EMC above 1GHz

ELECTROMAGNETIC COMPATIBILITY AT HIGHER FREQUENCIES IS AN ISSUE OF INCREASING IMPORTANCE, WRITES **RICHARD MARSHALL**

A calibration set-up for microwave emission testing. The Equipment Under Test (left foreground) is a reference source of wide-band noise. The measuring antenna (centre right) is a double horn. In the background is a TV camera

While the need for electromagnetic compatibility (EMC) above 1GHz has long been appreciated by the military, it has only recently become of wider concern. The upward march of computer clock frequencies (and their harmonics) and the massive deployment of radio users of these frequencies (such as cellular telephones and wireless data networks) have fuelled this concern. Interference issues have assumed considerable economic importance in view of the high prices paid for licences to use this part of the spectrum.

The totality of EMC testing has to take account of emission and immunity in up to five dimensions – the three dimensions of space and those of frequency and time. Frequency, when translated into wavelength (frequency in MHz = 300 / wavelength in metres) and compared with the size of the equipment under test (EUT) determines the radiation pattern of the EUT and so this ratio has long been used to determine an appropriate test and specification strategy. When the largest dimension of the EUT is much smaller than the wavelength, the EUT radiates much less efficiently than do the connected cables and the three spatial dimensions of test may be collapsed onto these cables. In the middle frequency range – generally taken as 30 to 1000 MHz – the standards and test communities have made considerable investment in radiated field strength test methods appropriate to open area test sites and to anechoic or semi-anechoic rooms.

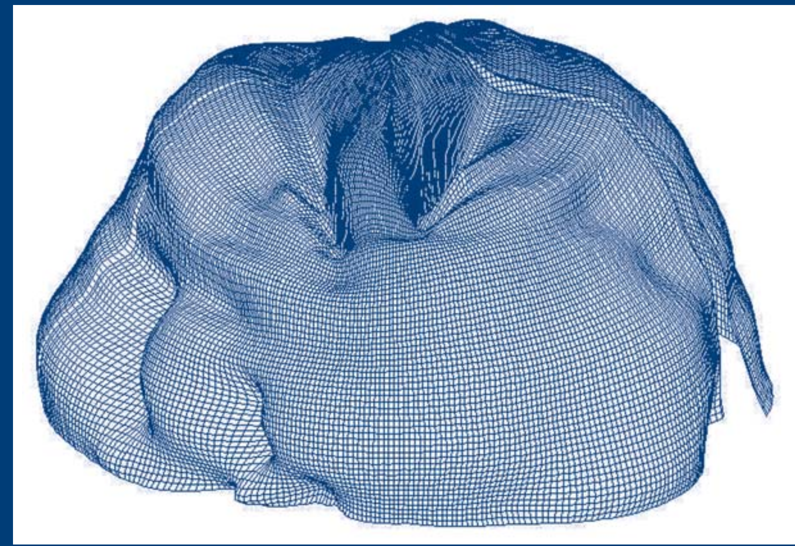
There have always been difficulties in dealing with physically large equipment such as telephone switching centres, data network cables, and electric railways, and the need to establish testing of everyday electronics above 1000MHz (1GHz) has brought these objects too into the "large compared with a wavelength" category. This may be understood from the two plots (see opposite page).

The world's standards bodies have been studying this problem for many years, and the IEE's professional network for EMC provided an update at a seminar on "EMC above 1GHz" on 29 November 2005. This was held jointly with the National Physical Laboratory Freemet Club and hosted by NPL at Teddington.

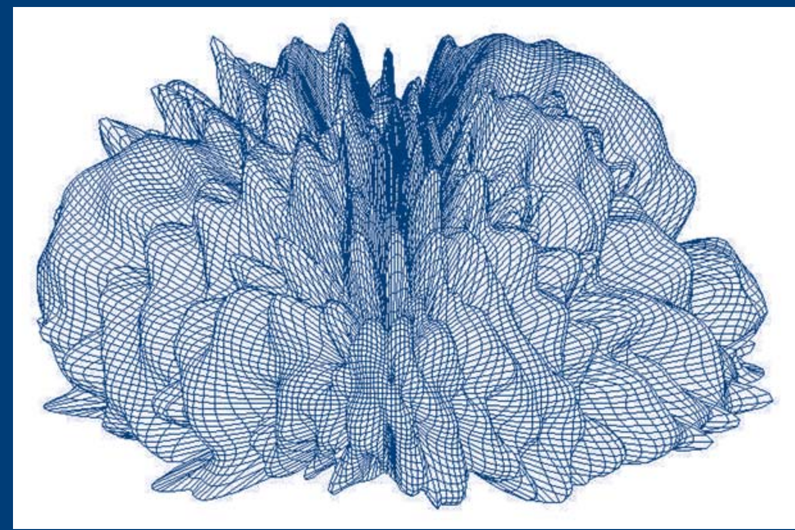
The programme covered the recent developments in commercial EMC Standards within the CISPR (Comite International Special des Perturbations Radioelectriques), the international body that deals with radio-frequency interference standards. This was complemented by presentations on the understanding gained by test houses and the military in the design and evaluation of products up to 6GHz – and in some examples up to 18GHz.

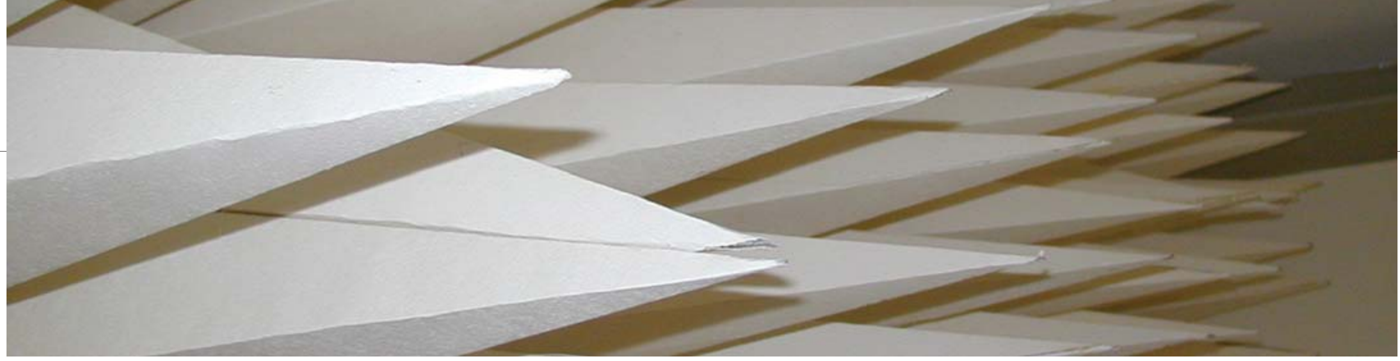
CISPR has decided to extend the methods used at lower frequencies rather than adopt the newer total power measurement approach of the stirred mode or mode tuned reverberation chamber. A method for measurements above 1GHz was approved in April 2005 and published in CISPR 16-1-4. Although measurement using two antenna heights has been shown by NPL and others to reduce substantially the uncertainties due to the complexity of the radiation pattern of an equipment-under-test (EUT) at microwave frequencies, nevertheless the approved method is based on the use of just one antenna height and so stands a good chance of missing off-boresight radiation. Also, because of the test geometry it appears not to give proper weight to emission from the top and bottom of large rack-mounted equipment.

The limits up to 6GHz published in CISPR/I/130RVC have also been approved recently. These limits are the result of pressure from mobile phone manufacturers on the one hand and IT and multimedia product manufacturers on the other, against a background of →



These graphics show 3-dimensional logarithmic plots of the vertically-polarised radiation from a wide-band source totally enclosed by a desk-top case that had originally been occupied by a computer with a 133MHz clock frequency. The plot above has been recorded at 1GHz where the case depth is approximately one wavelength. Traditionally this would be the highest frequency for civilian measurements by this method, and radiation is arguably uniform apart from a tendency for reduced emission in the vertical direction that no doubt results from the superior electrical continuity of the wrap-round top cover. However, the plot below at 5GHz, where the case depth is approximately five wavelengths shows considerable complexity due to the addition and subtraction of variously-phased radiation from different parts of the case. It becomes seriously difficult to suggest that measurements taken only in the horizontal plane could properly characterise this product as a 'culprit' emitter.





interference statistics that can be only vague estimates because of the lack of data that has resulted from decreased funding of such work. One speaker at Teddington commented that at least the existence of a set of limit figures should move disputes out of the hands of lawyers and into those of EMC consultants.

In the US the FCC has adopted a single limit level from 1GHz to 6GHz that is specified differently to the CISPR limits but is equivalent to approximately 60dBμV/m average measured at three metres distance for Class A (Industrial) application and 54 dBμV/m average for Class B (domestic). CISPR has matched these limits only from 3GHz to 6GHz, adopting limits 4dB tighter in the 1GHz to 3GHz band that is of greater commercial importance at this time. Since 4dB is scarcely more than the measurement accuracy, it remains to be seen what the effect of this will be on international trade.

Ongoing CISPR deliberations include the possible use of spectrum analysers rather than measuring receivers, which is already common practice under other standards, and new detector algorithms that might better simulate the vulnerabilities of digital radio transmission. However, such work will only lead to new basic standards that may or may not be taken into the product standards.

EXPERIENCE TELLS

To date, commercial test house practice is based on upon the relatively-relaxed limits of CISPR11, the standard for 'intentional emitters' – industrial, scientific and medical (ISM) products. The test method there is closely similar to that proposed for general use – except that Spectrum Analysers are already allowed, although this does give problems with signal-to-noise ratio. Special care has to be taken to obtain and maintain low-loss cables and connectors at microwave frequencies, and with the alignment of the EUT and antenna. Test chamber resonance is less of a problem than it is at lower frequencies, so that chamber calibration has not been thought necessary hitherto. However, CISPR is now working on this.

Floor-mounted pyramid absorbers to damp chamber resonance are specified in CISPR11, even though these obscure the line-of-sight to the measuring antenna for floor-level emission from the EUT.

The seminar was told that Military and Aerospace practice is rather different, thanks to the long period of development and use, the high field strengths required for immunity testing, and the size and complexity of the systems involved.

For emission testing UK Defence-Standard 59-41 has no requirement for the use of an EUT turntable nor for height scanning with the antenna – but it does require that both antenna and EUT should be oriented for maximum emission. Emission should always be tested first since it is quicker and more quantitative and gives a good first indication of immunity.

System immunity testing may be facilitated by a two-stage process. This involves 'Low Level Swept Field' testing of the system enclosure (aircraft, tank, etc) to determine the transfer function into the environment inside where the equipment will be exposed. The system enclosure may then be set aside and testing of the equipment alone accomplished directly with a lower field strength into a smaller test volume than would otherwise be necessary.

From the design point of view, the region above 1GHz may be seen as one where coupling within equipment changes from near-field to far-field mode, with consequent reduced benefit from separation and increased importance of cavity resonance of the enclosure. For connecting cables conventional shields become less effective and the emphasis moves to the management of discontinuities – particularly connectors. The trend towards faster circuits actually helps with EMC testing, since, for the circuit to work at all, local EMC issues must have already been resolved.

The design advice given may be considered in two categories: straightforward and ingenious.

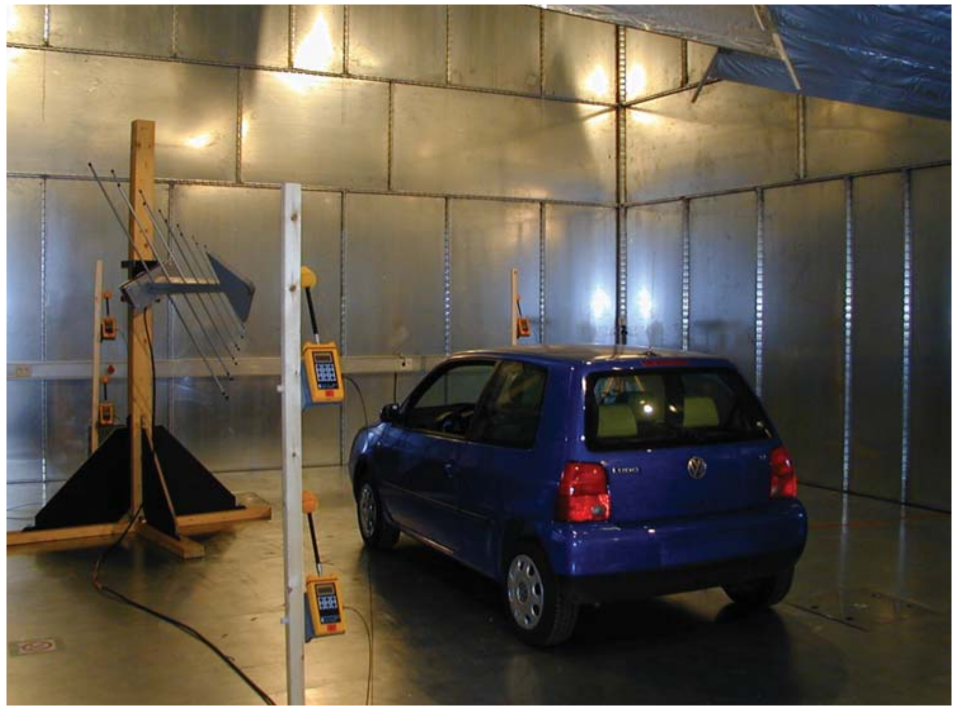
Packaging is critical. Use many small shielding boxes rather than few large ones to raise the cavity resonant frequencies. Metal-coated plastics should be avoided unless joins are very carefully bonded – but of course conductive plastic windows are a valuable technique. RF absorber on the inside walls of boxes becomes a useful technique at these frequencies, absorbing energy and reducing the Q factor of resonances. Placement is best decided with the aid of modelling software.

Lid and door seals must be bonded with screws, gaskets, conductive caulk or finger stock at spacings of a tenth of a wavelength or less, which is only 5mm at 6GHz. The choice of bonding method should primarily address corrosion, ageing, production tolerancing and misuse in the field. Shielding effectiveness may be considered an afterthought – though low bonding resistance may become important at low frequencies. Filtered connectors are less cost-effective at UHF than a shield box behind the connector to reduce its effective aperture size.

Within an equipment box the pcb designer's skill will show. Make provision for EMC capacitors and inductors but do not expect to use more than very few of them. Minimise the length of internal fly-leads since these are prone to resonance. Be prepared to adjust the design clock frequencies to avoid excitation of resonances of the packaging.

When it comes to testing, write down each step in your debugging action plan before you do it. Understand the source of the problem before you try to fix it – otherwise you will end up with more fixes than are actually needed.

- Design the circuits so that, with the use of special test software, functions can be disabled – for example to distinguish between the emission due to a CPU clock and that due to a bus clock – and which provides error indication and logging for immunity testing.
- Listen to demodulated interference; with experience this will help you to identify the source.
- One's hand is an excellent signal attentuating device; use it to locate leaks around doors, cooling slots, etc.
- Expect up to 4dB change in emissions due to software upgrades during product life.
- Since no commercial standards measure upward-focussed radiation, a test 'pass' may be facilitated by locating as many potential emission sources as possible on the top of the EUT. The remainder should be spread around the product circumference so that their radiation cannot add!



This reverberation chamber has a test volume suitable for a regular van and can be used from about 80 MHz upwards with no upper limit. The test volume is 11.0 × 7.6 × 7.2 m^3. The actual field strength is monitored by 8 field probes placed around the DUT.

[CREDIT: INSTITUTE FOR ELECTROMAGNETIC COMPATIBILITY, TECHNICAL UNIVERSITY BRAUNSCHWEIG, GERMANY www.emv.ing.tu-bs.de]

WHAT NEXT?

All the above comments apply to the traditional "Open Are,a Test site" or (semi) anechoic room test method, which has been adopted by CISPR since commercial industry has spent considerable sums of money on incremental improvement of test methods and test facilities of this sort. However it is clear that the complex radiation patterns of most equipment above 1GHz such as shown in the plot must lead to substantial error unless radiation at various elevations is measured – and such measurements increase the test time. Test time is a problem only if the laboratory is manned, which it need not be for emission testing if it is sufficiently automated. Military standards already allow use of reverberation chambers for susceptibility testing. A reverberation chamber has plain metallic walls that are highly reflective at radio frequencies. The resulting resonances are smeared out by moving a large paddle within the chamber. A key advantage for immunity testing is that such a chamber is almost loss-less and so requires only modest test power. Field strength up to 5KV/metre is practicable (the usual commercial limit is 3 or 10V/metre) even for a very large EUT such as an aircraft.

For both emission and immunity testing the removal of directivity effects by the mode stirring/tuning paddle has proved a crucial advantage. Successful identification of a susceptibility lobe only 1.2 degrees wide was mentioned at the Seminar. A difficulty is the potential interaction between timing effects within the EUT operation and those associated with the paddle movement.

At the seminar, opinions were divided on the wisdom of CISPR's choice of 'traditional' test methods. There are even different views on whether the fundamental objective is to measure the field strength radiated in a particular direction by a 'culprit' (as is achieved by the traditional method) or whether it would be better to measure the total emitted power (as is the natural result of reverberation chamber measurement).

Difficult areas remain. One is the statistical modelling of interference probability and the trade-off of this against product manufacturing cost. Another is the definition of legally-enforceable limits. Today these are based on 60 year old statistical concepts and open-area testing but they must be extended to different test methods– anechoic and reverberant chambers, and different measured parameters – cable current, field voltage and field power.

The debate continues within CISPR (which has recently called for more generalised evidence about the effect on accuracy of scanning at various elevations) but, rightly or wrongly, the first steps have been made and will be difficult to reverse. ■

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