delivers the audio quality intrinsic to the form of audio coding used; when the SNR is insufficient no audio whatsoever results, with a small range of SNR in between where the reception deteriorates from essentially-perfect to non-existent. The good news is that excellent audio quality is achieved at only moderate SNR — but any significant reduction in SNR below that leads to complete loss of service. It is expected that DRM would be introduced using transmitter powers of say 5 –10 dB lower than would presently be used for AM. Thus the RF SNRs achieved in the presence of cable-system emissions would be correspondingly 5 –10 dB lower

[2] Additional plots showing the effects over a range of distances are given in references 1, 2 & 3.

than given in the preceding plots. This could lead, for example, to *negative* SNR in the LF band with the NB30/MPT1570 proposals, and would not work at all!

Planning values for minimum field strength and SNR for DRM have been refined by ITU-R TG6/7 as a draft new Recommendation in course of approval by ITU-R. The existing ITU-R noise curves were used in their derivation.

4. Conclusions

The extent to which various proposals for emissions limits in the LF/MF/HF bands protect broadcast reception has been assessed.

Those proposals which have either passed into law (German NB30) or will do so very soon (UK MPT1570) are unfortunately quite inadequate to protect reception of broadcasting. Note that even worse proposals (as much as 30 dB higher than NB30) have been suggested within the Cenelec/ETSI JWG.

Conversely the EBU proposal is enforceable and does provide adequate protection, albeit requiring a certain degree of compromise in certain circumstances.

8. References

1. STOTT, J.H., 2001. Cumulative effects of distributed interferers. BBC R&D White Paper WHP 004.

2. STOTT, J.H., 2001. AM broadcasting and emissions from xDSL/PLT/etc; Compatibility analysis of various proposals for limits. BBC R&D White PaperWHP 012.

3. STOTT, J.H., 2001. Emission limits; a new proposal based on a limited increase in the noise floor. BBC R&D White Paper WHP 013.

These BBC R&D White Papers are available on the BBC R&D website at:
http://www.bbc.co.uk/rd/pubs/whp/index.html