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Compatibility analysis of various proposals for limits

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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.

This paper 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 datacarrying cables. (A separate BBC R&D White Paper, no. WHP 004, considers the cumulative effects of such emissions on far-off receivers).

The conclusion is 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. However, a proposal based on limiting the increase in the noise floor appears to offer promise and forms the subject of a separate paper.

It is hoped that the calculations presented here will guide regulators in setting limits to the emissions from potentiallywidespread xDSL/PLT/etc. systems so that radio users may be assured adequate protection from interference.

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.

This contribution assesses the level of protection that the proposals currently considered within SE35 afford to AM broadcasting services operating in the long, medium and short wave bands, for reception in the general vicinity of the cables carrying data.

Note that a separate paper [1] considers the cumulative effect of many such systems on far-off receivers.

□ 2. The proposals considered

These are taken from the current version of the draft ERC Recommendation on limits [2]. Two come from Administrations and have the status of current or imminent law in their respective countries, the others are proposals that have been made in SE 35. Note that the limits are in many cases measured and defined in terms of magnetic field strength but for convenience are expressed herein in terms of the equivalent electric field strength assuming the normal far-field relationships between E and H apply. All are measured in a 9 kHz bandwidth in the frequency range of interest here.

■ 2.1. 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. The equivalent E-field limits in the frequency range of interest are:

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

■ 2.2. United Kingdom MPT 1570

The UK has determined the limits it will apply for frequencies up to 1.6 MHz. 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. The equivalent E-field limits in the frequency range of interest are:

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

A subtle point to note is that the field is measured with a *spacing* of 1 m between the CISPR loop antenna (diameter 0.6 m) 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.

■ 2.3. NEDAP, NL

This proposal is identical to one considered (but not brought into effect) in earlier discussions in the UK. The measurement distance is not specified in the text of the draft ERC Recommendation; in the original UK discussions, peak measurement of the magnetic field was specified at distances of **1** m (LF/MF) and **3** m (HF), and these distances will be assumed to apply. The equivalent *E*-field limits in the frequency range of interest are:

$$E \leq 40 - 7.7\,\mathrm{Log}_{10}[f_{\mathrm{MHz}}],\;\; 0.15 < f_{\mathrm{MHz}} < 1.6$$
$$E \leq 20 - 7.7\,\mathrm{Log}_{10}[f_{\mathrm{MHz}}],\;\; 1.6 < f_{\mathrm{MHz}} < 30$$

■ 2.4. IARU

This proposal specifies a flat limit of 0 dBμV / m at a distance of **10** m. The applicable frequency range is not stated — perhaps HF only?

■ 2.5. EBU etc

This proposal is not elaborated in any detail in the draft ERC Recommendation; it is based on the concept of allowing the present noise floor (assumed to conform with the ITU-R curves in Rec.P.372) to be increased by a limited amount (e.g. 0.5 dB). Clearly, if interpreted literally, this will protect radio reception by definition. It is not assessed further in this note, but a future paper will develop the idea.

□ 3. What protection does broadcasting need?

■ 3.1. 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 ratio*. 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 strength*. 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, dBμV / *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.

■ 3.2. 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 *x*DSL 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 40 dB 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

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

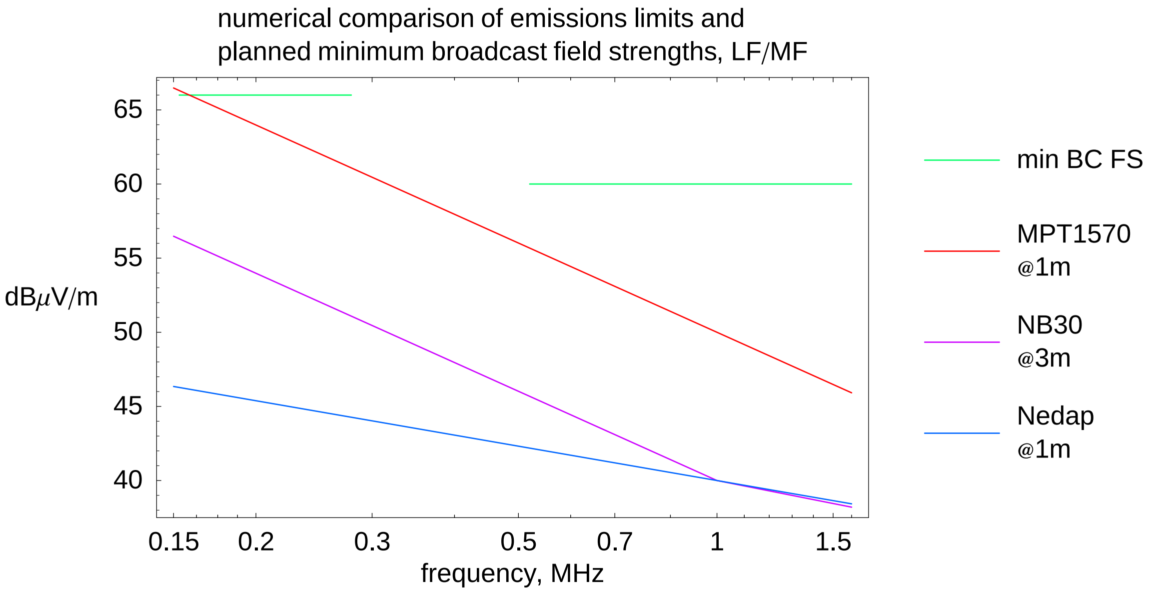
whereas proposed emission limits mostly relate to measurements of noise using a *peak* (not RMS or mean) detector. We may take it as a good approximation that the RMS noise level (for genuinely noise-like signals) is 10 dB less than the peak indication on the measuring receiver.

□ 4. The ‘protection’ given to LF/MF broadcasting by the proposals

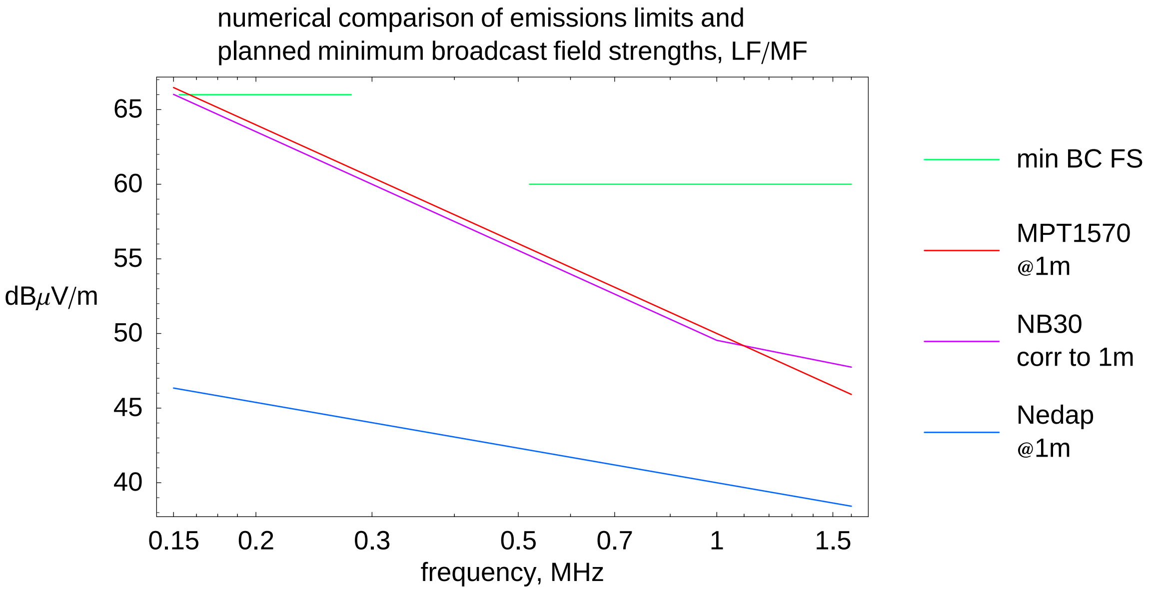
It is now instructive to compare the degree of protection that the various proposals afford to broadcasting.

■ 4.1. Plots of limits and minimum protected broadcast field strength

First we simply plot the numerical field-strength values as given. The frequency range encompassing both long and medium wave broadcasting is shown in the following graph (*next page),* with the minimum planned field strength shown for the two bands together with the various emissions limits.



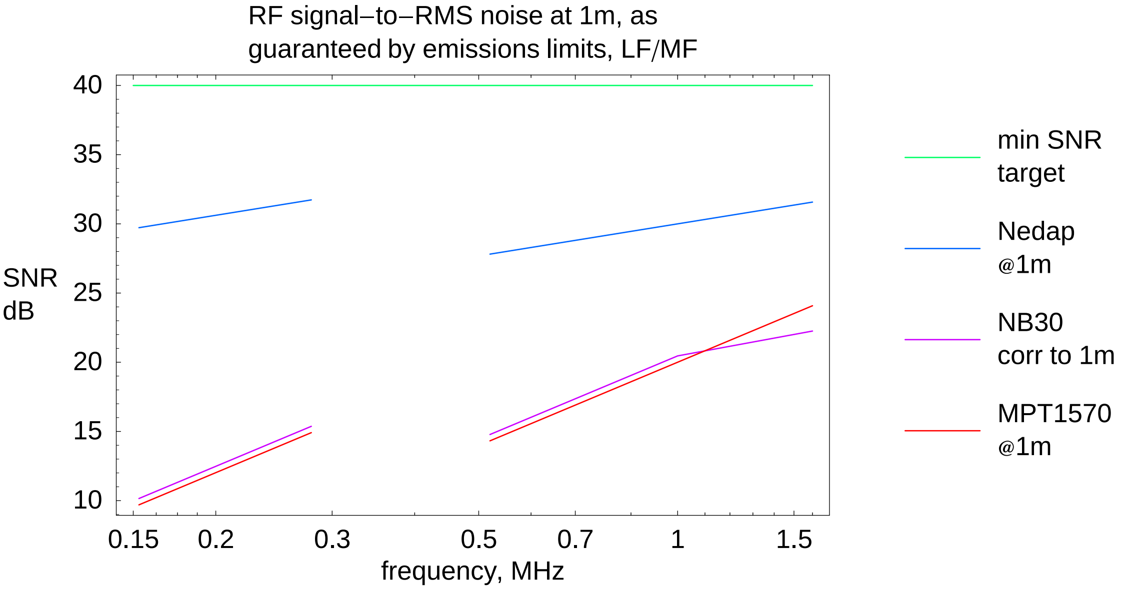
Note however that this diagram can be misleading. The NB30 limit is specified at a distance of 3 m, whereas the other two are specified at 1 m. It is customary to assume that the field falls off as $1/r$, whereupon a correction of $20\,\mathrm{Log}_{10}[3] \approx 9.54$ dB is appropriate to convert from one distance to the other. This is done in the following graph:



This now enables the protection given by the various limits at the distance of 1 m (representative of indoor listening) to be properly compared. It is clear that the Nedap proposal would give much greater protection than the other two — which are very similar. 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.

■ 4.2. 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. We include a correction factor of 10 dB under the assumption that the interference from *x*DSL/PLT/etc is Gaussian-noise-like in nature, for which the RMS value is about 10 dB less than the peak — which is what is regulated by the proposed limits. The resulting RF signal-to-RMS-'noise' values are plotted below:



Noting that a reasonable RF SNR target for LF/MF broadcasting is 40 dB, as identified earlier, we see that none of the proposals guarantees that this target is achieved.

The NEDAP proposal is best, achieving around 30 dB across the bands. This represents a loss of broadcasting quality but might perhaps be acceptable as a compromise.

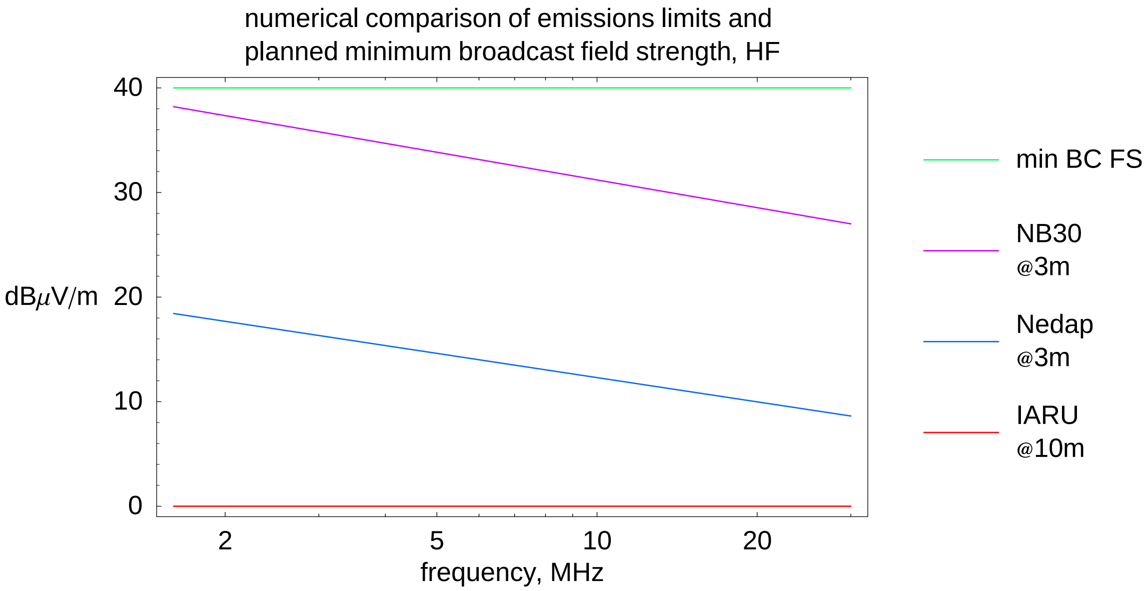
The NB30 and MPT1570 limits fall very far short indeed of the protection needed, especially at LF. An RF SNR of 10 dB would leave a signal of no entertainment value whatsoever. (Even an outdoor antenna at 10 m, giving a 20 dB improvement, would not achieve the target).

□ 5. The 'protection' given to HF broadcasting by the proposals

We now follow a similar procedure for the HF band.

■ 5.1. Plots of limits and minimum protected broadcast field strength

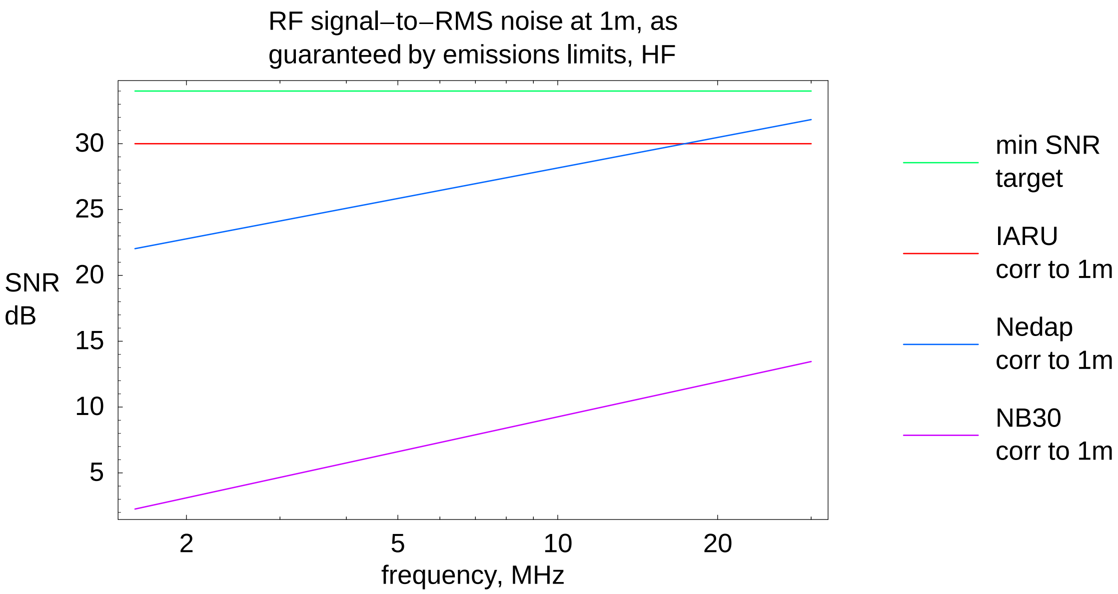
First we compare the various limit proposals and the minimum protected field strength, noting, as before, that the limits relate to the use of a peak detector and apply at different distances *(see graph on next page).*



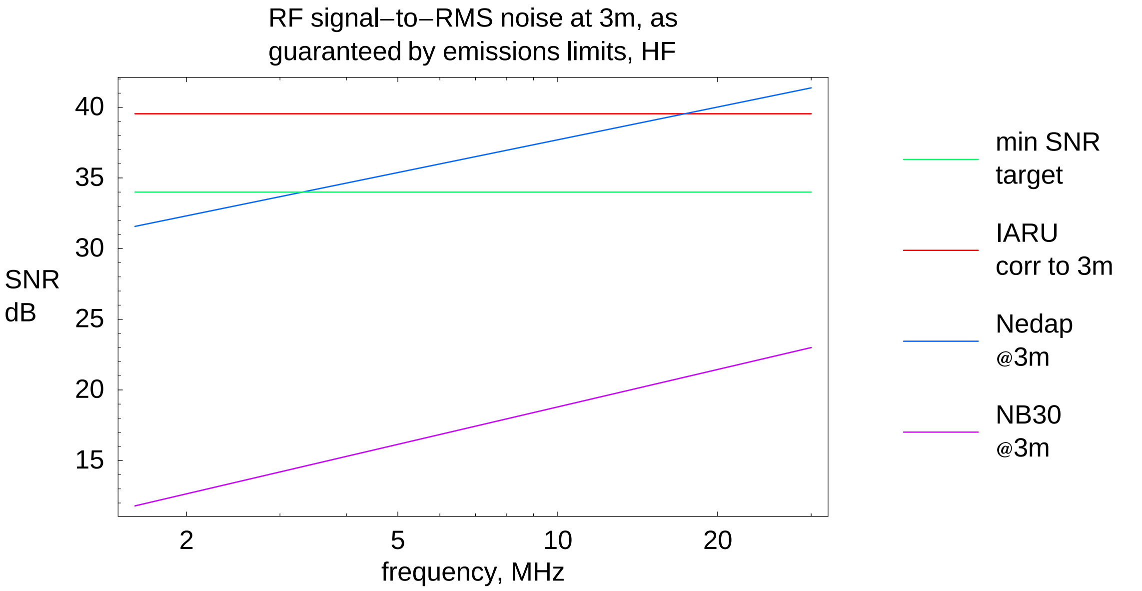
■ 5.2. Plot of effective signal-to-‘noise’ ratio that is guaranteed

We then derive the resulting RF signal-to-RMS-‘noise’ ratios as before. It is instructive to consider reception at three different distances from the interfering cable, once again assuming a $(1/r)$ dependence of field on distance. For LF/MF reception the use of portable receivers with built-in ferrite-rod antennas is virtually universal (excluding in-car reception), and so the distance of 1 m was a sensible choice. Most HF reception also uses built-in antennas (in this case a whip), but some users will have outdoor antennas.

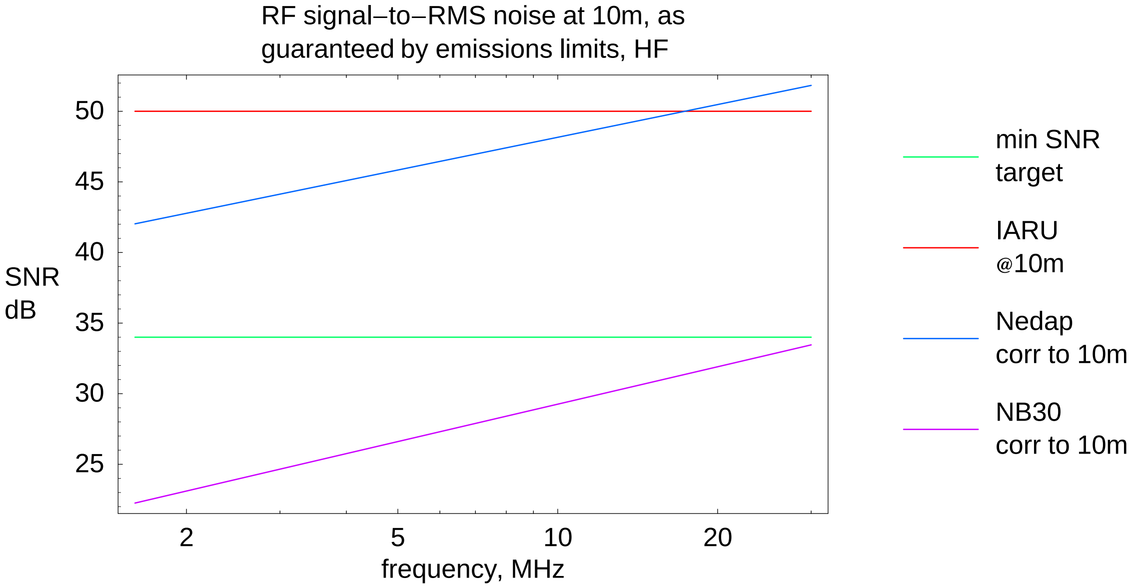
▫ Reception at 1 m



◘ Reception at 3 m



◘ Reception at 10 m



◘ Conclusions re HF reception

The three graphs are of course very similar, differing only in the absolute calibration of the vertical axis as far as the SNRs guaranteed by the various limits are concerned.

Taking an RF signal-to-RMS-‘noise’ratio of 34 dB as our target in this case we see that none of the proposals would ensure this is achieved at 1 m. The IARU is the best overall, as it gives a value of about 30 dB throughout the band. The NEDAP proposal is generally worse, except at the very top end of the band where it betters 30 dB. NB30 gives even less protection at these frequencies than it does at LF.

Things are gradually improved as the distance increases. For reception at 10 m, both IARU and NEDAP achieve the target, but NB30 still falls short, except at the very top of the frequency range.

The situation for indoor reception is clearly unsatisfactory, while NB30 does not protect even those listeners who have made the investment in an outdoor antenna.

◻ 6. 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 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!

The precise planning values for minimum field strength and SNR for DRM are still being refined in ITU-R TG6/7. No doubt these will be based on the existing ITU-R noise curves.

◻ 7. Conclusions

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

None of the proposals 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).

Further work is needed to develop a proposal which is enforceable and does provide adequate protection.

◻ 8. References

1. 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.

2. 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.