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Emission limits

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A new proposal based on a limited increase in the noise floor

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Abstract

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, is considering the issue and is tasked with drafting an ERC Recommendation and Report — although the final decision will be made by a higher body.

A separate BBC R&D White Paper, no. WHP 012, considers the various proposals for limits that are under discussion in CEPT SE35 at the time of writing and determines the degree of protection that they offer to reception of broadcasting services in the general vicinity of the data-carrying cables. It concludes that none of the limits proposed so far offers adequate protection to broadcast reception. Unfortunately this is especially true of the limits that have already gained legal status in Germany and the UK.

This paper develops 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. 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.

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 this proposal involves some compromise on the part of listeners.

Key words: radio interference, DSL, PLT, PLC, emissions, broadcasting, AM, NB30 MPT1570

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□ 1. Introduction

The use of existing cables — mains or telephone — to carry data can result in unwanted emissions as some of the signal energy 'leaks' from the cable. These unwanted emissions can cause interference to radio systems and various limits have therefore been proposed to restrict the emissions. Some countries have proposed national limits. An attempt is also being made to co-ordinate a single European approach to the problem. One of the relevant European bodies is the CEPT, a subgroup of which, CEPT SE35, is charged with drafting an ERC Recommendation and Report.

A separate White Paper [1] shows that none of the limits proposed so far provides adequate protection for reception of broadcasting as it is normally performed in the home, using portable receivers with built-in antennas. Unfortunately, the worst proposals are those which have either passed into law (German NB30) or will do so very soon (UK MPT1570). Indeed these latter proposals do not even fully protect reception using *outdoor* antennas.

In CEPT SE35, papers and presentations from both NATO and the EBU 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 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).

A brief SE35 paper [2] presented some simple graphical illustrations of the implications of applying this principle to the emissions from cable systems for frequencies from LF to HF.

What may not have been obvious 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/*x*DSL/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.

□ 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 1 m. 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 [3]. The limit proposed here has not yet been assessed for its cumulative effects).

So much for principles, the following section spells out some details.

□ 3. Details

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

▫ ITU Definition

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:

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

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

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

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

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 9 kHz bandwidth, using a dipole antenna:

$$E_n\ (\mathrm{dB}\mu\mathrm{V/m\ in\ 9\,kHz},\ \lambda/2\ \mathrm{dipole}) = c' - d'\,\mathrm{Log}[10,\ f_{\mathrm{MHz}}]$$

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 our curve 'M'

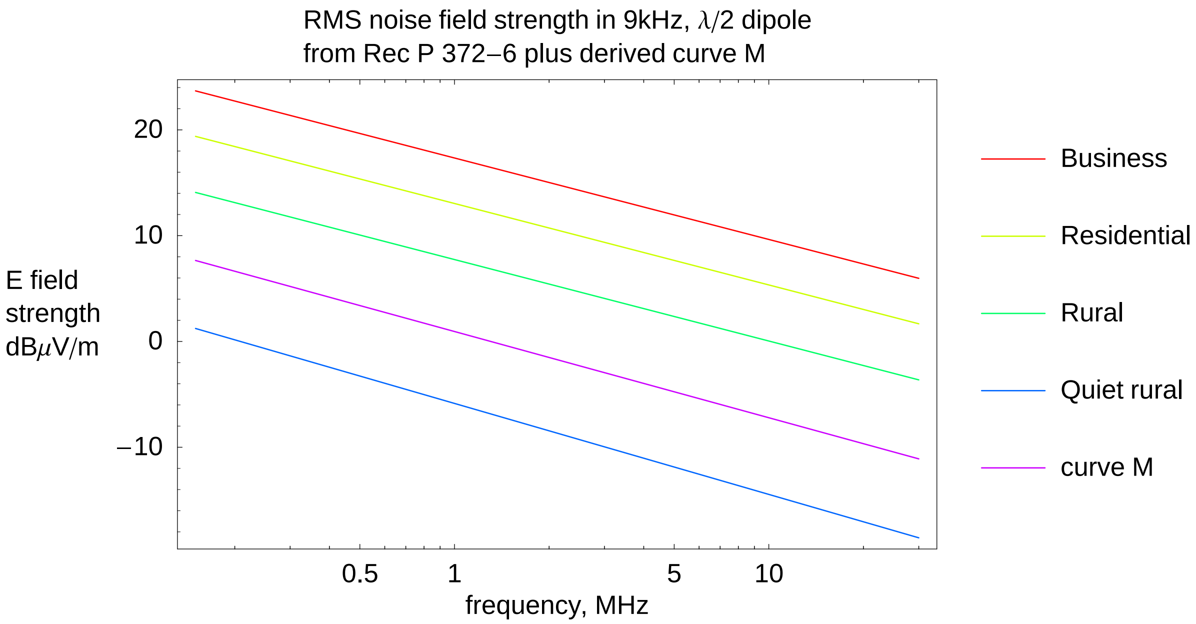
Following the previous EBU suggestion, we take the mean of curves C and D. Curve M is thus defined by:

$$E_n\ (\mathrm{dB}\mu\mathrm{V/m\ in\ 9\,kHz},\ \lambda/2\ \mathrm{dipole}) = 0.94 - 8.15\,\mathrm{Log}[10,\ f_{\mathrm{MHz}}]$$

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 E-field strength according to ITU curves

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



■ 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:

$$10\,\mathrm{Log}[10,\ 10^{x/10} - 1]\ \mathrm{dB}.$$

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.

■ 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 20 dB. 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:

$$E_n \text{ (dB}\mu\text{V / m in 9 kHz, peak)} = \text{curve M} - 9.14 + 10 + 20$$
$$= 21.8 - 8.15\,\text{Log}[10,\ f_{\text{MHz}}]$$

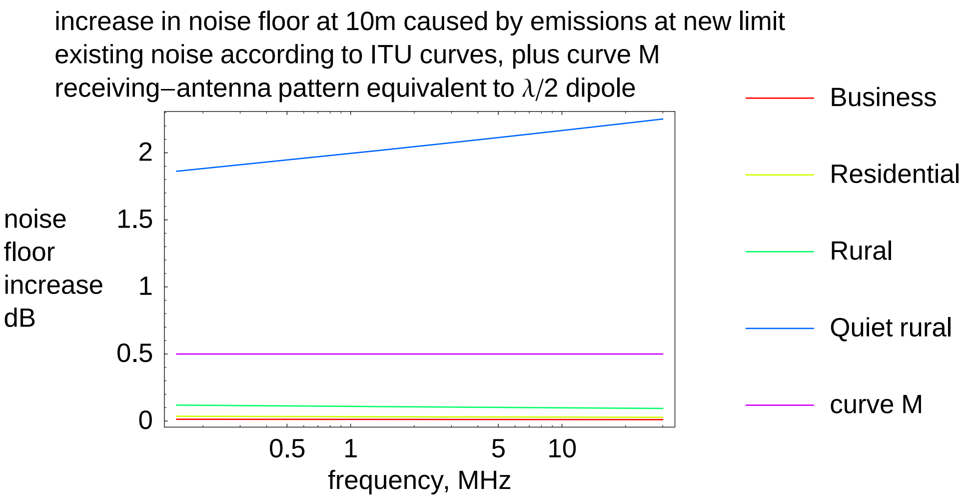
The corresponding magnetic field (which is what is measured, and is thus the definitive proposal) is obtained by subtracting the familiar factor of 51.5 dB for the impedance of free space:

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

■ 3.4. Impact of the proposed new limit

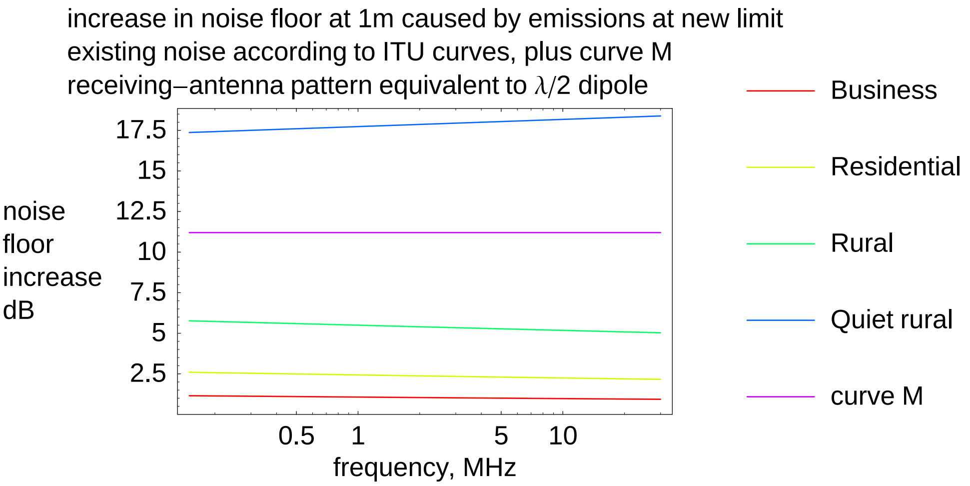
We have chosen the limit so that the noise level at 10 m distance is increased by 0.5 dB as a result of emissions at the limit — if the existing noise floor corresponds to our hybrid curve M. What is the impact if the existing noise level is different? The following graph shows the increase in noise level at a distance of 10 m, where the existing noise accords with the various ITU-R curves (as shown in § 3.1).

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



The increase is 0.5 dB exactly for curve M (just as we designed it). Where the existing noise floor is lower (e.g. ITU-R "Quiet rural") the increase is greater, while for areas where the existing noise level is worse than curve M the increase is negligible. We may conclude that outdoor-antenna reception is, as intended, well protected by the new limit proposal.

Reception at 1 m distance will be subjected to 20 dB greater emissions, so we expect greater impact, as shown in the next graph:



The compromise inherent in the new proposal is now clear. Those locations where pre-existing noise levels indoors remain low will be 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.

□ 4. Comparison with other limit proposals

We can compare our proposal with the others listed in the draft ERC Recommendation prepared by CEPT SE 35 [4]. Note that they are all taken to be peak-detected in 9 kHz bandwidth.

■ 4.1. The previous proposals

□ German NB 30 (measured at 3 m)

$$E \le 40 - 20\,\mathrm{Log}_{10}[f_{\mathrm{MHz}}],\ \ 0.15 < f_{\mathrm{MHz}} < 1$$
$$E \le 40 - 8.8\,\mathrm{Log}_{10}[f_{\mathrm{MHz}}],\ \ 1 < f_{\mathrm{MHz}} < 30$$

□ United Kingdom MPT 1570 (measured at 1 m)

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

□ NEDAP, NL (measured at 1 m LF/MF, 3 m HF)

$$E \le 40 - 7.7\,\mathrm{Log}_{10}[f_{\mathrm{MHz}}],\ \ 0.15 < f_{\mathrm{MHz}} < 1.6 \text{ (at 1 m)}$$
$$E \le 20 - 7.7\,\mathrm{Log}_{10}[f_{\mathrm{MHz}}],\ \ 1.6 < f_{\mathrm{MHz}} < 30 \text{ (at 3 m)}$$

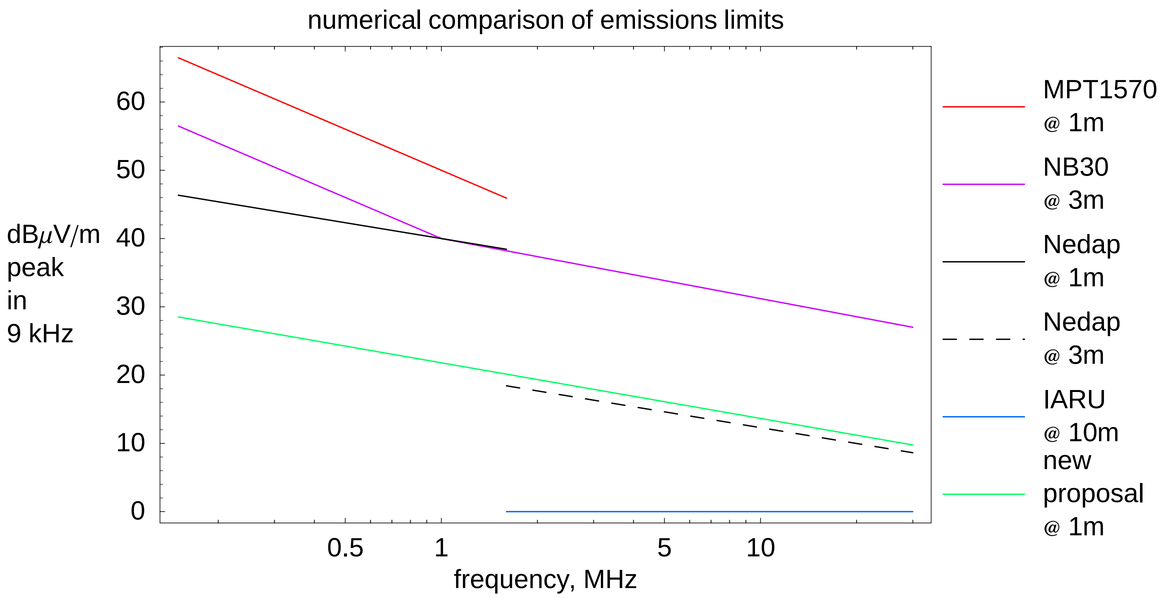
□ IARU

This proposal specifies a flat limit of 0 dBμV / m at a distance of **10** m. The applicable frequency range is not stated but may be assumed to apply only to the HF range 1.6 to 30 MHz. It is not explicit whether this limit is intended to be measured with a peak detector.

■ 4.2. Comparative plots

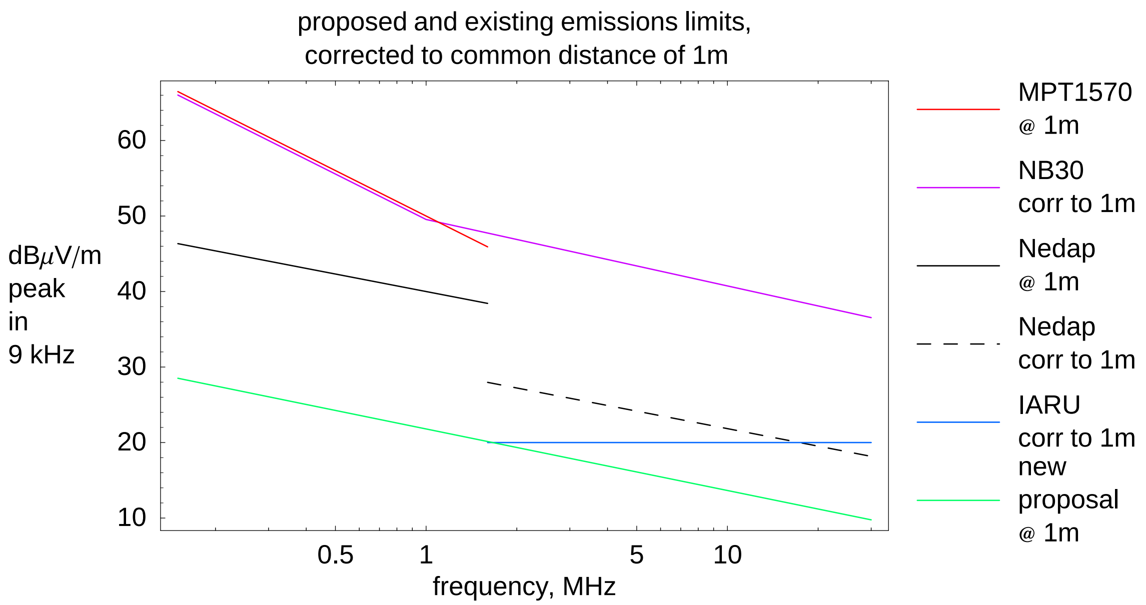
◽ Numerical comparison

The following plot simply compares the numerical values of the various limits. Note however that they are not strictly comparable, as some are applied at 3 m, while others are applied at 1 m.



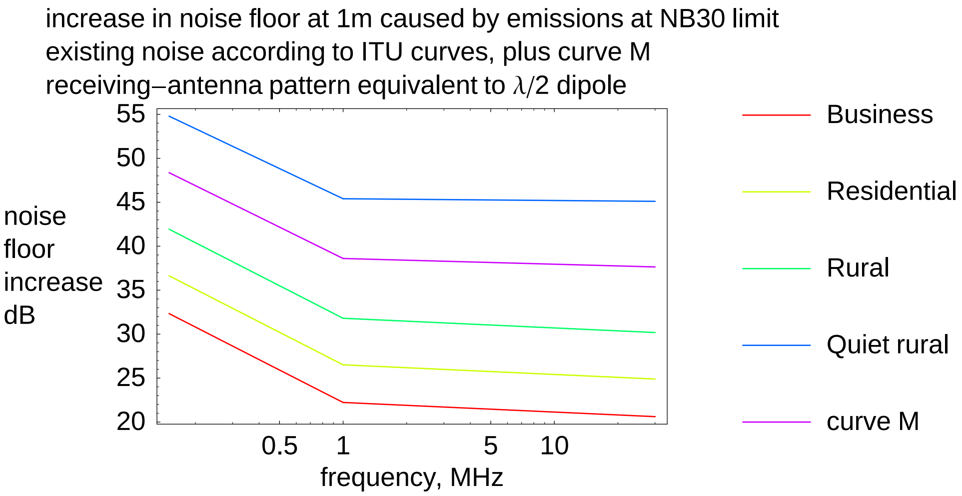
◽ Comparison at common distance of 1 m

To permit fairer comparison, for the following plot we convert all the limits to the common distance of 1 m using a $(1/r)$ law:



■ 4.3. The impact of the NB30 limit on the noise floor, for comparison

To put the significant disparity between the new proposal and say the NB30 limit into context, we can repeat the plot presented in § 3.4. There we examined the increase in the noise floor caused by emissions at the proposed new limit. Here we do the same but assuming the NB30 limit applies. The following graph shows the result of doing this, for reception at 1 m.

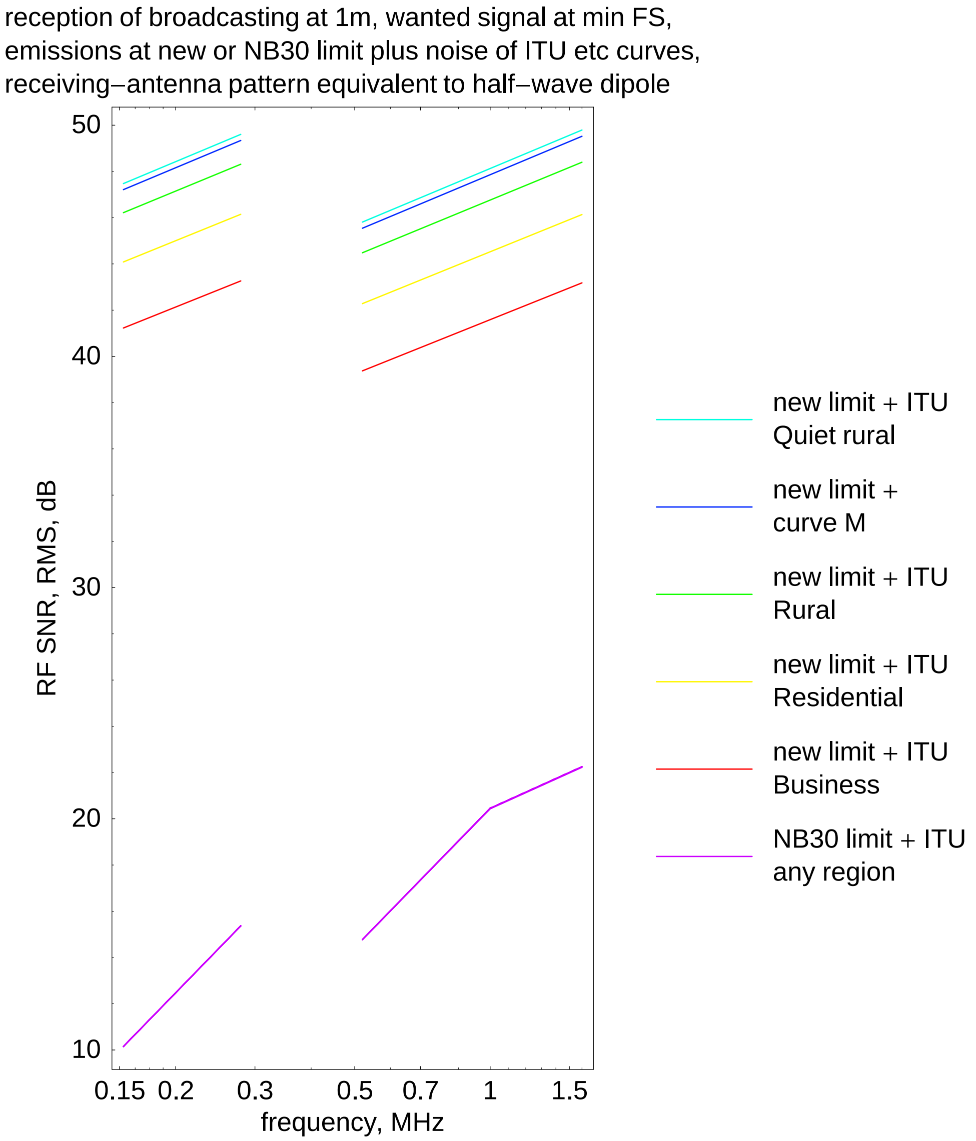


The *smallest* noise-floor increase arises where existing the indoor noise corresponds to ITU-R “Business”, and is then 20 to 33 dB. Other regions suffer greater noise-floor increases, up to 55 dB! In comparison, the plot presented in § 3.4. shows that the new proposal causes *at most* an increase of about 18 dB at 1 m.

■ 4.4. An example of the impact on broadcasting

Taking the minimum protected field strengths from [1] we can plot the overall RF signal-to-noise ratio achieved in indoor reception of LF/MF broadcasting and compare it with the 40 dB target also assumed in [1]. This is done in the graph overleaf. Curves are shown where the total ‘noise’ is taken as the sum of the pre-existing noise according to the various ITU-R curves (and our curve M) and the ‘noise’ from a cable system operating at the new limit.

The same is repeated where the cable system is operating at the NB30 limit — in this case, as the NB30 limit is so high, the choice of ITU-R curve makes negligible difference. They are all plotted, but cannot be distinguished and are therefore all plotted in the same colour.



The 40 dB RF SNR target is essentially met under the new limit, for all ITU noise regions, whereas the NB30 limit falls short by up to 30 dB.

□ 5. Conclusions

None of the limits currently proposed in CEPT SE35 is adequate to protect reception of LF/MF/HF broadcasting from emissions from cable-systems carrying data, as is shown in [1].

The alternative idea of permitting a specified limited increase in the noise floor of radio receivers (of any service) has been introduced in SE35 by EBU and NATO representatives. This concept is perfectly reasonable — a similar idea is often applied in co-ordination between radio services. However, it would be difficult in practice to apply a requirement for potentially-interfering cable systems to cause no more than x dB increase in the noise floor of *any* radio-system receiver.

A 'conventional' field-strength limit has therefore been devised, starting from the *concept* of a 0.5 dB increase in the noise floor being permissible in a reference scenario. This reference scenario has been chosen as outdoor reception, 10 m from a potentially-interfering cable, assuming that the pre-existing noise floor is intermediate between the 'Rural' and 'Quiet rural' cases given in ITU-R Rec. P 372. (This is representative of the noise level currently experienced in suburban gardens in the UK). The new limit is then derived from that, assuming that the measurement distance will be 1 m from the cable to the centre of the loop used to measure magnetic field strength. The limit is spelt out below, and is intended to apply over the LF/MF/HF range from 150 kHz to 30 MHz:

Magnetic field strength (definitive)

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

Equivalent electric field strength (informative)

$$E_n \text{ (dB}\mu\text{V / m in 9 kHz, peak)} = 21.8 - 8.15\,\text{Log}[10,\ f_{\text{MHz}}]$$

The choice of this limit is a compromise. It protects the reference scenario well (by definition) and in general provides reasonable protection for reception of any radio service at 10 m from a cable system, although the quietest sites will see a greater noise-floor increase than 0.5 dB. For indoor-antenna reception (e.g. at 1 m from the cable system) greater compromise has to be accepted by the listener. This case of indoor reception applies principally to broadcasting, so it is broadcasting which makes the greatest compromise here.

This proposal is commended to regulators in order that they can provide protection to radio services in general, not just broadcasting. It is logically derived on the basis of providing such protection, and involves a degree of compromise on the part of radio-system users, especially for the case of indoor reception which plays a major part in broadcast listening.

Any less-restrictive proposal should be examined closely. An emissions limit introduced with a stated aim of protecting radio services should be able to demonstrate that it achieves this aim. Many proposals presented so far demonstrably do not.

Note that any proposal should also be checked to determine whether it protects against cumulative interference [3].

□ 6. References

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

2. STOTT, J H, 2001. Emissions limits based on raising noise floor by *x* dB. SE 35 (01) 94rev1

This paper is not publicly available outside CEPT.

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

This paper is available on the BBC R&D website at http://www.bbc.co.uk/rd/pubs/papers/pdffiles/jhs01-tn1670.pdf. In CEPT SE35 it has the reference SE 35(01) 81.

4. Draft ERC Recommendation: Radiation limits for cable transmission limits.

This paper is not publicly available outside CEPT. The working draft referred to has the CEPT numbering SE(01)127 Attachment 2, also available as SE35(01)48rev6. The UK and German limits are publicly available and represent final positions, while the other proposals are simply opinions expressed in SE35 and may be subject to change.