

A Pragmatic Approach to Setting Limits to Radiation from Powerline Communications Systems

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1. Abstract

Current EMC standards give limits above 30 MHz. Below this, only conducted emission limits are specified. Various proposals have been made for E- and H-field limits below 30 MHz with a view to protecting existing radio users from interference while enabling this potentially economically and socially valuable development to proceed. If limits are set such that the existing noise floor in the immediate vicinity of the powerline is not degraded at any frequency, then it becomes impractical to implement a powerline communications system. However, if a pragmatic approach is taken to set radiation limits, whereby the limit is set according to the frequency in question and the location of the nearest radio receiver, then powerline communications can be made to co-exist with existing radio systems. Experimental data is presented illustrating the signal levels required to achieve a reasonable reach on the cables and the likely radiated field strengths that would result in the near and far fields. A proposed standard is presented.

2. Introduction

The two companies Nortel Networks and United Utilities formed a joint venture in 1998 called NOR.WEB DPL Ltd to develop and market products in the field of powerline communications. In particular, the Digital Power Line (DPL) product is intended to give access to customers' homes using the underground low voltage distribution wiring from the substation. Early work by Dr Paul Brown (1) at Norweb (now United Utilities) demonstrated the feasibility of using the underground low voltage distribution cables for communication with carrier frequencies above 1 MHz. This was followed by co-operation between Nortel and United Utilities which resulted in a 15 user trial of a powerline communication system at Stanley Road in Manchester, which provided a telephony service to customers up to a range of 300m, operating in the frequency range 2-6MHz

The system was installed in 1995 and gave good service for the two year duration of the trial. Following the voice trial Nortel developed a system, which was aimed at providing a data service, in particular Internet access to the home. This system had the advantage that it could statistically multiplex packetised data, rather than relying on a circuit switched architecture. NOR.WEB has further developed this system and the product is currently being market trialled with a number of utility companies.

The Digital PowerLine data system operates in two frequency slots 2.2 – 3.5 MHz and 4.2 – 5.8 MHz. The frequencies were chosen to allow co-existence with other users of the HF band (2). It has been found by measurement that various sections of an underground powerline network, in combination with the overground connections to it, might act as a distributed antenna with a rather poor antenna efficiency (in the range –17 dB to –27 dB with respect to a dipole (dBd)). The low power spectral densities employed (approx. –40 dBm/Hz) ensure that interference effects are localised, but broadcast and amateur radio frequencies are avoided, since the near field effects at these frequencies would otherwise cause interference to radio receivers in the home.

Currently there is not an accepted standard limiting radiation from powerline communications systems. This is an area of active debate, with working groups set up in the UK and Germany involving powerline communications equipment manufacturers, HF radio users, and the radio regulatory authorities. The approach preferred by the regulatory authorities is to apply a limit to the radiated field strength, which follows a smooth curve with frequency, and does not include “chimneys”, i.e. higher limits at defined frequencies. This certainly is a straightforward approach, but unfortunately it would prevent the commercial development of powerline communications systems operating in the HF bands, since the limit would be set at a level necessary to protect amateur and broadcast bands, but applied in addition across the whole band. The argument put forward in this paper is that a pragmatic approach should be taken in setting the limit to radiation, whereby the limit is set at a level which will be different according to the frequency and the geographical location. This is certainly a more complicated and inelegant approach and has been accused of being “piecemeal”. However, it is necessary in order to allow commercial exploitation of powerline communications systems. This can be done without causing interference to existing radio users, provided that a pragmatic approach is taken in setting the limits (3).

The economic benefits offered by the system are as follows:

- EU economy - British product - made in Northern Ireland - world market
- Local loop competition - without digging up streets
- Fast data to homes, schools, small business - low cost
- Makes the Internet useable
- Supports “life long learning”
- Reach beyond the major conurbation
- E-commerce
- Home working
- Community development
- Energy management and environmental improvement
- Telemedicine
- Home security and automation

3. Objective of Limits

The purpose of setting a limit to the radiated field is the resolution of disputes, in which a radio user is experiencing a problem. The question is whether the radio user is at fault in terms of his equipment or whether the interference levels from the powerline system are too high. The proposed method is that the radiated field from the powerline is measured at the victim receiver, and the received radio signal strength is also measured at receiver. If DPL emissions are above the proposed limit, then the DPL system is at fault. If the received radio signal field strength is below standard, then the radio system is at fault. The field strength at 10m from installation is of no special significance, but is useful as a reference level.

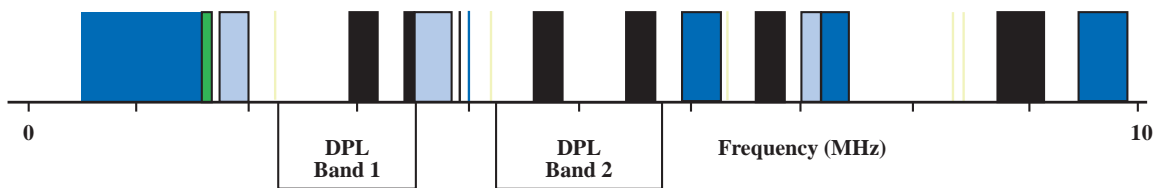
4. DPL Effects

There has been some concern expressed that the DPL system will cause a “general raising of the noise floor”, thus polluting a “natural resource” and preventing its use by radio systems. In investigating the effects of the DPL system on the radio environment, we should consider three cases:

- 4.1 Near Field
- 4.2 Line of Sight Far Field
- 4.3 Over the Horizon (Sky Wave) Far Field

In each case the emissions should be below the limit *measured at the victim receiver* at all *applicable frequencies*, if interference is to be avoided. We intend to show that in each of these cases, DPL will not cause a problem to radio users.

First let us consider the existing allocation of the HF frequency band. This is illustrated below. It should be remembered that the entire band is, of course, allocated, but only portions of it as indicated are in use by the general public. The DPL system operates in two carefully controlled bands, which avoid broadcast and amateur radio frequencies. It is at these frequencies that the near field effects would be relevant in a residential area.

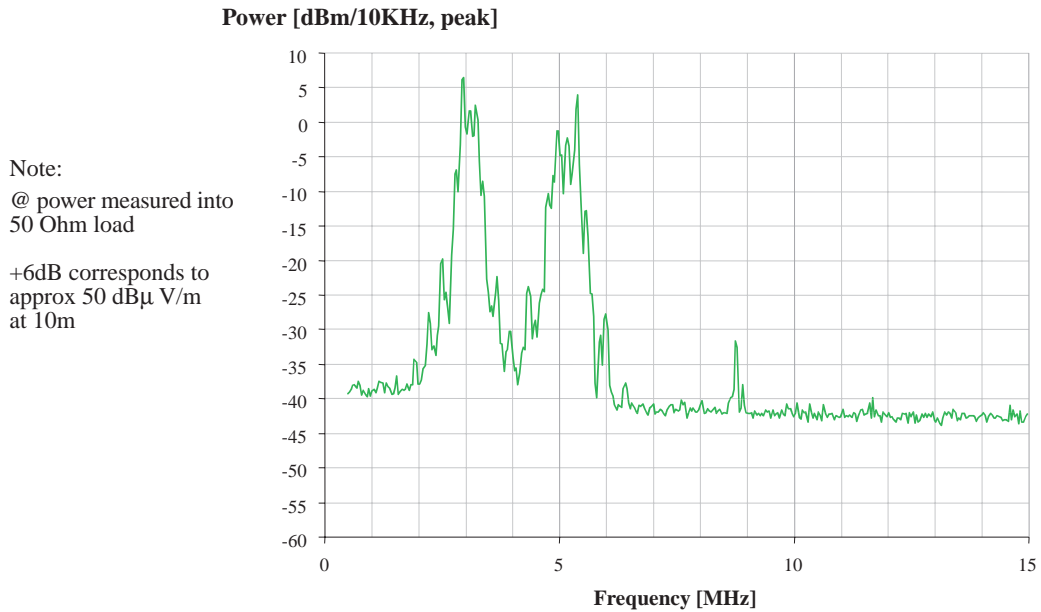


Key Spectrum Usage 0 to 10 MHz for ITU Region 1 : Civilian Use

- DPL System avoids frequencies received in homes

Key:	
Protection needed in user premises	
Broadcast	
Amateur	
Cordless phone	
Distress	
Farfield Protection needed:	
Aeronautical	

Output Spectrum of DPL (Conducted Signal)

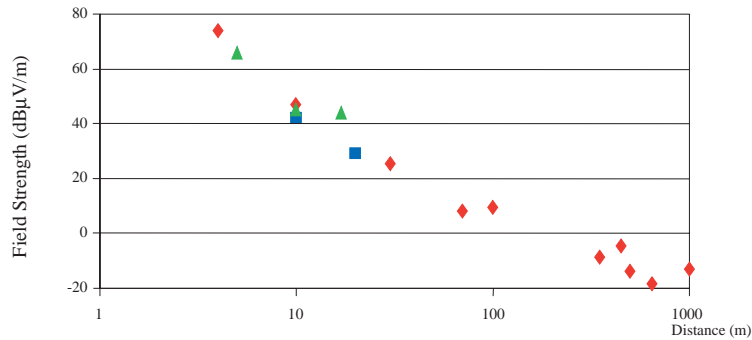


DPL Occupies Two Carefully Controlled Frequency Slots

The levels of emissions from the powerline have been extensively studied and typical results are given below:

4.1 Near Field Emissions

The first case to consider is that of near field emissions. The levels of emissions from the powerline at 10 metres and beyond have been extensively studied and typical results are given below (independent tests by the ERA confirm these findings):



Radiated Emissions at 10m from DPL system:

50 dB μ V/m* in band (but no receivers at this distance, at this frequency)

* 80% of equipment, 80% confidence

Key :

Measurements from a variety of sites in the UK and Sweden

▲ Sweden

■ Sweden

◆ Manchester

4.2 Line of Sight Far Field (Cumulative)

The second case to consider is line of sight far field effects. This has been modelled making reasonable assumptions on number of equipped substations per square kilometre, mean transmitted power, and antenna efficiency of the powerline (measured by conducting a flight trial over Manchester).

It has been concluded that powerline noise will not degrade aircraft HF reception. Also at the ground level, there will be no general raising of the noise floor in the far field. The signal strength reduces in relation to the distance, to the power of -2.5 , and therefore contributions from distant substations are negligible.

4.3 Over The Horizon Far Field (Sky Wave)

The third case is the over the horizon far field radiation. Propagation studies have shown that DPL will not significantly degrade the noise floor due to over the horizon propagation. This is a specialist field, and we refer to a paper by Widmer (4). This paper concludes that if all substations in Germany are equipped with a powerline comms system, if the power spectral density is -40 dBm/Hz (as is our system) and if a 10 dB factor is allowed for power control and traffic activity, then noise floor due to sky wave is not significantly degraded.

5. Efforts to Reduce Radiation

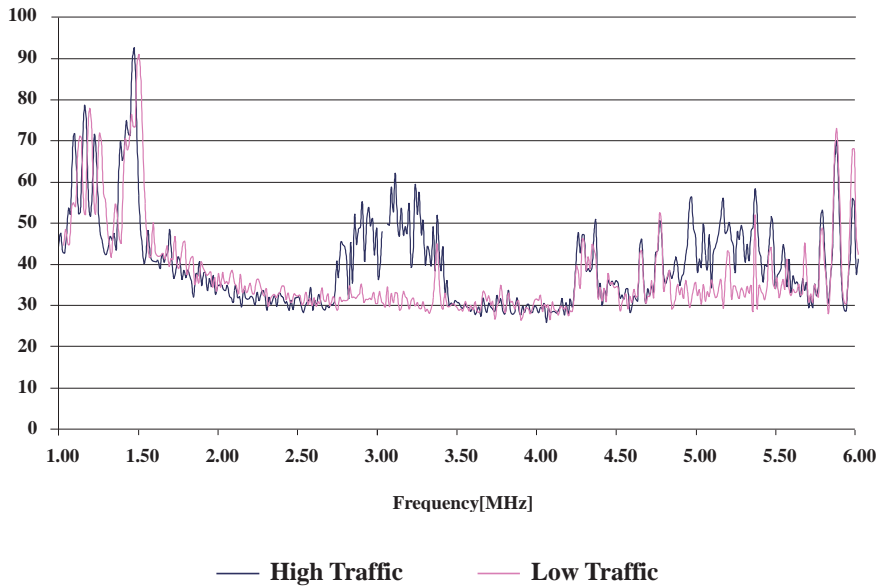
In making the case for the proposed radiation limits, we need to show that due diligence has been taken in reducing the radiated limits to the minimum that is consistent with offering an economically viable system. In the pursuit of this aim, the following techniques have been investigated:

- 5.1 Reduced background polling frequency (traffic activity factor)
- 5.2 Filters
- 5.3 Reduced power
- 5.4 Repeaters
- 5.5 Power control
- 5.6 Spread Spectrum

These will now each be considered in turn:

5.1 Traffic Activity Factor

This limits the transmit periods in line with the users' real-time data transmission requirements, therefore reducing the mean transmitted power. Activity may be reduced by up to a 50:1 ratio, although at times of peak traffic, little reduction is possible.



Measured spectrum
(@ approx 3m from
powerline system)
At high and low
data traffic states:
note reduction at
low traffic state.

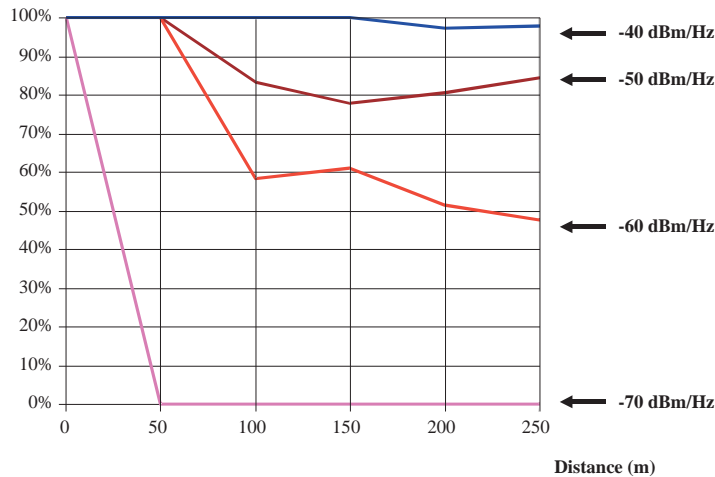
5.2 Filters

Filters can be installed to isolate sections of the powerline which have a higher radiation efficiency, in particular overground sections such as the wiring inside premises and also street furniture. This technique may have some value in reducing “hotspots”, but filters are very expensive to install and if they were used widely the system would become uneconomic. Also, the effectiveness of filters in reducing radiation is very variable in practice, since it is difficult to filter out common mode components.

5.3 Reduced Power

It is clearly necessary to reduce the transmitted power spectral density to a minimum in order to minimise radiation from the powerline. The degree to which this can be done however is limited by the variable transmission properties of the cables, so that in order to get reasonable percentage coverage, it is necessary to use power levels as shown below:

% Coverage vs Distance vs Power



Note : DPL Band 1

Note : Power spectral density of -40 dBm/Hz required for economically viable system (50mW total)

5.4 Repeaters

It is proposed to use repeaters as part of the DPL system, in limited circumstances. These:

- Extend reach for a given power
- Reduce data speed to users, but do not occupy additional spectrum
- But the costs are significant
- Numbers required increase exponentially as reach falls
- Uneconomic for large scale use

5.5 Power Control

Power control is an effective way to reduce the mean, rather than the peak level of radiation from the powerline system. This will reduce the cumulative effects in the far field.

- The present power level is required to reach furthest units
- Closer units could operate with lower power levels
- Requires significant hardware and software revisions
- Plan to build into future versions
- Will reduce mean emissions
- Will not impact peak emissions

5.6 Spread Spectrum

Spread spectrum systems can in principle reduce power spectral density by occupying a wider frequency band. E.g. If they occupy ten times the bandwidth, they can transmit ten times less power per Hertz, i.e. 10 dB less *assuming no increase of attenuation with frequency*.

Unfortunately, on underground cables the attenuation increases rapidly with frequency.

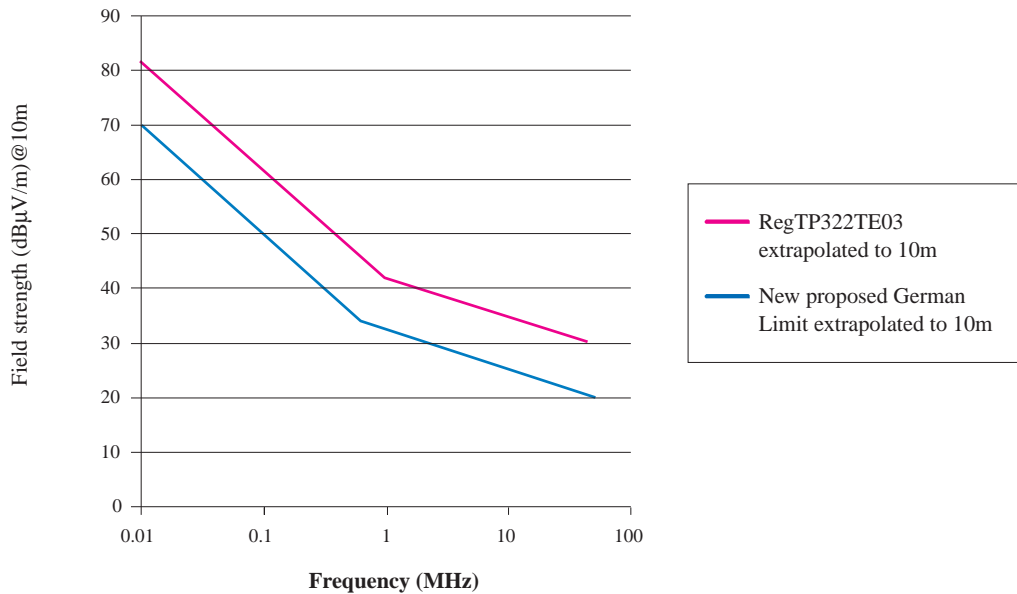
Studies show that spread spectrum systems give no benefit in reducing radiation with this degree of frequency slope.

6. Proposed Standards

To put the proposed limits for DPL emissions in context, let us consider some existing standards:

	Limit dBμV/m@10m	Reference
FCC	48.6	FCC pt 15
DPL (mean)	50	Measured
Single light	64	EN 55015 Chimney limit for Philips lighting
Arc Welders	80	EN 50199 Level at 30 MHz
Induction furnaces	85	EN 55011 Deduced over DPL band 1
Trains & trams	90	DD ENV 50121-2 E field derived from H field limit in DPL band 1

6.1 German Proposed Limits



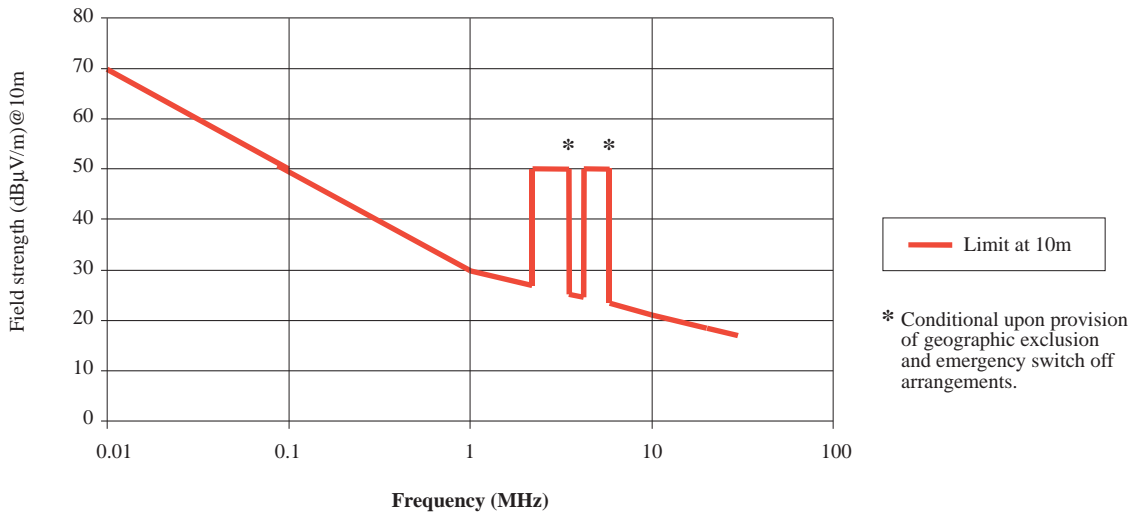
Note : The above is a general limit, but the regulator is considering exceptions with conditions attached at certain frequencies and locations.

6.2 Digital PowerLine Proposal

We envisage that general standards would be set providing low level limits below which any use of the spectrum is permitted. Where higher levels of emission are required then it is necessary to consider the specific frequencies involved and the way in which they are used in order to determine acceptable emission levels. By taking this pragmatic approach, interference to radio systems can be avoided and the exploitation of Powerline Communications as an economically and socially valuable access medium can be enabled.

Specifically, we propose a “chimney” exception for DPL allowing up to 50dBµV/m at 10m within the frequency bands 2.2-3.5 MHz and 4.2-5.8 MHz, which would be conditional upon provision of geographic exclusion zones and emergency switch off arrangements. An example of the resulting field strength limit mask is given below. In this case, the stop band limits are based on the German RegTP proposed limits.

6.3 Example of Proposed DPL limit at 10m



Example of Proposed DPL Limit

Note 1: "Chimneys" are treated as local exceptions to a general standard (Proposed RegTP German standard)

7. References

- 1) "High frequency conditioned power networks", Dr Paul A Brown, Proceedings of UTC Annual Conference, pp 213-229, July 31-August 4, 1995.
- 2) "Coexistence of Wideband Carriers above 2 MHz on the LV Distribution Network with Radio Systems", R.P.Rickard, Powerline Telecommunications Forum, Dusseldorf, 25 Nov 1997.
- 3) "Vorlage für eine Stellungnahme zur Mitteilung 1/1999 der RegTP Anhörung zum Entwurf der Frequenzzuweisungsplanverordnung" (Submission for a statement on the report 1/1999 of the RegTP Hearing for the draft of the frequency assignment plan regulation), Prof. Dr.-Ing. habil. K. Dostert, Institut für Industrielle Informationstech, Universität (TH) Karlsruhe.
- 4) "On the Global EMC Aspect of Broadband Power Line Communications Using the HF Frequency Band", Dr. H. P. Widmer, Ascom Systec AG, Online 99 conference, Dusseldorf, 4 February 1999.