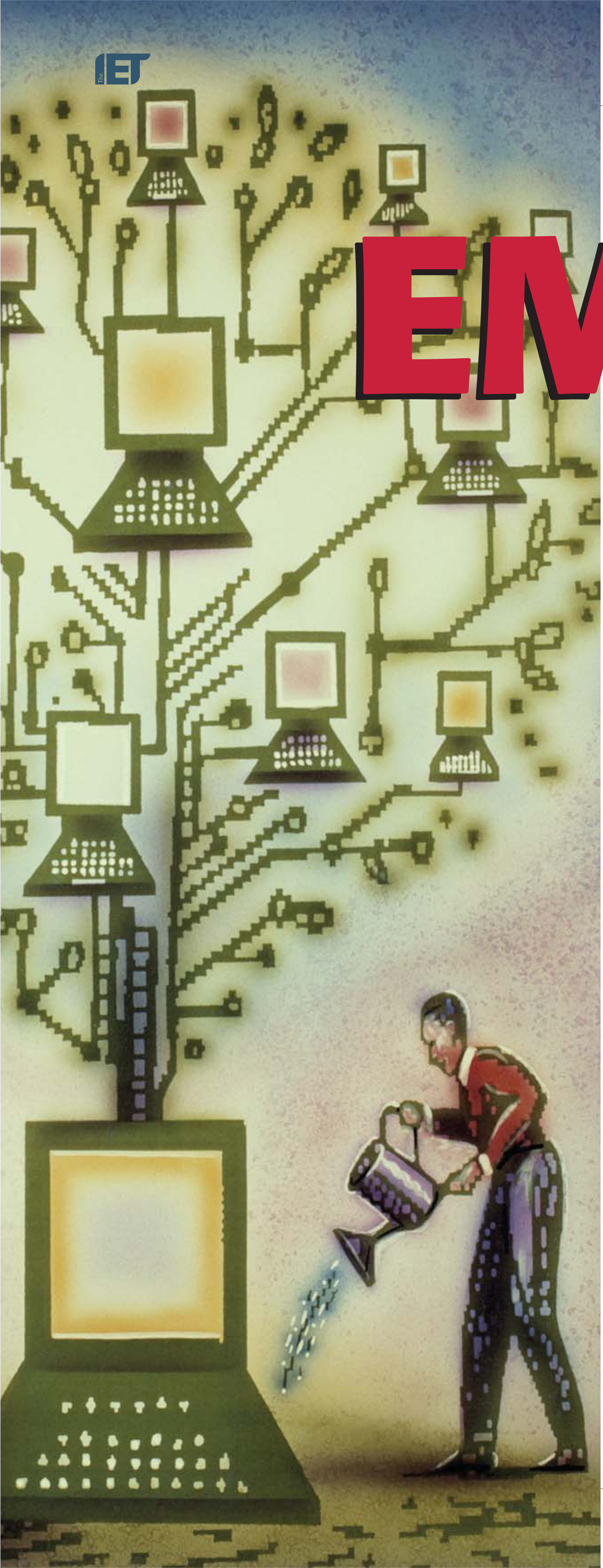

# EMC of Networks

COMPETITIVE PRESSURE TO PROVIDE FASTER DELIVERY OF EVER MORE SOPHISTICATED SERVICES OVER EXISTING NETWORKS HAS TO BE MODERATED BY CONSIDERATION OF ELECTROMAGNETIC LEAKAGE, ARGUES **RICHARD MARSHALL**

Wired data networks have proliferated, as computing has proliferated, in commerce and in the home. Their required data rate has been driven steadily upwards. Potential electromagnetic leakage from these networks alarms the users of the radio spectrum and raises serious problems for all parties.

Until computers appeared on every desktop, data networks were either very low-speed or they were carried on dedicated shielded cables. The original Ethernet local area network (LAN) for office deployment also used shielded cable and operated at 10Mbit/s, but this was quickly replaced by twisted pairs. At first these were operated at 10Mbit/s, but cable and line coding improvements coupled with market demand have made 100Mbit/s the norm and 1000Mbit/s is now available.

*Local area networks are subject to the CISPR22 requirement that sets a limit on the common-mode voltage or current launched onto the cable. For disturbance converted by the cable itself from its differential-mode signal the standard allows a 10dB relaxation. This is to be reviewed in the light of experience.*

Wider-scale networks initially used dial-up telephone lines with much the same spectral content as speech, but the last few years have seen a dramatic growth in broadband xDSL usage of the same circuits at much higher data rates. For the greater part, downstream frequencies of 138KHz to 0.5MHz or 1.1MHz are used, while the slower upstream transmission of the asymmetrical data-rate signal fits in below 138KHz. However, the desire to offer xDSL to a larger percentage of telephone subscribers (and to provide services such as video on demand) has lead to improved coding efficiency and is also pushing up the frequency spectrum usage of telephone line data services: they are rising to 2.2MHz (ADSL2+) from the exchange and, in future, will rise up to 7MHz in the UK (VDSL2) from the street cabinet. These recent enhancements make better use of the spectrum and have been taken note of Electromagnetic Compatibility (EMC) by using much lower powers at the higher frequencies than are in current use at the exchange. Taking the UK as a whole, only one case of interference from xDSL has been reported.

Domestic LANs across the existing power wiring are now manufactured to various specifications, one of which is that of the 'Homeplug' Alliance. This system uses the frequency range from 4.49MHz to 20.7MHz with notches to protect amateur radio, but there is no protection for short-wave broadcast or point-to-point services. The system is seriously handicapped by the use of mains cabling: such cable exhibits large attenuation at these radio-frequencies; its configuration leads to cable resonance, reflection and radiation, and it is not economically practicable to install the high-current filters that would be required to isolate it from the street power distribution network.

The system must operate also in the electromagnetic environment of the mains network. This is polluted by other interferers, many of which conform to the same emission standards as should be applied to a mains-network LAN. To achieve a useful signal to noise ratio, such a system necessarily requires a higher emission level, which, if allowed, would lead to appeals from other interferers for similar treatment. If granted, these would nullify the desired benefit. Only innovative data coding can help with this problem. The Homeplug Alliance system specification does not ensure conformity to any formally-approved international EMC Standard.

In the wider area, Power Line Communication (PLC) or Telecommunication (PLT), or Broadband over Power Line (BPL) as it is known in the USA, has had a chequered history. It generally operates at lower frequencies than do in-house systems, though BPL has been reported to use frequencies up to 80MHz. The limitation of only one circuit per substation that must be shared by all the connected data-users results in pressure for high launch power and wide spectrum usage. Because of the lack of filtering between premises, the data signal is introduced with equal power into the premises of non-subscribers also.

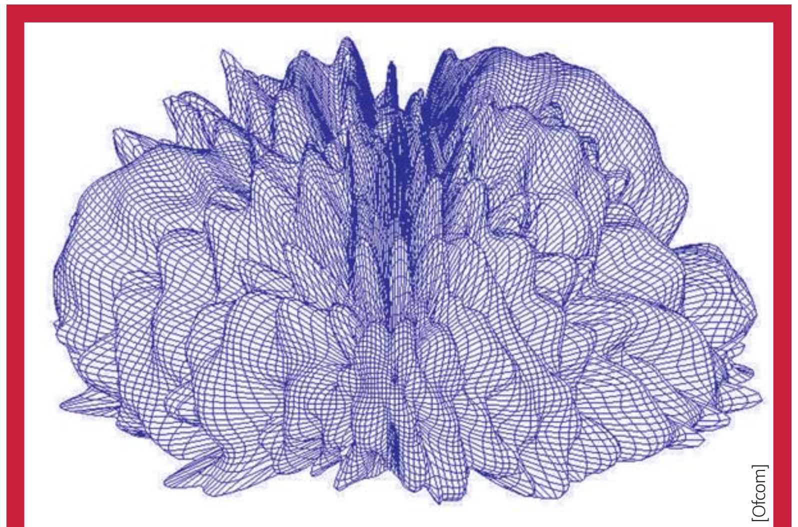


*Fig 1: A 3D logarithmic plot of the vertically polarised radiation from a wide-band source totally enclosed in a computer desk-top case. The plot is recorded at 5GHz where each case dimension is several wavelengths.. On theoretical grounds, a radiation pattern of comparable complexity is to be expected from a data network, though because the network is so much larger this pattern will be evident at a much lower frequency.*

## WHY NETWORKS ARE DIFFERENT

From the EMC point of view a network is an entity that is large compared with the wavelength of any interfering emission or susceptibility. This is the same basic problem that was considered for small products in the article 'EMC above 1GHz' in *Communications Engineer* Feb/Mar 2006. But the problem is scaled a thousand-fold down in frequency and proportionally scaled up in physical size.

On theoretical grounds, the complex radiation pattern shown in fig 1 is to be expected here; but it would be manifest at only a considerable distance where measurement in the presence of other signals would be extremely difficult. →

[Scottish and Southern Electricity]

A repeater installed in a customer's meter box at a Power Line Telecommunication (PLT) trial installation. For this particular system the repeater was required to translate data signals in the 1.9 to 11.3MHz band from the street cables up to 18.7 to 25.1MHz for in-house distribution. Note that the repeater input and output share the same wires and there is no filtering to separate the street signals from those indoors. For economic reasons this feature is common to both in-house and access PLT.

> "Taking the UK as a whole, only one case of interference from xDSL has been reported"

The mathematics of antenna theory distinguishes between the near-field and far-field situations. The frequencies range and the practical limitations on victim location and test measurement distance mean that both field situations are relevant to real interference scenarios. The analysis is then very complex and has yet to be reduced to a set of rules useful to the EMC engineer.

Broadly speaking, EMC emission standards define the maximum permissible electric field strength due to unintentional emission. This is measured close to a single product in a bandwidth matched to that of a potential 'victim' radio or TV receiver. Networks are different in several respects:

- They comprise a number of interference sources spread over a wide area. It is entirely possible that the point of greatest emission is a long way from those who gain benefit from the data. This feature is exacerbated for mains power networks as these have a branched configuration and include many potential point sources such as joints and tees that will have been engineered without consideration of their radio-frequency characteristics.
- Unlike classical interferers such as hair-dryers, broadband data networks are usually energised 24 hours per day. Statistical considerations of the probability of interference underlie the standards for product EMC and these are inappropriate here. Despite this, network designers do not always optimise the transmission formats to minimise emission when the channel is idle or only lightly loaded.
- In the quest for maximum data-rate, a network is driven with the maximum allowable power over the whole of the chosen frequency band. What is allowable may be defined within the system (see box below) or by external environmental considerations. This is a very different situation from that of an 'unintentional emitter', such as a computer clock, that emits only at a very few frequencies and once again classical EMC standards are inappropriate.

All three factors suggest that the total radio frequency emission from a network is much greater than that of a simple product that meets the same field strength limit. On environmental pollution grounds, would it be better to specify, say, the total emitted power per half-octave of bandwidth?

## SELF-DISCIPLINED

Networks based on telephone cables are inherently self-disciplined by cross-talk between circuits. This is emphasised by the need for co-existence in the same cable between different technologies providing different services and, with local loop unbundling, different service providers. This discipline is provided by European and global xDSL product standards and the UK Access Network Frequency Plan. Accordingly national or international EMC regulations are of only secondary importance.

[British Telecommunications plc]

*The termination block of an external cable on the main distribution frame at an exchange. The various colours of jumper wire carry different services such as broadband ADSL and ISDN as well as the normal telephone service*

## THE ROCKY ROAD TO STANDARDS

CATV (cable television) has a well-established European Standard EN50083, and the use of power cables for low-speed data below 148.5 KHz is governed by EN50065. Broadly speaking, both these standards limit emission to an extent comparable with the generic standards that underlie most product standards.

Broadband xDSL (ADSL and VDSL) was subject to thorough discussion in the UK which resulted in the draft national standard MPT1570. In Germany, standard NB30 was formulated. The implementation of both these was postponed to give time for EC implementation of a common standard.

These standards are broadly acceptable to radio users but none of them provide sufficient headroom for the operation of high-speed networks using the existing mains wiring. This is a major issue. Many qualified observers have commented that the desires of radio users and mains-communication proponents are 60dB apart and that a compromise would destroy the prospects of both radio services and PLT. This general situation has been discussed at a Seminar hosted by the IET's Professional Network for EMC (see web links at the end of this article).

The approach to standards has been on two fronts: towards a product standard for a modem that might interface data to the mains cable and towards a network standard that would specify an acceptable level of emission from a cable.

The modem product standard would appear as an amendment to the international CISPR22 standard for information technology equipment, within which it would be specified as a definition of the interface to a 'multifunction port' for both power and data. The appropriate sub-committee has found it difficult to reconcile the existing line-to-earth emission limits as measured via a 'V' network for mains-borne interference with the much higher line-to-line limits desired for PLT. These higher limits are vital for the viability of PLT because data signals must achieve a certain signal to noise ratio. As coding technology develops, the minimum ratio may be relaxed but there is also pressure to divert such development towards achieving higher data rates.

Within CISPR, higher line-to-line limits must assume a degree of balance in the mains network that has yet to be demonstrated convincingly. The argument is made complex by the lack of an acceptable measuring method for power line balance and by the evident physical differences among mains networks. Last year, in the face of the official IEC time limit of five years for the development of a standard, the first period for developing an amendment to CISPR22 for PLT timed-out because of the difficulties in achieving consensus across the 60dB divide. Because the issue remains critical, CISPR will continue study into a second five-year period and, accordingly, a new work item has been established.

In 2001 the European Community mandated the European Telecommunications Standards Institute (ETSI) and the Comité Européen de Normalisation Electronic (CENELEC) to set up a Joint Working Group (JWG) to establish a standard for the permitted emission of data networks →

## INTERFERENCE TO AND FROM DIGITAL SYSTEMS

When interference disturbs a digital system it is extremely difficult to determine the cause from the effect. If a TV picture freezes or goes blank, then the viewer is given no clue about the reason and may not even recognise this as interference. Accordingly, the number of reported cases of interference substantially understates the true situation. This is just as true for cellular phones as it is for digital TV and handicaps the tracing of culprit emitters and the collection of statistics to support the limits in EMC standards. Both culprits and victims should embody more diagnostics.

[Scottish and Southern Electricity]

The practical problems in measuring the radiation from data networks include deciding on a representative measuring distance and then gaining access to it.

viewed as passive installations of cable. Using 'level playing field' arguments that appeared to be aimed at enabling the roll-out of a competitive technology rather than being purely technical, the EC stated that this network standard should be applied to all networks including CATV, xDSL, and PLT. The mandated standard was to be harmonised under the EMC and RTTE (Radio and Telecommunications Terminal Equipment) Directives, although some commentators doubted whether existing networks could be brought within its scope.

Under this mandate, the JWG has produced a number of drafts for consideration by the national representatives of its two parent organizations. None of these has proved acceptable since the 60dB divide still remains.

Last year, the JWG sent out a 'final' draft EN50471 from which the radiated field limits below 30MHz had been removed in an attempt to reconcile the conflicting views.

Some of the conflict had related to the difficulties in making measurements of field strength, and so national representatives were offered limits on common-mode current ("longitudinal mode current" in telephone parlance) only. In the case of a single pair cable, such a measurement is relatively easy to make but the draft was unclear about how the limit would be applied to any more complex configuration such as three-phase power or multi-pair telephone cables.

> **"A common-mode current limit is not in the public interest, nor in the interest of technological progress"**

The translation between common-mode current and radiated field is subject to enormous uncertainty due to the antenna properties of the cable. These vary according to its topology and proximity to other objects such as cable shields, other cables, metallic ducts and bulk earth or building materials. Accordingly, the statistics of interference are just as important as the absolute limit values.

The removal of the radiated field limit can be interpreted as a transfer of most of the uncertainties from the standards writers and the network owners to the potential victims of interference. Since the EU EMC Directive seeks to control electromagnetic disturbance so that it "does not exceed a level allowing radio and telecommunications and other apparatus to work as intended" one could reasonably conclude that this cannot be achieved by a common-mode current limit, unless the standard set this at an unreasonably low absolute value. Furthermore, a common-mode current limit removes from the owner any benefit from improved engineering practice in the network implementation and maintenance that might minimise radiation. This is not in the public interest, nor in the interest of technological progress.

ETSI and CENELEC separately consulted their national representative groups about their joint draft. The UK's response to ETSI came from a group convened by Ofcom, and that to CENELEC from an ad-hoc committee with representatives from British Standards Institution product committees together with Ofcom and the Department of Trade and Industry. The two groups submitted substantially similar comments.

Taking Europe as a whole the various national committees expressed many conflicting views about the draft. These included comments that the subject was not yet sufficiently mature to permit standardisation.

It is understood that the standard is not to be put to a formal vote and that work on it is suspended until developments justify resumption. In the UK, Ofcom and the DTI had already held a meeting with interested parties to explore the options should this happen. There was seen to be a case for a national enforcement document covering interference from networks – but the devil will be in the detail.

In conclusion, network EMC is a systems problem. For example, the EMC issues could be minimised by improvements in data coding, and the particular problems of PLT could be minimised by the availability of low-cost mains filters.

Timing is crucial in the co-development of new services and standards, but this is a problem that can probably be solved only by the wider acceptance of the simpler, more generic standards that are more independent of product and network technology.

The difficulty in establishing interference levels for use within standards is being increased by the spread of digital systems, which cannot assist their users to identify problems, and by the unwillingness of administrations to spend money on collecting and interpreting interference data as an input to the standardisation process.

Given the present hiatus in European and international network standards development, it may be necessary to re-visit national enforcement standards, extending those already in place to meet the new requirements.

Success in these efforts will be as important to those taking financial responsibility for new networks as it will be for our environment. ■

**Richard Marshall, MA, C Eng., FIEE is MD and principal Consultant of Richard Marshall Limited www.design-emc.co.uk**

**For web links to more information, go to www.theiet.org/communications, and click on Features to go to the weblinks for this issue**