the emc journal

Issue 82 May 2009

ISSN 1748-9253

BT Vision

"Substantial concerns of interference"

Read the article by Tim Williams

See Page 15

What's In This Issue

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The EMC Journal

Free to readers worldwide
May 2009 - Issue No. 82
Published every other month
First Issue March 1995

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IEEE EMC Society UKRI Chapter Demonstration Sessions at EMCUK

As with previous EMCUK events, the IEEE EMCS UKRI Chapter will once again be organising a series of table-top practical demonstrations. If you have a favourite practical demonstration or computer based demonstration of an effect, phenomena or solution associated with EMC, we would like to hear from you and you are invited to participate in the sessions described below.

The demonstrations are informal, similar to poster sessions, repeated continuously throughout the day and intended to emulate those given at the IEEE EMC Society International Symposia. The demonstrations are well received, adding an extra dimension to the event.

The practical experiment sessions are intended to demonstrate EMC concepts and principles, phenomena and effects, and measurement methods. For example: the effects of PC board radiation coupling, component-cable crosstalk, grounding and shielding strategies, spectral analysis techniques using test hardware, effective EMC test methods and practices, use of EMC instrumentation to measure interference at the device or component level, how fairly simple test hardware can be used to quantify various electromagnetic effects, etc.

The computer solutions sessions are intended to illustrate EMC modelling approaches and simulation methods through a series of interactive computer demonstrations. Various computational electromagnetic (CEM) modelling techniques may be demonstrated illustrating their application to simple canonical-type problems in order to show how specific EMC problems can be solved. Demonstrations could include: shielding effectiveness simulation, EMC simulation for PCB emissions, radiation through gaskets, joints and apertures, PCB board edge effects, FDTD modelling of DC power buses; system analysis using MLFMA, etc.

Participants would be expected to produce a short description relating to the demonstration as a handout and provide their own equipment. If you would like to be included in the session please contact either Paul Duxbury (paul.duxbury@ieee.org) or Roy Eddiss (roy.ediss@ieee.org), with a title and a brief outline of the proposed demonstration.

Further information on the activities of the IEEE EMCS UKRI Chapter, including the presentations from previous events, can be found on the website; www.ieee.org.uk/emc.html

News Flash

EMC Technical Conference details now on Web site.

The Technical Conference Programme organised by the IET together with Online Booking details is now available on the web site. Full lunch and refreshments are included.

All delegates to the Technical Sessions will also be allowed FREE entry to the parallel EMC Academy Training sessions and will also receive the printed Proceedings. An excellent reference source (see details page 10).

EMCUK Newbury 13/14th October
www.emcuk.co.uk

News and Information

CST Completes Acquisition of SimLab Software GmbH

Computer Simulation Technology AG (CST), today announces that SimLab Software GmbH has become a 100% subsidiary company of CST AG. The acquisition of all outstanding shares followed the successful partnership and participation agreement signed in June 2007.

Design engineers interested in PCB and cable harness simulation will profit from this acquisition through full exploitation of synergies in product development and support. This step will accelerate the incorporation of SimLab's cutting edge technology into CST's design environment.

Two products, based on SimLab technology, have already been integrated successfully in CST STUDIO SUITE™. CST PCB STUDIO™ (CST PCBS) and CST CABLE STUDIO™ (CST CS) are used to study signal propagation on PCBs and cable harnesses, with high efficiency.

CST PCB STUDIO

CST PCBS is a specialist tool for the investigation of Signal and Power Integrity and the simulation of EMC and EMI effects on Printed Circuit Boards (PCB). Applications include high speed digital, analog/mixed signal, and power supply. CST PCBS seamlessly integrates into various design flows, calculating parasitic crosstalk effects and simulating the electronic network in time or frequency domain. Of particular interest is the interface with CST MICROWAVE STUDIO® (CST MWS) which enables linking PCB simulations with subsequent full 3D analysis of electromagnetic emissions.

CST CABLE STUDIO

CST CS is focused on the analysis of SI, EMC and EMI effects in cable harness systems. Applications include the optimization of shielding, weight and space consumption on single wires, twisted pairs, and complex cable harnesses with an unlimited number of cables. Typical analyses include voltage distributions on probes, current flow through components, scattering parameters, impedances, and emissions simulation through CST MWS.

"The aim of this acquisition was to address the growing demand for EMC and Signal Integrity analysis tools," commented Dr. Bernhard Wagner, Managing Director, CST. "SimLab's extensive know-how in the EMC market has proven invaluable, and complements CST's expertise in the 3D EM simulation market. Our customers will benefit from a combination of tightly integrated technologies which is unique in this market."

Availability

CST CABLE STUDIO™ and CST PCB STUDIO™ are available as part of CST STUDIO SUITE™ 2009. More information from **www.cst.com**

emcia Member

Link Microtek signs 3-year sponsorship deal with National Register of RF Workers

Link Microtek, the leading UK supplier of RF radiation safety equipment, has signed a 3-year sponsorship agreement with the National Register of RF Workers, which is a database of individuals whose work brings them in close proximity to transmitting antennas on telecommunications or broadcasting masts or other similar structures.

Established in 2002 to fulfil one of the key recommendations of the Stewart Report, the National Register of RF Workers aims to investigate whether there are any adverse health effects resulting from long-term occupational exposure to RF radiation.

Commenting on the sponsorship agreement, Link Microtek's technical director Hugo Bibby said: "We are pleased to be able to support this important area of research by helping to secure the long-term future of the Register of RF Workers."

The register is owned by the Health & Safety Executive and administered by the Institute of Occupational & Environmental Medicine at the University of Birmingham.

The picture shows Hugo Bibby of Link Microtek presenting a Red Letter Day voucher to the winner of the register's annual prize draw, Jayne Bagley, who is an RF systems technician at Arqiva.
www.linkmicrotek.com www.radhaz.com

Würth Elektronik eiSos appoints Thomas Schrott as CEO

As of 1 January 2009, Würth Elektronik eiSos GmbH & Co. KG, located in Waldenburg, Baden-Württemberg (Germany), has appointed Thomas Schrott (37) as CEO. He will take on responsibility for Sales and Marketing. Besides Thomas Schrott, Oliver Konz is also responsible for the company's undertakings.

Thomas Schrott has been with Würth Elektronik for over 13 years; in his previous position as Sales Director Europe he was responsible for German and international sales. **www.we-online.de**

Farnborough International Airshow 2010 to be better than ever for business

Farnborough International Ltd (FIL), organiser of the biennial Farnborough International Airshow (FIA) is upbeat about plans for the forthcoming show, which is to take place 19-25 July 2010. The company plans, between now and July 2010, to re-evaluate aspects of the show with an emphasis on enhancing and increasing networking and meeting opportunities and improving site services, in line with feedback from exhibitors, particularly from the business aviation sector. **www.farnborough.com**

MULTIFUNCTION GENERATOR NSG 3040 –

BIG THINGS COME IN SMALL PACKAGES

It is small, smart and has a high-contrast 7" touchscreen color display and the rotary wheel for quick input with appealing ease of operation. With its open modular architecture, the NSG 3040 is the ideal immunity test companion for smaller engineering labs – with amazing capacities for demanding EMC testing companies and for easy integration into the production process. The electromagnetic pulses generated from this multipurpose unit are especially tailored for CE marking requirements of the EU in addition to the national and international standards. Like its big brother, NSG 3060 (6.6 kV), the NSG 3040 also has a SD memory card where test files can be saved easily and expanded at any time.

- **Modular, expandable system**
- **Surge voltage to 4.4 kV**
- **EFT/Burst to 4.8 kV/1 MHz**
- **PQT to 16A/260 VAC & DC**
- **Easy-to-operate 7" touchscreen color display**
- **TA (Test Assistance) for rapid test resolution**
- **Parameters can be changed during test**

Teseq Ltd. Wokingham UK
T+44 845 074 0660 www.teseq.co.uk

TESEQ
Advanced Test Solutions for EMC

AR Celebrates 40th Anniversary

AR, a recognized leader for testing and communications solutions in the worlds of EMC, military, wireless, and beyond, is celebrating a milestone this year. 2009 marks the 40th anniversary of the international company that began in the basement of one of its founder's homes.

Donald "Shep" Shepherd, one of the three men who founded the company and the current chairman of AR, has said "We started the company in my basement because the only place we could go from there was up." But even the founders had no idea just how far up the company would go.

From working in Shep's cellar, and driving around their only sample amplifier in the trunk of Shep's car, the little amplifier business now encompasses four companies, employs over 200 people, and after 40 years continues to lead the industry with innovative products and a global support system that is second to none.

"AR began when we designed an amplifier for test applications," Shep explains. "That amplifier solved some problems that testers were experiencing, and it made some tests easier to conduct. That's what we've been doing ever since: solving problems and making testing easier."

Formerly known as AR Worldwide, AR now consists of a family of companies: AR RF Microwave Instrumentation, AR Modular RF, AR Receiver Systems, and AR Europe. These companies create and market everything from power amplifiers, antennas, TWT amplifiers, complete test systems, probes, monitors, software and receivers to amplifier modules that can be customized to meet the toughest specs.

Shep sums it up like this: "With the combined resources of all the AR companies, we simply have more options, more solutions, and more innovations. Our customers get the benefit of it all when they connect with any AR company. We're one company with infinite solutions. And after 40 years, we're only just beginning."

New Distribution Agreement

MDL Technologies is pleased to announce it's new distribution agreement for the UK and Ireland with ETS-Lindgren for all product lines.

ETS-Lindgren is an innovator & market leader of systems and components for the detection, measurement and management of electromagnetic, magnetic and acoustic energy. The company was formed in 1995 when industry leaders EMCO, Rantec and Ray Proof combined their resources to create EMC Test Systems. In 1997 ETS acquired Euroshield followed in 2000 by Holaday Industries and Lindgren RF Enclosures to become ETS-Lindgren. ETS-Lindgren employs more than 750 professionals in offices and manufacturing facilities around the world and is a subsidiary of ESCO Technologies.

ETS-Lindgren provides amongst others the following test equipment and facilities: Anechoic Chambers; RF Shielded Enclosures; Antenna Measurement Test Systems; Absorbers; Antennas; Positioning Equipment; RF Field Probes; TEM Devices and RF Filters

MDL Technologies is a newly formed company drawing on over 20 years experience in the electronic test and measurement markets within the UK and Europe. It' s key personnel have long experience of ETS-Lindgren products and provide consultancy, sales distribution, project management, installation and testing of electronic test equipment and facilities.

www.mdltechnologies.co.uk
www.ets-lindgren.com

CST Workshops in London

CST are holding two workshops in London, focused on successful design using the latest 3D electromagnetic simulation software. These seminars are part of the CST 2009 Innovations Workshop Series.

Recent innovations have made EM simulation an essential and easy to use part of any high frequency or high speed design workflow and these workshops will explore how you can best exploit the technology for your own design area. Application based throughout, the workshops will look at local industry requirements including EDA/SI, RF/Microwave/Antenna, and EMC/EMI and how simulation can significantly improve throughput and reduce costs.

These workshops will be held in June and July in London. More detailed information, the provisional agenda, and online registration is available from the CST website.

Electronics, 17 June 2009, offered in cooperation with NEW - National Electronics Week. http://www.cst.com/Content/Events/Details.aspx?eventId=1287

Microwaves and Antennas, 2 July 2009 http://www.cst.com/Content/Events/Details.aspx?eventId=1270

www.cst.com **info@uk.cst.com**

emcia Member

Microwave electronics from TMD highlighted at IMS 2009

TMD Technologies will be highlighting its full range of travelling wave tubes, power supplies and amplifiers at the IEEE's International Microwave Symposium in Boston, MA in June 2009.

As well as components for radar, EW and communications applications, the UK company will be displaying its instrumentation TWTAs for high intensity RF EMC testing and other laboratory applications.

From its rugged amplifier range, TMD will focus on its pulsed and CW microwave power modules for radar, EW and communications. These MPMs have the advantages of being ultra compact and lightweight as well as offering high efficiency and reliability. They are also fully integrated, making installation safe and simple.

Exhibiting at the symposium for the first time, TMD Technologies can be found on Stand 2714 at the IEEE International Microwave Symposium on 7-12 June 2009, Boston, MA, USA. **www.tmd.co.uk**

Training Sessions

emc ACADEMY — EMC Training for Industry by Industry

EMC UK 2009

The Racecourse, Newbury 13/14 October 2009

Who should attend:
Design engineers of electronic products in all sectors (consumer, medical, industrial, military, transport, telecom) who have to meet high frequency EMC compliance requirements.

Benefits:
Delegates will hear from two of the most respected lecturers in the business. After attending this course, delegates will be able to review their designs with confidence in all aspects – mechanical drawings, PCB layouts and circuit schematics – for adherence to principles of minimum disturbance emissions and maximum interference immunity.

Fee:
£135 plus VAT including lunch, full copy of proceedings and attendance certificate. Why pay more.

Running in parallel will also be the IET Technical Conference Programme. All delegates to those sessions will be allowed FREE entry to the Training Sessions and will also receive the proceedings.

Book Online Now!

www.emcuk.co.uk

Tuesday 13th October 2009

Electronic Fundamentals for Good EMC

Presenters:
Keith Armstrong, Cherry Clough Consultants
&
Tim Williams, Elmac Services

09.10 - 10.30	Shielding Theory; Effect of apertures and seams; The slot-in-a-box model; Conductive gaskets; Conductive coatings; Using the shield as ground; Cable layout and large enclosures
10.30 - 11.10	Coffee and Visit to Exhibition Stands
11.10 - 12.30	EMC Techniques for PCB Layout Saving time and money; Segregation; Interface analysis, filtering, and suppression 0V and power planes; Power supply decoupling; Transmission line techniques; Layer stacking; Some useful references
12.30 - 14.00	Lunch and Visit to Exhibitions Stands
14.00 - 15.20	EMC in Circuit Design and in the selection of Active Components Digital design for EMC; Analogue (not RF) design for EMC; Switch-mode design for EMC; Communication design for EMC; Optoisolator design for EMC; Checking device EMC characteristics; Some useful references
15.20 - 16.00	Tea and visit to Exhibition Stands
16.00 - 17.20	Filtering and Cabling Filter configuration; Components: capacitors and ferrites; I/O and mains filtering; Mode of propagation; Unscreened cables: using twisted pair; Screened cables - screen operation, transfer impedance & the effect of the connector; Transducer and communications interfaces

Wednesday 14th October 2009

Basics of Emissions and Immunity Testing

Presenter:
Keith Armstrong
Cherry Clough Consultants

Synopsis
There are certain issues common to all emissions and immunity tests, that the test standards may not make very clear. If they are not understood, significant differences between test laboratories can result.

This morning's session describes these issues, and is intended for those new to commercial EMC testing.

09.10 - 10.30	Making Emissions Measurements
10.30 - 11.10	Coffee and Visit to Exhibition Stands
11.10 - 12.30	Making Immunity Measurements
12.30 - 14.00	Lunch and Visit to Exhibitions Stands

Immunity requirements related to design choices

Presenter:
Tim Williams
Elmac Services

Synopsis:
Immunity test requirements are standardized for many products, either under the EMC Directive or through product specifications, and even without standardized requirements, good EMC immunity is the hallmark of a well-designed product. Since immunity can only be verified through testing, a test plan should be drawn up at the start of each design; but how do circuit, PCB and mechanical design choices relate to this test plan?

This afternoon's session is aimed at electronic product design and development engineers, who need to be able to implement a design in the knowledge that, when it comes to the immunity tests, they have anticipted and allowed for the electromagnetic stresses that their product will undergo.

14.00 - 15.20	RF Immunity Immunity of analogue circuits, cable coupling at low frequencies; high-Z and low-Z common mode filtering; required common mode rejection; effect of circuit and cable resonances; radiated coupling to structures; layout, circuit bandwidth, shielding if necessary; RF immunity of digital circuits.
15.20 - 16.00	Tea and visit to Exhibition Stands
16.00 - 17.20	Transient and LF Immunity Immunity of digital circuits; ESD effects on edge-triggered signals; layout, filtering and decoupling; enclosure design to control ESD strikes; ESD protection of interfaces; integration with RF filtering; capacitive filtering for EFT/B; effectiveness of the ground reference for EFT/B; HF filtering of power supplies; surge protection of power supply and interfaces, integration with RF filtering; LF immunity: AC supplies - dips, interrupts, inrush current; DC supplies: same, plus overvoltage and reverse polarity protection.

Banana Skins...

Editor's note: The volume of potential Banana Skins that I receive is much greater than can possibly be published in the Journal, and no doubt are just the tip of the EMI iceberg. Keep them coming! But please don't be disappointed if your contribution doesn't appear for a while, or at all.

536 Coronal Mass Ejection – inevitable Armageddon for the developed world

It is midnight on 22 September 2012 and the skies above Manhattan are filled with a flickering curtain of colourful light. Few New Yorkers have seen the aurora this far south but their fascination is short-lived. Within a few seconds, electric bulbs dim and flicker, then become unusually bright for a fleeting moment. Then all the lights in the state go out. Within 90 seconds, the entire eastern half of the US is without power.

A year later and millions of Americans are dead and the nation's infrastructure lies in tatters. The World Bank declares America a developing nation. Europe, Scandinavia, China and Japan are also struggling to recover from the same fateful event - a violent storm, 150 million kilometres away on the surface of the sun.

Surely the sun couldn't create so profound a disaster on Earth. Yet an extraordinary report funded by NASA and issued by the US National Academy of Sciences (NAS) in January this year claims it could do just that.

Our modern way of life, with its reliance on technology, has unwittingly exposed us to an extraordinary danger: plasma balls spewed from the surface of the sun could wipe out our power grids, with catastrophic consequences.

The projections of just how catastrophic make chilling reading. "We're moving closer and closer to the edge of a possible disaster," says Daniel Baker, a space weather expert based at the University of Colorado in Boulder, and chair of the NAS committee responsible for the report.

The surface of the sun is a roiling mass of plasma - charged high-energy particles - some of which escape the surface and travel through space as the solar wind. From time to time, that wind carries a billion-tonne glob of plasma, a fireball known as a coronal mass ejection (see "When hell comes to Earth" below). If one should hit the Earth's magnetic shield, the result could be truly devastating.

The incursion of the plasma into our atmosphere causes rapid changes in the configuration of Earth's magnetic field which, in turn, induce currents in the long wires of the power grids. The grids were not built to handle direct current. The greatest danger is at the step-up and step-down transformers used to convert power from its transport voltage to domestically useful voltage. The increased DC current creates strong magnetic fields that saturate a transformer's magnetic core. The result is runaway current in the transformer's copper wiring, which rapidly heats up and melts. This is exactly what happened in the Canadian province of Quebec in March 1989, and six million people spent 9 hours without electricity. But things could get much, much worse than that.

.....the grid's interdependence with the systems that support our lives: water and sewage treatment, supermarket delivery infrastructures, power station controls, financial markets and many others all rely on electricity.

.....it is clear that a repeat of the Carrington event (*1859, stunning auroras even at equatorial latitudes*) could produce a catastrophe the likes of which the world has never seen.

According to the NAS report, the impact of what it terms a "severe geomagnetic storm scenario" could be as high as $2 trillion. And that's just the first year after the storm. The NAS puts the recovery time at four to 10 years. It is questionable whether the US would ever bounce back.

"I don't think the NAS report is scaremongering," says Mike Hapgood, who chairs the European Space Agency's space weather team. Green agrees. "Scientists are conservative by nature and this group is really thoughtful," he says. "This is a fair and balanced report." Neither is Europe sufficiently prepared. Responsibility for dealing with space weather issues is "very fragmented" in Europe, says Hapgood. Europe's electricity grids are highly interconnected and extremely vulnerable to cascading failures.

When Hell comes to Earth

Severe space weather events often coincide with the appearance of sunspots, which are indicators of particularly intense magnetic fields at the sun's surface. The chaotic motion of charged particles in the upper atmosphere of the sun creates magnetic fields that writhe, twist and turn, and occasionally snap and reconfigure themselves in what is known as a "reconnection". These reconnection events are violent, and can fling out billions of tonnes of plasma in a "coronal mass ejection" (CME).

If flung towards the Earth, the plasma ball will accelerate as it travels through space and its intense magnetic field will soon interact with the planet's magnetic field, the magnetosphere. Several things can then happen. If the fields are oriented in the same direction, they slip round one another. In the worst case scenario, though, when the field of a particularly energetic CME opposes the Earth's field, things get much more dramatic. "The Earth can't cope with the plasma," says James Green, head of NASA's planetary division. "The CME just opens up the magnetosphere like a can-opener, and matter squirts in."

The sun's activity waxes and wanes every 11 years or so, with the appearance of sunspots following the same cycle. At the moment the sun appears calm. "We're in the equivalent of an idyllic summer's day. The sun is quiet and benign, the quietest it has been for 100 years," says Mike Hapgood, who chairs the European Space Agency's space weather team, "but it could turn the other way." The next solar maximum is expected in 2012.

(Extracted from "Gone in 90 Seconds" *by Michael Brooks, New Scientist, 21 March 2009, pp 31-35, www.newscientist.com. The report mentioned is:* "Severe Space Weather Events—Understanding Societal and Economic Impacts: A workshop report"*, http://www.nap.edu/catalog.php?record_id=12507.)*

(Other recent articles on this subject include "The 2012 Apocalypse — And How to Stop It" *by Brandon Keim, Wired Science, 17 April 2009, http://www.wired.com/wiredscience/2009/04/2012storms/, and* "2012: The Year Of Looming Solar Disaster, When Civilization Devolves?" *by Brian Dipert, EDN, 5 May 2009, http://www.edn.com/blog/400000040/post/1810044181.html?nid=3351&rid=9249788.)*

(The Editor writes: Banana Skin No. 448 discussed a US Congressional report, available from:

Continued on page 12

http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf, that described how a single airburst nuclear bomb would knock the USA – or any developed nation – back into the iron age, with huge numbers of deaths and complete breakdown of civil society, simply because of the damage it would do to the HV distribution transformers on which – it turns out – almost every aspect of our lives relies if we live in a developed country.)

(Nobody keeps spare HV transformers, and they take at least a year to manufacture <u>if all the necessary services are readily available</u> – which they won't be if the HV grid is down. And how do you start up a power plant with no grid power available? Where are you going to find the 100MW you need to jump-start your 400MW generator?)

(We could at least believe that we could prevent an airburst nuclear explosion over our country, whether this belief was justified or not, But there is no way to stop a coronal mass ejection like the 1859 Carrington Event, which would destroy most HV grids around the world, could happen tomorrow, and is <u>certain</u> to occur one day.)

537 **EMC Trends and Needs**

The main building blocks of an electronic system are the integrated circuits (ICs). According to the International Technology Roadmap for Semiconductors, the communication speed between the chips is increasing and is projected to be 10 GHz with an on-chip clock of 15 GHz in the year 2010.

Given this projection, logic thresholds will be lower, the noise margin will decrease, and ICs will become more vulnerable to interference. Radiated emissions will increase because of faster switching edges and the concomitant increase in energy in a harmonic spectrum that extends to higher frequencies.

Over the coming decade, the number and variety of potential disturbance sources and victims is set to increase exponentially—leading to an astronomical increase in the risk of interference. Consequently, controlling this interference is becoming a key issue in system design.

The market needs safe, secure, highly reliable, low-cost products that are interference-free and EMC-compliant. To achieve this goal, new methods and tools must be developed to reduce emissions and to boost the immunity of components, interconnects, and subsystems. The future electromagnetic environment must be controlled by legislation and standardization with new test methods, frequency bands, and limits.

EMC Design

A high-speed digital lifestyle (including digital radio/TV, Internet, and new applications and services) is fast emerging. By 2010 all products will incorporate digital technology. Multimedia products combine radio, TV, PC, and wireless functions. Such device integration only increases the risk of self-pollution. The explosive growth in the popularity of wireless devices will lead to greater interference challenges. In-home digital wired and wireless networks will cause non-traditional EMI scenarios.

Time-to-market and product life cycles are becoming increasingly shorter. For consumer electronics, the first six months on the market are the most profitable. If the product launch is delayed, a significant share of the life-cycle profits may be lost. EMI problems can thwart speedy movement along the critical path of product creation. The risk of re-design must be reduced, and design efficiency must be improved. Better design methodologies are needed to reduce emissions and to increase immunity. Possibilities include simulation/diagnostic tools, new design rules, and expert systems in CAD tools.

An integral EMC design approach is needed to achieve an optimum cost-effective integration of technologies at the chip, package, board, cable, module, enclosure, and system level. Signal integrity (SI) thermal, software, and cost must be factored into any effective approach.

EMC Standardization

Crucial areas for improvement include:

More and stricter EMC regulations must be developed for products with high clock frequencies, for digital modulation techniques, and for wired and wireless communication devices. An increase in the number of microprocessors in homes, businesses, factories, and vehicles will lead to a rise in interference problems. New emission and immunity test methods must be developed for higher frequencies (mode-stirred chambers, fully anechoic rooms, etc.)

Reassessment of present EMI limits is warranted given the changes taking place in the electrical environment. EMC practitioners must develop a database of defined protection levels for radio services that can be used as a basis for deriving future EMC limits.

Digital radio services have tolerances to broadband and narrowband interference that differ from those of analog services. There is an urgent need to investigate the impact of these differences when determining interference limits and test methods for digital radio/TV products. Resolving the digital EMC problem will be a major challenge in the coming decade.

The EMC of networks and installations constitute the "missing link" in the current mass of EMC standards. Many wired home networks use existing power or telephone wiring and—without coordination—such an arrangement will lead to EMC problems.

EM Safety

Product safety issues must be addressed. All electronic devices are subject to errors or malfunctions caused by electromagnetic interference. A functional safety perspective on EMC is needed in those cases in which errors could result in injury or harm to the health of users. Failure to do so puts consumers in jeopardy and leaves manufacturers exposed to financial risks including liability lawsuits, product recalls, negative publicity, and loss of consumer confidence. In fact, the risks caused by EMI-related functional safety lapses are increasing because of:

- Rapidly increasing use of electronics in safety-related applications,
- Worsening electromagnetic environment,
- Increasing use of electronic devices.

At the present time no published safety or EMC standards adequately control EMI-related functional safety issues.

(Extracts from: "Towards an EMC Technology Roadmap", *by Marcel Van Doorn, Technology & Strategy Manager of the Philips Electromagnetics & Cooling Competence Center, http://www.interferencetechnology.com/articles/articles/article/towards-an-emc-technology-roadmap.html.* The brochure: "Vision 2020:The EMC Technology Roadmap" may be downloaded from www.emc-esd.nl, link:ETN-SEE.)

Banana Skins

Banana Skins are kindly compiled for us by Keith Armstrong.

If you have any interesting contributions that you would like included please send them, together with the source of the information to: keith.armstrong@cherryclough.com

Although we use a rather light hearted approach to draw attention to the column this in no way is intended to trivialise the subject. Malfunctions due to incorrect EMC procedures could be life threatening.

John Woodgate's Column

We have to keep meeting like this

The standards meeting season has well and truly started; in spite of all the pressure to shorten the time taken to produce standards, the season now seems to start in April, adjourn during July and August and start again in earnest in September. So the 'year' is actually about six months. This is undoubtedly due to the people involved being very busy, like everyone else who actually has a job. Now there is the additional factor of restrictions on travel due to the recession. This can cause on-going problems, because meetings do not include representatives of all interests, with the result that the outcomes in the form of draft standards are challenged at the National Committee comment stages, and this inevitably results in delay and the need to go over ground at least twice. In fact, not sending an expert to a meeting may well cost a company far more than the cost of sending him or her.

The EMC scene

Stable standards?

Although standards are supposed to remain stable for as long as possible, this seems to be a very short time in the case of Basic standards, in the CISPR 16 and IEC 61000-4 series. It is undoubtedly true that EMC measurements are difficult and imprecise, but there is still a question whether relatively small changes are really worth the cost of developing them, and the cost to test houses of becoming equipped and accredited to perform the revised methods.

Low frequencies (IEC SC77A)

Work continues on IEC/EN 61000-3-2, resolving the difficult issues raised in previous years. New work has begun on limits for 'solid-state lighting', which means LED lamps and, in due course , OLED lighting and maybe other technologies. The concentration is on very low powers, that are not covered by existing limits, but such products are likely to be installed in extremely large numbers, quite quickly after they become available at reasonable prices.

IEC TR 60725 has been updated to include systems other than 230 V 50 Hz.

IEC 61000-3-3 will not be amended to change the reference lamp for flicker assessment from a 60 W incandescent lamp to something more ecologically acceptable.

IEC TR 61000-3-4 is to be withdrawn, because now that IEC/EN 61000-3-12 exists, the TR applies only for loads over 75A/phase, and the connection of these needs to be negotiated on a case-by case basis between the customer and the infrastructure operator.

On the other hand, IEC TS 61000-3-5 is revised to apply only to loads over 75 A/phase, but is to be retained as a TS, because it refers to specific limits in EC 61000-3-3. It will not be converted to a standard.

IEC TS 61000-3-15 is about requirements for dispersed LV generation systems, and is likely be come a standard in future.

There are specific problem areas under discussion, including:

- emissions from variable-speed drives, including emissions above the 40th harmonic;
- test conditions for air conditioners;
- test conditions for heat pumps (where an EN on energy efficiency has pre-empted some of the work).

High frequencies (IEC SC77B and SC77C and CISPR sub-committees)

It's not practicable to list all that is going on at the technical level, and in fact, the main concerns in this area are political rather than technical. Specific enquiries regarding emission or immunity requirements can be sent to the email address at the end of this article.

Alternative test methods

We now have a situation that CENELEC, the European Commission and the IEC Standards Management Board have all come down on the side of alternative methods without a referee method specified in the standard, leaving the way open for the referee method being the one used by the manufacturer. However, certain elements, notably in the Advisory Committee on EMC (ACEC), continue to oppose the principle, on grounds that appear increasingly contrived. There are also signs that some National Committees are not being properly informed about these activities.

A particular case, apparently separate from the above controversy, is that CISPR/H is resisting the inclusion of limits for emission measurements in reverberation chambers in IEC 61000-6-3.

PLT

Up to now, the concentration in considering PLT emissions from cables has been differential-to-common mode conversion in the two power conductors. But there is a third conductor present, nominally 'earthed'. For common-mode signals, the two power conductors in parallel form a two-wire transmission line with this third conductor. In a flat installation cable, it is physically unsymmetrical, and in a flexible cable, somewhat less so. Nevertheless, lack of symmetry does not disqualify the arrangement from being a transmission line. A single conductor above an infinite conducting plane is a transmission line, and that is *really* unsymmetrical!

This has a profound effect, in theory at least. A two-wire line radiates any common-mode signals present on it; it is a long-wire antenna at high frequencies and an end-fed untuned wire at most lower frequencies. But the third wire creates a new two-wire line in which the original common-mode (CM) signals are now differential mode (DM), and don't radiate. Of course, these 'new DM' signals may themselves be subject to mode conversion, creating 'new CM' signals that do radiate. But the conversion loss may be quite enough to make a significant reduction in the amount of radiation to be expected, and indeed, to the amount that would be measured if the ambient field strength at HF were low enough to make measurement practicable. As it is, indirect methods have to be used to assess the emission levels.

Safety matters

Hazard-based standard

Intensive work is taking place to prepare an FDIS text for IEC 62368 now that the standard has (just!) passed its first-stage vote (CDV). It is unlikely that the FDIS will be allowed to fail, considering the millions spent on its preparation, but work starts immediately on a companion rationale document and a second edition. With luck, that means that no-one will insist on applying the first edition. However, IT MUST NOT BE DISREGARDED. Companies whose experts have participated in its preparation will already have a head start in designing products to comply with it, and the second edition is likely to have more content rather than different content, in most cases.

Energy economy

CENELEC has set up a group composed of experts on household appliances and home ITE to produce a methods of measurement standard for stand-by and off-state power consumption. But at present, consumer electronics experts are not involved, and they must be. Meanwhile, manufacturers of products affected by imminent energy economy legislation should seriously consider including a real mains on-off switch, which could save a lot of hassle. This could even apply to plug-transformers, and would be especially valuable where the device includes a linear power supply because the associated product, e.g. a radio, will not work **in close proximity** (forget 3 m or 10 m measuring distances and consider 10 cm!) to a switch-mode supply, however well suppressed.

General

Annex ZA

This Annex in ENs and HDs derived from IEC standards lists the IEC or other standards called up in the underlying IEC standard, with the corresponding ENs to be used in their place. Unfortunately, the wording of the heading text is marginally capable of misinterpretation. It is proposed to add a sentence to ensure complete clarity:

The EN/HD listed in column 4 applies, unless there is a dash, or no EN/HD, in that column, in which case the publication in column 1 applies.

Let us hope that CENELEC will agree. The text may not be ambiguous in French or German (or people in those countries may be less ingenious in finding unlikely interpretations).

Tailpiece

For those actually involved in standards work, new editions of the ISO/IEC Directives Part 1 and IEC Supplement are now available for free download from the IEC website, http://www.iec.ch, by following the links "Standards Development", "IEC documentation", "Statutes and directives". It should be noted that the hyperlinks in both parts of the Directives along with the supplement are only operational when used on the IEC Website or when both parts and supplement are downloaded and stored in the same folder.

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RF Emissions of Powerline Ethernet adaptors

By Tim Williams, Elmac Services

A previous article [1] discussed the issues raised by PLT (Power Line Telecommunications) in the context of EMC. In passing, it mentioned the BT Vision in-home entertainment system. Since that was published, the author has had the opportunity of making some emissions measurements on a pair of Comtrend PowerGrid 902 Powerline Ethernet adaptors, as supplied with every BT Vision package. This article reports the results and discusses their implications.

The BT Vision PLT component

The BT Vision package [2] is a system provided to a residential customer by which streaming video can be sent down an ADSL (broadband) line and circulated around the customer's house to allow a choice of TV programmes and other video content in each room. The communication around the house is provided by a local area network, and this can be implemented either by wired Ethernet, or wireless networking, or by using a pair or more of adaptors to convert the Ethernet data to a signal that can be passed across the mains power wiring in the house.

The adaptor uses a form of modulation which spreads the data across a spectrum extending from 2MHz up to 26.5MHz and applies this spectrum as a differential signal between live and neutral of a standard 13A mains plug. It can be plugged in to any available mains socket, and a mating adaptor elsewhere on the ring main then re-converts the received data to Ethernet format. As supplied, the adaptors are "plug-and-play", that is they will negotiate a link automatically as soon as they are switched on and need no further attention once set up.

The approach is a very convenient and easy-to-implement way of passing broadband data around a house, especially in situations where wireless networking is impossible or inadequate. But unlike other wired and wireless methods, it raises substantial concerns of interference to innocent third-party users of the radio spectrum in the neighbourhood and perhaps beyond. These were discussed in some depth in [1], and here we will concentrate on the performance of the adaptors as actually supplied.

Measurements on the Comtrend adaptors

Two adaptors taken from a supplied BT Vision package have been measured in a standard CISPR conducted emissions measurement set-up. The configuration used is shown in Figure 1 and is compliant with the usual CE test as described in CISPR22/EN55022 and familiar to all EMC test labs. In order to ensure a clear communication channel the two units were plugged into a single multi-socket strip which was itself plugged into the LISN (CISPR 50 ohm/50µH V-network) via a 1m cable length. This should give the most favourable conditions for the devices, since there is virtually no path loss, no interference, and a flat, defined differential mode impedance of 100 ohms. The Ethernet port of one unit was connected to a battery-powered laptop via a short (50cm) UTP cable, located next to the test units; that of the other unit was connected to the local Ethernet router via a 2m UTP cable. File transfer could be initiated across the Ethernet link to test the adaptors' emissions in standby mode or when communicating continuous data.

The measuring instrument was an Advantest R4131B spectrum analyser. The measurement method was exactly as described in CISPR22:2005, that is, the voltage levels across Live to Earth and across Neutral to Earth were measured separately and the maximum value at each frequency taken. The significance of this will become clear later.

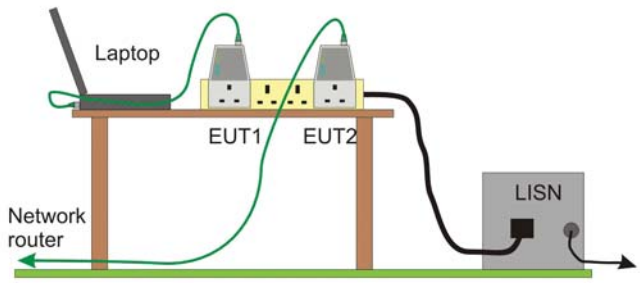

Figure 1 Schematic of the measurement set-up

The results compared against the class B (residential) QP limits are shown in Figure 2, and those compared against the Class B average limits are shown in Figure 3. Measurements were made beyond the CE top frequency of 30MHz, to see if there were any emissions that might fall into the radiated frequency band, although radiated emissions testing was not performed. Three sets of data are shown in each plot; with the units plugged in but switched off (the STATUS LED showing red), labelled "quiescent"; with the units in standby, i.e. with all LEDs showing green but not transferring data; and with continuous file transfer taking place across the link. Quasi-peak measurements were made at spot frequencies, as is typical test house practice, shown by diamonds on the plots.

To check the effect of the test set-up, the Ethernet links were separately disconnected in standby mode and the laptop was moved relative to the test ground plane. No effect on the measured levels was seen, showing that these were generated across the Live and Neutral terminals with no reference to the Ethernet port or to the ground plane. This was confirmed by using the LISN diagnostically to show that the emissions were largely in differential mode (L – N) rather than in common mode (LN – E). Values at all frequencies were essentially identical on both Live and Neutral lines.

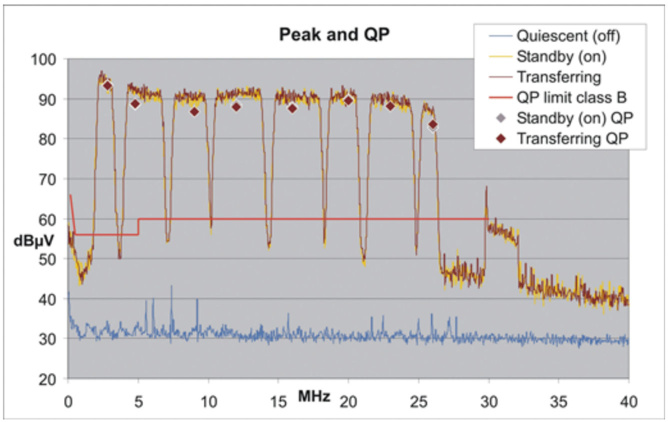

Figure 2 Conducted emissions: peak and quasi-peak

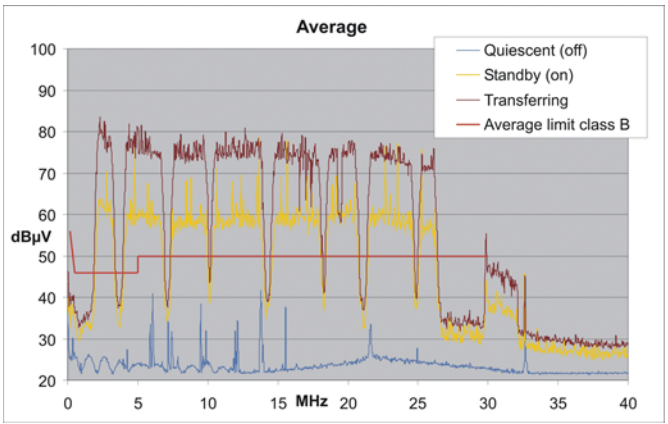

Figure 3 Conducted emissions: average
NB spikes visible on the quiescent trace are local ambients, not caused by the adaptor

The headline result here is that for both average and quasi-peak limits, the system is approximately 30dB over the CISPR limit, not at isolated frequencies but over large swathes of the conducted emissions range, with notches to below the limit at certain frequencies. When not transferring data the average level drops, though still well above the limit, but in QP there is essentially no difference as to whether the unit is transferring or not. Unless the user deliberately switches the units off – in which case the products are comfortably compliant, illustrated by the "quiescent" trace – they will be putting out the full signal level 24 hours a day.

Notches

The notches in the emitted spectrum fall below the limit at frequencies which roughly correspond to the UK amateur bands at 3.5MHz, 7MHz, 14MHz, 18MHz and 21MHz. These are shown in Figure 4.

These notches are as supplied from the factory and cannot be changed; also as supplied, by default there is a specific exclusion for the frequency range 26.5-28MHz which is to prevent interference to wireless mouse connections, which use the 27.12MHz free radiation frequency. This can be disabled via the unit's web user interface, in which case the emissions extend up to 28MHz, and this has indeed been found experimentally to interfere with a wireless mouse in the vicinity. It is also possible to insert extra custom notches via this interface, with a concomitant reduction in data transfer rate. Whilst a technically able user could do this in order to mitigate a case of interference at a specific frequency, it would be unreasonable to suggest this as a default method of interference control in the hands of a naïve user.

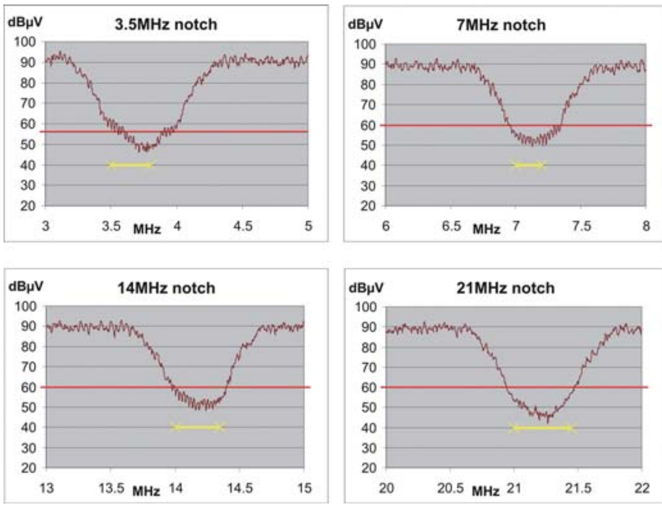

Figure 4 Notches at various frequencies
The yellow lines correspond to the UK amateur bands

The web user interface also shows that power control is enabled on both units as supplied, but there is no indication that the power level is being adjusted in real time to minimise the amount of RF passed into the mains.

The use of notches creates a further issue of concern, which is intermodulation. The plots in the figures above were taken without a transient limiter in circuit in the LISN. Figure 5 below shows the effect of switching in a limiter, as may be standard practice in some test labs to protect the front end of the measuring instrument. In the measurement system shown, the limiter is a pair of back-to-back silicon diodes preceded by a few dB of attenuation, which imply a clipping threshold of around 1V at the measurement point. The effect of a limiter in general EMC testing was discussed in [3]. In Figure 5, it can be seen that the limiter raises the apparent noise floor of the measurement to 70dBµV and "fills in" the notches. This is because the intermodulation generated by the non-linearity of the limiter creates frequency components that were not present in the original signal; if the original signal is broadband, the intermodulation will cover all frequencies that were notched, including those above the source spectrum, as is evident in Figure 5.

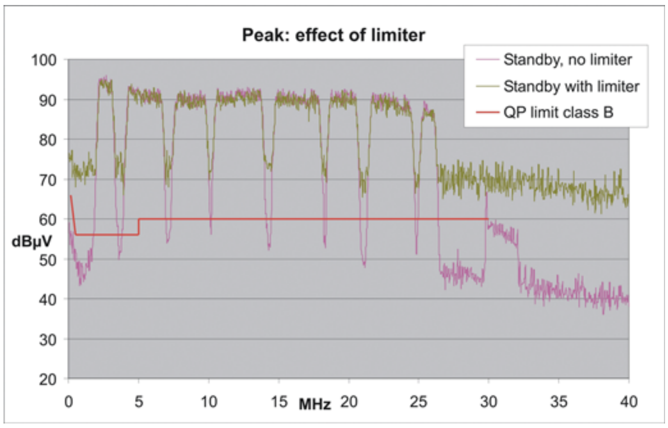

Figure 5 The effect of intermodulation from a transient limiter

This is an artefact of the measurement system; the total peak amplitude of hundreds of mV is quite sufficient to push a standard limiter into non-linearity. However, it is relevant to a PLT installation since any mains network is likely to include a variety of non-linear devices, principally the rectifier diodes at the input of any connected electronic apparatus or the triacs in, for instance, lighting dimmers. So that, although intermodulation should be guarded against in the measurement set-up, it is dangerous to rely on notches to protect any part of the radio spectrum since in real life, and depending on the individual installation, the unavoidable non-linearities will defeat their purpose.

Discussion

These measurements lead to the unavoidable conclusion that the Comtrend PG902 adaptor exceeds the allowable limits in CISPR 22/EN 55022 by a factor of 30dB, continuously, over the majority of the frequency range. Any reputable manufacturer of electronic equipment would not market such a device until it had been redesigned and brought into compliance. Yet, British Telecom are supplying these units in their hundreds of thousands to BT Vision subscribers, and in October 2008 extended their contract with Comtrend to continue supplying them for a second year [4]. The adaptors are CE Marked, implying that their manufacturer believes that they are compliant with the appropriate European Directives. How can this discrepancy be explained?

A clue lies in the declaration of conformity that Comtrend place in their user guide for the PowerGrid 902 model [5]. Within this DoC we find the following:

(reference to EN 55022:2006)

Other specifications and Technical Documentation:

CIS/I/89/CD Amendment to CISPR 22: Clarification of its application to telecommunication system on the method of disturbance measurement at ports used for PLC (Power Line Communication)

PowerGrid 902 TCF Technical Construction File of PowerGrid 902 ref. PG902CTTCF0508v1

This Certificate is guarantee by the following support documentation:

…

CISPR I/89/CD Test Report IE_ICEM_COM080101-IN issued by ENAC accredited laboratory 190/LE1113-4 ITACA and therefore complies with the essential requirements and provisions of the EMC and LV Directives

CISPR/I/89/CD

The reference to CISPR/I/89/CD is significant. This was a draft document [6] circulated for comment in November 2003 by CISPR in an attempt to create a mechanism within CISPR 22 that would allow PLT devices to comply directly with it. It was withdrawn before being developed further; as discussed in [1], later developments included a new document, CISPR/I/257/CD, which has also been rejected in turn. As is usual with draft documents, CISPR/I/89/CD includes the standard warning "THIS DOCUMENT IS STILL UNDER STUDY AND SUBJECT TO CHANGE. IT SHOULD NOT BE USED FOR REFERENCE PURPOSES." Nevertheless, some Competent (now Notified) bodies in Europe have used it as the basis for an opinion, and this is clearly the case here: ITACA is an accredited EMC test lab (although, to be clear, not accredited against CISPR/I/89/CD, and therefore referring to them as an "ENAC accredited laboratory" in this context is irrelevant) in Valencia, Spain who have apparently taken this approach in agreeing Comtrend's Technical Construction File.

The method proposed in CISPR/I/89/CD relied on the balance of the mains supply when used for RF broadband communication. Its introductory note stated that

The current document is based on the principle that PLC equipment must have a positive signal to noise ratio in order to function, and therefore must be allowed higher signal levels on the power mains. The interference potential at the multi purpose port is thus measured twice:

1) in its function as a power consumer (i.e. communication function disabled) using the familiar V-network and limits in tables 1 and 2 of CISPR 22 and;

2) in its function as telecom device using the T-network specified within this document and applying the limits in tables 3 and 4 of CISPR 22.

National committees are advised that this application of separate limits for the different functions is a new approach in CISPR/I and are asked to comment on this approach.

The first sentence was highly controversial and most probably contributed to the document's failure, but in the context of the PG902 adaptor the technical basis was also unacceptable. Clearly, if the device is disabled but still consuming power it satisfies case 1) above and, as can be seen from the plots shown earlier, it easily meets the normal limits of CISPR 22. But for the PG902 the distinction between "disabled" and "standby" is vital; when turned on, the unit operates 24 hours a day in standby mode and is putting out its full spectrum signal even though it is not transferring data. The "communication function disabled" state is irrelevant in the real world.

Case 2) refers to "the T-network specified within this document" and this is a network with a flat longitudinal conversion loss (LCL) of 30 ±6dB (see [1] for an explanation of LCL). This author has not been able to measure the samples with this network to see if they meet the limits referred to in case 2). Because no published standard has specified such a network it is not commercially available, although an enterprising test lab could undoubtedly construct one. But given that the signal is applied differentially between live and neutral, emissions which appear at the levels shown in the plots above when measured with a normal LISN could indeed just about meet the telecom port limits when measured with a T-network of LCL 30 ±6dB. Therefore, taking CISPR/I/89/CD at face value as a contribution to an EMC Technical Assessment according to the EMC Directive, it is possible that the PG902 could be shown to comply with it.

But CISPR/I/89/CD cannot be taken at face value. Apart from being withdrawn by CISPR, it included a statement which effectively torpedoes even what limited merit it may have had. Describing the specification for the T-network, it states (and the sentiment is repeated in the introductory note)

This ISN is only representative for low voltage distribution networks where the two conductors, usually Phase and Neutral, that are being symmetrically driven by the PLC equipment are cabled together. This ISN is not appropriate for representing networks where one of the driven

> *conductors is run independently of the other driven conductor as may be the case in some remotely switched circuits.*

Such independently run mains wiring is commonplace, at least in the UK, where for instance the live wire can be run away from its neutral return to a light switch or other switching circuit, and back again. This effectively unbalances the phase and neutral conductors and negates the assumption of a 30dB LCL. So any measurements to CISPR/I/89/CD cannot be used to offer a justification for compliance of a product that is used in UK residential properties. Again, this would have been a reason for rejection of the document within CISPR/I.

Consequence of excessive emissions

What are the consequences for such an egregious disregard for limits accepted as mandatory by all other manufacturers of electrical and electronic equipment, especially when the unit in question is supplied in volume by the largest telecom utility in the UK?

Firstly, is there an actual interference problem? Continuously exceeding the limits by 30dB suggests this might be expected, and indeed it is easy to demonstrate that HF broadcast reception is seriously affected by the operation of the adaptors (audio recordings of this interference can be found at the Elmac Services website, **www.elmac.co.uk**). But more than this, the spread of BT Vision has given rise to a protest group, UKQRM, whose reported discussions with Ofcom, the regulator, can be found on their website [7]. Their on-line petition calling for an immediate ban on power line adaptors of the type currently supplied by BT has attracted 3,500 signatures, suggesting that experience of interference problems is indeed widespread.

Secondly, what kind of message does this give about official attitudes to the EMC Directive? Make no mistake, BT wields very considerable clout in CISPR, and is no stranger to the EMC world. Most of the readers of the EMC Journal will be compliance engineers in companies that have elected to make sure their products comply with the pan-European standards harmonised for the EMC Directive. This is because there is a legal requirement on them to do so. EMC is not a lightweight discipline; considerable effort and cost is needed in both design and testing to confirm that the standards are indeed met. If BT appear to be able to ignore these standards, in placing on the market to the end user a high-volume product which clearly does not meet them, what is the worth of other companies continuing to make these efforts?

References

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[2] www.bt.com/vision
[3] *The hazard of the transient limiter*, Tim Williams, Elmac Services, EMC Journal March 2007 Issue 69 pp 22-24
[4] *BT Vision Extends Comtrend Power Line Deal*, Jan Harris, IPTV Watch, October 29, 2008
[5] *PowerGrid 902 Quick User Guide for UK*, Comtrend, p.14; from www.comtrend.com; DoC dated 24th April 2008
[6] CISPR/I/89/CD, *Amendment to CISPR 22: Clarification of its application to telecommunication system on the method of disturbance measurement at ports used for PLC (Power Line Communication)*, CISPR/I, 14th November 2003
[7] www.ukqrm.org

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Terminating cable screens (shields)

By EurIng Keith Armstrong, C.Eng, MIET, MIEEE, Cherry Clough Consultants

This is the first in a series of *short* technical articles, dealing with practical EMC engineering issues – the 'nuts and bolts' of EMC, if you like.

This particular topic was very kindly suggested by John Woodgate, who pointed out that in my articles for product designers and system integrators, I always seem to be recommending 360° termination – sometimes called circumferential or peripheral bonding, for the cable's screen – at *both* ends of the cable.

I will not go into the details of this technique here, or discuss its ramifications. If you are interested, see Chapter 2.6 of [1]; Chapters 13.1.4 through 13.1.7 (pages 344 to 352) of [2]; Chapters 3.7.5 through 3.8 of [3]; Chapter 7.2 of [4] (pages 164 to 175) or pages 32-11 through 32-16 of [5]. Many of these references also discuss the issue of the so-called 'ground loop' currents that flow in a screen that is terminated (conclusion: not a problem for correctly-designed electronics, and cables with symmetrical screens).

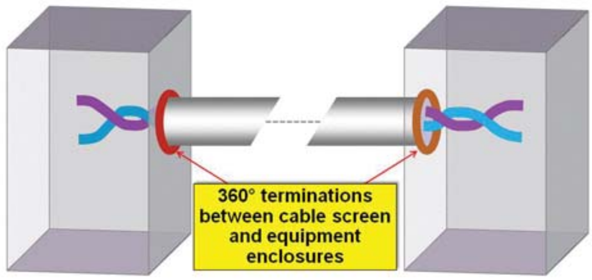

Figure 1: 360° screen termination at both ends of the cable

When I am writing about good EMC engineering, I always make the point that to achieve the best shielding performance a cable is capable of, its screen must be 360° bonded to the RF Reference (usually the equipment's connector panel, electrically bonded to its chassis) at both ends.

But – apart from chapter 7.2.4.3, on page 173 of [4] – I haven't often written about how best to improve the cable shielding performance in a legacy installation where existing (poorly-designed) equipment would suffer from excessive noise if screen currents flowed due to screen termination at both ends.

Such problems almost always occur at low frequencies, mostly related to the mains power frequency and its harmonics up to a few kHz, which is why an alternative name for 'ground loops', is 'hum loops'.

Low frequency – in this context – means frequencies for which the wavelengths are shorter than about 6 times the length of the cable (e.g., for a 10m cable, frequencies above 5MHz). At frequencies for which the cable is longer than a wavelength (e.g. above 30MHz for a 10m cable), much the same current flows in the screen whether it is terminated at one end, both ends, or at neither end.

In some situations, terminating a cable screen to the RF References at each end may not be enough, it may need to have its screen bonded to an RF Reference at one of more intervals along its length, see pages 32-11 through 32-16 of [5]

Where 360° screen termination at both ends causes 'ground loop' problems for (poorly-designed) equipment, there are several possible solutions:

a) Replace the (poorly-engineered) equipment with products that don't suffer from excessive noise due to 'ground loop' currents in their cable screens.

Because of the perceived high cost and delay, not many people do this. However, looking back after the required EMC has *eventually* been achieved, they generally admit that they should have replaced the equipment, as it would actually have been the lowest-cost *overall* solution, and very much quicker.

b) Modify the (poorly-engineered) equipment to remove 'ground loop' problems.

This requires galvanic isolation of the troublesome inputs or outputs. Replacing the screened cable with a fibre-optic one is by far the best solution for galvanic isolation and EMC performance. Several suppliers offer connectors for standard digital interfaces, that convert to and from optical fibre, but custom designs might be needed for some interconnections.

Other galvanic isolation techniques include fitting opto-isolators or isolating transformers, usually in a separate shielded box. It may be possible to do this whilst maintaining 360° shielding integrity from the box containing the optos or transformers, to the equipment – but this generally means modifying the connectors or connector panels of the equipment.

Of course, modifying equipment invalidates its manufacturer's warranty. But I know of one London-based audio/video equipment hire company – the kind of company that can provide ten or more huge juggernaughts filled with gear to provide a complete rock concert for an audience of any size anywhere in Europe – that modifies every item of equipment they purchase (if it needs it) so that they will not suffer ground loop problems in real-life installations.

Unlike an installation such as a theatre, office or industrial process plant, they cannot afford to spend any time hunting down 'hum loops' when they erect a touring system on a site. It must reliably function with acceptable quality immediately following its erection, because there is simply no time available for fiddling about to find the best solution for that particular set-up. Manufacturer's warranties are a very secondary financial concern to such companies.

c) Fit a 'Parallel Earth Conductor', PEC, as described in BS IEC 61000-5-2 [6]).

Despite their name, PECs are not concerned with safety earthing. Detailed descriptions of how to use them in practice are given in Chapters 2.5 - 2.7 of [3], and Chapter 7.4.3 of [4] (pages 188 to 192).

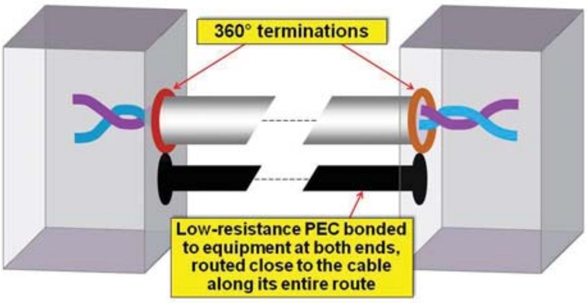

Figure 2: Adding a PEC

PECs divert the majority of the mains-related currents from the cable screen into themselves, because at such low frequencies they have a much lower impedance than the cable screen they are routed very close to. They have a very much lower *resistance*, inductance only becoming the dominant issue for cable impedance above a few kHz.

The 18th Edition of the IEE Wiring Regulations, BS7671 – expected to be published in 2011 with a new EMC requirements clause – calls PECs "bypass conductors". But a better term than either would be 'parallel bonding conductor', suggested by John Woodgate.

A common problem with using this technique in legacy installations, is that there may not be the physical room in the cable ducts to add all the PECs required.

As the above references show in some detail, so-called 'natural metalwork' such as cable support systems, steel girders, etc., can be very effective PECs. Where adequate natural metalwork exists, all that might be needed is to electrically bond all the pieces together along the entire cable route. Plus, of course, bond the resulting PECs at both ends to the frames of the equipment the screened cables connect to.

d) Fit a connector or gland that uses an annular capacitor to terminate the screen to the chassis *capacitively* in 360° at one end only.

The screen at one end of the cable enjoys 360° termination, and when a capacitor is used to terminate the *other* end it is often called hybrid screen termination. An annular (i.e. ring) capacitor maximises the shielding effectiveness of this technique.

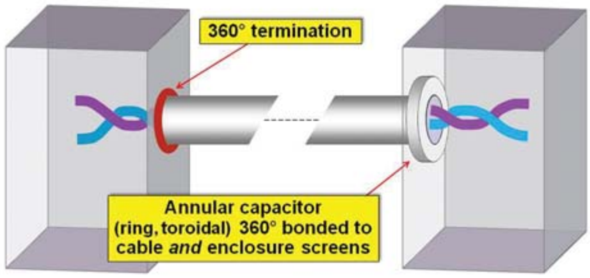

Figure 3: Hybrid termination with an annular capacitor

When using annular capacitors, the equivalent series inductance is vanishingly small, so good shielding effectiveness is maintained over a very wide range of frequencies.

Unfortunately, screened connectors or glands that connect annular capacitors in series with the cable screen are very costly, and very few are commercially available.

Where cables using capacitive screen termination can be long (say, longer than 30m), their capacitors will generally need protecting against the surge overvoltages caused by lightning channel currents within a couple of kilometres.

MOV surge arrestors have a high level of capacitance, so it might be possible to create the annular capacitor out of MOV material to get inherent surge protection.

Alternatively, routing the cable in a metal cable tray or duct (ideally, in a circular metal conduit) that is used as a PEC (see above), could provide sufficient shielding against the lightning induction.

e) Terminate one screen end with a discrete capacitor.

All the same comments apply as for the annular capacitor described above, except for the issue of the frequency range over which the termination method will allow the cable to achieve good shielding effectiveness.

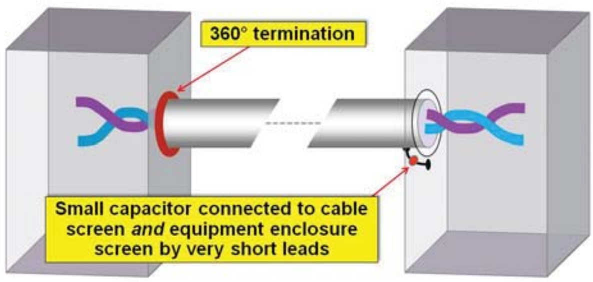

Figure 4: Hybrid termination with a two-terminal capacitor

Two-terminal capacitors, unlike annular types, unavoidably have a high level of series inductance in the capacitor and its connections. This inductance series-resonates with the capacitor ($f_{res} = 1/2\pi\sqrt{LC}$), making the screen's termination (and thus the shielding effectiveness of the cable) only effective over a limited frequency range.

As a result, it is often necessary to choose a capacitor value that 'tunes' the resonance to provide the optimum benefit for the installation in question, at a particular time.

This is usually not too difficult if the RF threats are all around the same frequency, but 'tuning' the capacitive screen terminations is always time-consuming in practice.

Of course, it is possible that new RF sources might arise later on, making it necessary to try to retune all of the screen-terminating capacitors to achieve an adequate overall performance, which – if the frequency range is wide – might not be possible.

Perhaps the best discrete capacitors for this purpose are those embedded in silicone inserts, such as the EESeal™ supplied by Quell, Inc. These are very small, have very short connections, and are very quick and easy to assemble, even in multi-way connectors.

Figure 5 shows the insertion loss *vs* frequency for an EESeal capacitor connected between a connector's pin and its bodyshell. For a cable shielding effectiveness adequate for many general domestic, commercial and industrial applications, we would aim for a screen termination impedance of 1 ohm or less. Since Figure 5 was measured with a 50 ohm source impedance – a 1 ohm impedance corresponds to an insertion loss of 34dB.

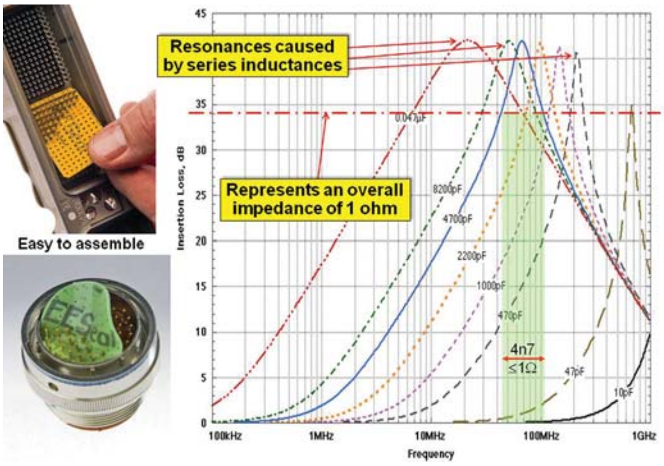

Figure 5: Insertion loss example for a discrete capacitor connected between pin and chassis (EESeal™ from Quell, Inc., www.eeseal.com)

The figure shows that for Quell's 4.7nF capacitors, we could only expect a screen-terminating impedance of 1 ohm or less, over the range 41 - 110MHz.

Very small multi-layer ceramic capacitors are, of course, readily available – but assembling them inside a connector or gland using very short leads is not at all easy or quick, and will almost certainly not exceed the performance of the EESeal™ types.

Hybrid screen termination using a discrete capacitor degrades the shielding effectiveness of the enclosure of the equipment at the capacitor-terminated end, although it can be recovered by connecting a suitably-specified filter (ideally a 'feedthrough' or 'through-bulkhead' type) to the wall of the enclosure at the point where the cable enters.

The performance of discrete capacitor shield termination can be significantly improved by using two or more capacitors in parallel. To make the best of this technique, they and their connections must be arranged symmetrically around the circumference of the connector or gland.

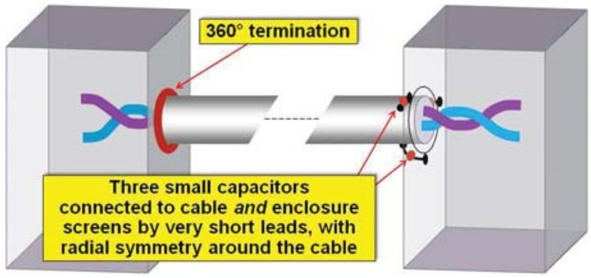

Figure 6: Hybrid termination with three two-terminal capacitors

f) Terminate the screen at one end only (OEO)

Unless the length of the cable is less than one-sixth of a wavelength at the highest threat frequency (e.g. under 5MHz for a 10 metre cable) – this is really only an appropriate technique when all else has been tried and desperation sets in.

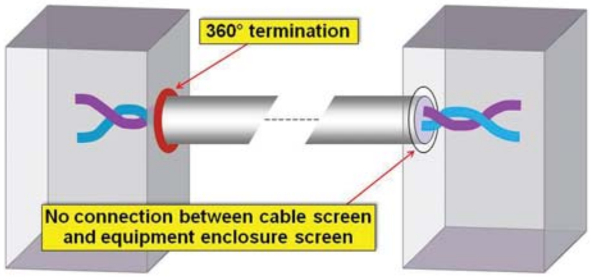

Figure 7: One-ended screen termination

Someone talking on a cellphone, and getting within a couple of metres of the cable, could quickly reveal its total lack of shielding effectiveness at higher frequencies.

Nevertheless, in situations where the RF environment is relatively quiet, other cables and equipment in the system and installation are also quiet at RF frequencies, and cellphones and the like will not be used nearby, OEO screen termination might be acceptable.

Such situations were common worldwide 50 or more years ago, making OEO screen termination a perfectly good way of protecting analogue signals (they were nearly all analogue) from the electrostatic (stray capacitance) coupling from mains distribution networks. Only cables used near radio transmitters, which were few and far between in those days, needed to use 'proper' RF termination (360° termination at both ends).

This is why EMC textbooks first written many years ago distinguish between "low frequency" and "high frequency" cables, based on the signals they are intended to carry, and recommend different screen termination techniques for each type.

These days, when every product contains *at least* one digital processor with significant levels of continuous common-mode noise emissions to *at least* 300MHz (increasing with every new generation of ICs), and the environment is increasingly polluted with RF communications and industrial/scientific/medical RF noise from 150kHz to at least 2.45GHz – <u>*all*</u> cables must be treated as "high frequency" types, regardless of the actual differential-mode signals they are intended to carry.

Of course, even if OEO termination achieves adequate overall performance at that time, future changes to the system, to nearby systems, or to the electromagnetic environment, could well mean that the cable's shielding effectiveness becomes inadequate, possibly causing very costly downtime.

It is important to be aware that OEO screen termination effectively ruins the shielding effectiveness of the enclosure of the equipment at the non-terminated end. This can be recovered by connecting a suitably-specified filter (ideally a 'feedthrough' or 'through-bulkhead' type) to the wall of the enclosure at the point where the cable enters it.

When the equipment manufacturer species OEO screen termination

Quite often, such a specification in an Installation Manual is an indication that the product's designers don't understand how to design products so that they can easily be installed and used in real life (never mind comply with the EMC Directive).

This is not theoretical posturing – I write this from personal experience over decade: before 1990 I was just such a designer. Figure 9 shows one way of using such an item of equipment, without compromising the shielding effectiveness of the cabinets in which the equipment is housed. Passing *any* conductor through the wall of a shielded enclosure without either:

a) directly termination it to the wall at that point

b) 360° termination its cable shield to the wall at that point

c) filtering the conductors using filters that are connected to the wall at that point

– would completely ruin the shielding effectiveness of the cabinet (see 4.3.17 of [7]; 3.10-1 – 3.10.3 of [3], and pages 148, 153, 154 of [4]). Figure 9 shows how b) above can be implemented whilst still complying with the manufacturers installation specifications.

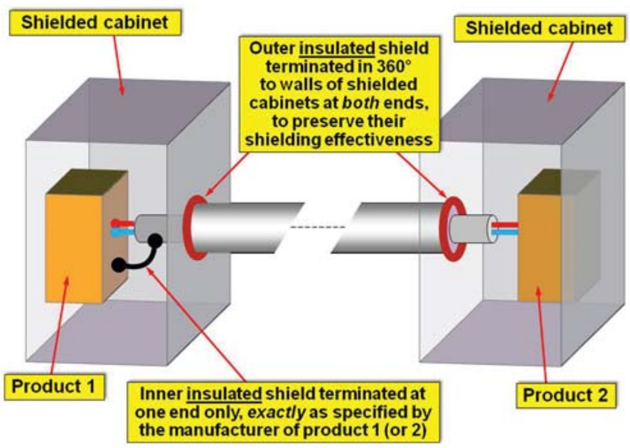

Figure 8: When termination a cable shield at both ends would contradict manufacturer's installation instructions

The cable used between the shielded enclosures must be a double-insulated-screen type. This is *not* the same as an ordinary double-screened cable, in which two shielding layers are laid one on top of the other, in contact.

The outer of the two insulated screens need not be part of the cable, it could be a shielding conduit applied over the top of one or more screened cables.

If I were you, I wouldn't start from here (cost-effectiveness in the real world)

If a product, system or installation is designed with the intention of terminating cable screens at only one end, and interference problems are experienced during commissioning, the connector types that have been used often make it difficult and costly to modify so as to achieve hybrid or 360° termination at both ends.

Even a few days delay in commissioning a system can cost a great deal more than it would have done to construct the system with hybrid or 360° screen termination at both ends in the first place.

But if one starts with a system constructed using 360° cable screen termination at both ends, it is easy and quick to modify it to use one of the other methods.

This is why Bob Plowman, then EMC expert for Rolls Royce Marine Ltd. and very experienced indeed with all manner of installations, gave me the following advice during a break in an EMC seminar in the early 90s:

It is generally much more cost-effective overall to design using 360° termination at both ends, and connect all cable armour to use it as a PEC. Then degrade the cable shielding effectiveness as necessary on a case-by-case basis during installation and commissioning, using hybrid or even one-end-only termination.

Safety and criticality considerations

Of course, this brief article does not consider anything that could have an impact on safety or financial risks.

Where such risks exist, degrading the designed shielding effectiveness of the cables because of installation difficulties on the site, would require rather more serious thought than simply allowing a contractor to gaily work his way down the a) to f) list of screen termination options above, as he feels is best!

Official guides

There are many official guides on how to install electronic equipment, and some of them are not up-to-date. Even when they do describe current good practices, many installers still seem to do what they learned 30 years ago as an apprentice, disregarding all official guides and manufacturers' installation manuals.

For instance, DEF STAN 59-41 Part 7: 1995 (since superseded by DEF STAN 59-411, Part 5: 2007), gives guidance on good installation practices for EMC in HM Ships. In 1999 I was training a bunch of atomic submarine designers on that topic, and when I said cable screens must be terminated 360° at both ends, they all looked horrified! Oh no, (they all said, quite loudly) cable screens must only be terminated at one end, to prevent ground loops. Surely I knew that?

But having met this reaction before, I had come prepared! Yes, they all agreed, DEF STAN 59-41 Part 7:1995 was their installation ‘Bible’ – so I showed them its Clause 10.26, on page 70, which very clearly states that to provide RF protection a cable’s screen must be peripherally (i.e. 360°) bonded to the equipment *at both of its ends*. They were all quite obviously shocked, then went quiet and looked rather thoughtful for a while.

In 2008 I saw an article in “The Industrial Ethernet Handbook”, that insisted that screened Ethernet cables must only be terminated at one end, “to prevent ground loops”.

Unfortunately, the requirements of BS EN 50174-2 – that Ethernet installers are supposed to follow, requires 360° screen termination at *both* ends (see Clause 6.3.2, pages 15-16 of its 2001 Edition).

Some industry guides and standards are very good, but unfortunately some are sadly in need of revision as regards the EMC installation techniques required these days. So when following an industry guide on screened cable installation, it is best to be aware of current good installation practice, and not follow *any* guides uncritically.

I hope you have found this short article interesting and useful. Unless a better idea presents itself, in the next one in this series I intend to cover how to design I/Os so they will not suffer from so-called ‘ground loop’ problems due to shield currents.

References

[1] Keith Armstrong, “*Design Techniques for EMC, Part 2 – Cables and Connectors*”, at http://www.compliance-club.com/KeithArmstrong.aspx. You will have to register, but it only takes a few seconds and access is immediate.

[2] Tim Williams, “*EMC for Product Designers, Edition 4*” Newnes, 2007, ISBN: 0-7506-8170-5

[3] Keith Armstrong, “*EMC for Systems and Installations*”, at http://www.compliance-club.com/KeithArmstrong.aspx. You will have to register, but it only takes a few seconds and access is immediate.

[4] Tim Williams and Keith Armstrong, “*EMC for Systems and Installations*”, Newnes, 2000, ISBN: 0-7506-4167-3, RS Components Part No. 377-6463

[5] John R Barnes, “*Robust Electronic Design Reference Book, Volume 1*”, Kluwer Academic Publishers, 2004, ISBN 1-4020-7737-8

[6] BS IEC 61000-5-2:1997, “ *Electromagnetic Compatibility (EMC) – Part 5: Installation and Mitigation Guidelines - Section 2: Earthing and cabling*”

[7] Keith Armstrong, “*Design Techniques for EMC, Part 4 – Shielding (screening)*”, at http://www.compliance-club.com/KeithArmstrong.aspx. You will have to register, but it only takes a few seconds and access is immediate.

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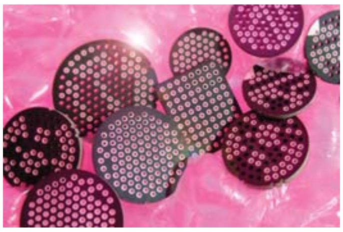
Lightning strikes and spikes contained on the outside

The latest range of Metal Oxide Varistor (MOV) planar arrays from **Syfer Technology** are designed specifically to deliver comprehensive protection against lightning strikes and other transient events in military, aerospace and other safety critical applications. Incorporated into the connectors on the external wall of the subsystem, the devices are key to protecting the increasing volume of sensitive electronic circuitry found in today's complex systems.

"Potentially damaging voltage spikes need to be suppressed or grounded sooner rather than later," highlighted Chris Noade, Marketing Manager with Syfer Technology. "Relying on PCB-based transient voltage protection means that the spike is already inside the box.

Filtered connectors provide the ideal means of stopping the spike on the outside," he explained. With multiple, interconnected 'black boxes' it is vital that spikes are not



allowed to propagate from one unit to the next.

Syfer's application specific MOV planar arrays are typically built into military style filtered connectors, including circular shell sizes 8 to 24, Arinc 600 and 404 series, as well as rectangular 24308 series and regular, subminiature and micro D types. Planar array technology has the added advantage of weight and volumetric efficiency over other transient protection or capacitor devices.

MOVs are suitable for protecting against several types of transient event. With a material response time of less than 500ps, no leads/tracks, and a low inductance geometry MOVs are more than capable of suppressing lightning induced transients. The devices are also ideal for protection against voltage spikes caused by power supply glitches and noisy switching circuits.

Operating over the full military temperature range from -55°C to +125°C, the devices are specified with leakage current of 5 A at +25°C, 50 A at +125°C, and with maximum working voltages from 10 to 45Vdc, and 7 to 35Vac.

Capacitance, measured at 1Vrms at 1kHz, depends on working voltage, planform, hole size and unit thickness, but typically ranges from 3nF at 10Vdc, 7Vrms to 500pF at 45Vdc 35Vrms. In operation, the MOV acts as a high value resistor, such that once the voltage reaches a certain value, the device becomes highly conductive and provides a fast and efficient short circuit route to ground to limit surges or pulses, and dissipating potentially destructive energy as heat. With the MOV Planar Array's inherent capacitance, it can be used as a simple C filter or as one half of a Pi or unbalanced Pi filter.

When used together with Syfer's Capacitor Planar Arrays, the MOV planars can provide a complete over-voltage transient protection and EMI filtering solution to connector manufacturers. Devices are RoHS compliant.

Syfer works closely with OEM customers and connector manufacturers to provide custom products meeting exact requirements. Manufactured at Syfer's Norfolk, UK facility, raw materials are in stock and a secure supply is readily available. Orders are manufactured to demand, with a typical lead-time of 8 weeks. Prices start from £5, depending on specification and volume of order.

Tel: +44 (0)1603 723310
sales@syfer.co.uk
www.syfer.com

New Antenna Design Product Launched

CST is delighted to announce the release of a new software product to accelerate the antenna design and modelling process.

Antenna Magus - the first antenna design tool of its kind - has a huge database of antennas that can be explored to find, design and export models of designed antennas to CST MICROWAVE STUDIO. It is expected that Antenna Magus will become an invaluable aid to antenna design engineers, EMC engineers requiring antenna models, and to system integrators who require antenna models for antenna placement studies.

Its feature set is targeted at aiding engineers to get to the customisation phase of an antenna design quickly and reliably. Validated, parametric models of the initial design are exported seamlessly into CST MICROWAVE STUDIO, where in-depth analysis and optimization can be performed.

Evaluate Antenna Magus

The evaluation version is limited to only a few antennas but is fully functional, so you can explore the database, design, estimate

performance, and export your chosen antenna to CST MICROWAVE STUDIO.

You can download your limited time evaluation copy from the CST website at http://www.cst.com/Content/Products/AntennaMagus/Overview.aspx

Launch Discount

A special launch discount of 50% on all Antenna Magus licences is currently available. This special offer allows you to purchase Antenna Magus Professional for only EUR 4550/USD5900! Please contact your local sales representative for a quotation.

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Cost-Effective Custom RF Filter Solutions

ETS-Lindgren announced the expansion of its custom radio-frequency (RF) filter solutions for the control of electromagnetic inference (EMI). Well known for its commercial and military off-the-shelf power, signal, communication and control line filters for RF shielded enclosures and anechoic chambers, ETS-Lindgren has expanded its line of custom filter solutions in direct response to an increasing number of customer requests for specialized filter designs.

"We've been quietly providing custom filters for decades now and serve a wide variety of industries, including the military, electromagnetic compatibility (EMC) testing laboratories, medical device manufacturers, automotive industry related companies and many aerospace companies" noted Sergio Longoria, ETS-Lindgren's Principal Electrical Engineer. "Now, word has spread about our custom filter capabilities so we have increased our resources to meet the demand. I feel our success in this area is largely due to customers who appreciate working directly with our design engineers in Cedar Park. The unique partnership we offer results in the optimal filter solution for a specific application."

Due to its considerable expertise in RF filters, ETS-Lindgren is able to offer customized filters at a cost effective price. Value-added capabilities include extensive testing of all filter designs for high voltage and current, endurance, as well as many of the electrical testing requirements set forth in UL-1283, IEC 60939, MIL-F-15733, MIL-STD-220, and CISPR 17. All filters are designed for high reliability and long life. Most importantly, all filters are assembled and manufactured at ETS-Lindgren's facility in Cedar Park, Texas. As an ISO 9001:2000 certified facility for the design, manufacture, calibration and construction of electromagnetic compliance equipment and facilities, customers can be confident of receiving quality RF filters.

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Probe detects electric fields from 100 kHz to 6 GHz

Narda Safety Test Solutions has just unveiled a new probe for the NBM series of wideband field strength meters. It can be used for safety measurements on the electric fields emanating from transmitting equipment, covering the entire range from long wave up to the latest generation of mobile phone base station frequencies.

With its frequency range from 100 kHz to 6 GHz, the new probe detects the high frequency electric fields output by radio and TV transmitters, telecommunications equipment, and industrial installations. The dynamic range covers 65 dB without any need to switch measurement ranges when used with the NBM basic unit. The sensitivity of 0.35 V/m means that fields emanating from WLAN and WiMAX installations can be measured reliably. The probe exceeds the requirements of EN 50492 for safety assessments of mobile phone base stations and is ready for the forthcoming IEC 62232 standard.

The probe is isotropic, which means it gives the correct measurement regardless of the direction of the field. The sensors comprise three dipoles with detector diodes arranged in an orthogonal configuration. The NBM basic unit automatically calculates the field strength resulting from the three

spatial components measured by the sensors.

The probe is calibrated at several frequencies. The individual calibration data are stored in an EPROM in the probe and are taken into account automatically by the NBM basic unit. Calibrated accuracy is thus guaranteed with every combination of probe and NBM basic unit. This applies to a further twelve probe types that are offered by Narda for the NBM series of field strength meters, covering applications with frequency ranges up to 60 GHz.

Tel: +49 (0)7121 97 32 777
support@narda-sts.de
www.narda-sts.de

Teseq NSG 4070 Test System for Conducted and Radiated Immunity

Teseq, has announced the introduction of its updated NSG 4070 multifunctional EMC immunity test system.

The Teseq NSG 4070 offers a wide test frequency range, from 9 kHz to 1 GHz and its modular set-up, using internal or external amplifiers, make it suitable for a wide variety of test applications.

Paul Dixon, Managing Director of TESEQ comments, “The NSG 4070 is a simple to use, comprehensive, multifunctional EMC immunity test system. It provides a complete and convenient solution for Test Laboratories and OEM design verification and is a cost effective alternative to the commonly used plug-and-play system approach requiring a number of individual instruments. The NSG 4070 ensures compatibility, traceability and very convenient control and automation functions.

Teseq provides a traceable calibration certificate with each tester and accredited calibration services are also available from TESEQ calibration labs upon request.

Tel: +44 (0)845 074 0660
michael.hill@teseq.com
www.teseq.com

High Current SMD Common Mode Line Filter for power supplies

Würth Elektronik extends the existing WE-SL5 family with the SMD Common Mode Line Filter, WE-SL5 HC, for high currents.

With impedances up to 1000 Ω, a current capability up to 5 A and a rated voltage of 80 V_{DC} (42 V_{AC}), the SMD line filters are especially suitable for power supplies.

Additional characteristics of the WE-SL5 HC are the 9.5 x 8.3 mm footprint and a height profile of only 5.5 mm. The WE-SL5 HCs are reflow solderable and work within an operating temperature of -40 °C to +125 °C.

The SMD Line Filters are used for suppression of common mode interference in power supplies as

well as for data signals and sensor lines.

All catalogue products are available ex stock. Samples are free of charge.

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ANSOFT TOOLS couple with Ansys for real-world simulation

ANSYS, Inc. (NASDAQ: ANSS), a global innovator of simulation software and technologies designed to optimize product development processes, today announced a first milestone in coupling ANSYS® and Ansoft™ products, successfully performing multi-physics simulations that involve electromagnetic applications. As electronics become more embedded into automotive, aerospace, industrial and consumer products, engineers must consider factors such as circuitry's ability to withstand vibration shocks, heat generation and electromagnetic interference. The combined depth and breadth of solutions from ANSYS is key to solving problems that involve these complex systems.

In performing several case studies, ANSYS engineers deployed the electromagnetic effects determined by Ansoft software directly in ANSYS thermal and structural simulation. Work is ongoing to fully integrate Ansoft software directly into the ANSYS® Workbench™ platform for future bidirectional and seamless operation.

www.ansys.com
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5003 DC inlet with filter now snaps in, simplifying assembly

Schurter is pleased to announce the added snap-in version of the series 5003 DC power entry module for 48V telecom and other DC-powered equipment. The new DC module features two different standard connector styles, AMP Universal MATE-N-LOK and Molex HCS-125. The connectors are encased with a single stage filter rated up to 15 A at 125 VDC. The filters provide wide-band attenuation in frequencies ranging from 100 kHz to 30 MHz.

Tel: +44 (0)1243 810810
sales@schurter.co.uk
www.schurter.com

PRODUCT GALLERY

Murata enhances performance of EMIFIL chip ferrite beads giving up to 60% lower DC resistance

Murata has enhanced the performance of its high performance EMIFIL chip ferrite beads to help designers save power and space in portable equipment designs. New ceramic materials and process technologies have allowed Murata to lower the DC resistance of its chip ferrite beads by up to 60%, increasing rated current to create the BLM15AX_SN series.
Compared to their BLM15AG_ SN predecessors, the new BLM15AX_ SN series has DC resistance as low as 0.02Ω, a reduction of 60%. Corresponding maximum rated current has increased from 1000 to 1740mA. The series comes in 0402-size packaging (1.0 x 0.5 x 0.5 mm), perfect for designers seeking to reduce board space without performance degradation in portable equipment designs. The

series' low DC resistance also helps reduce power consumption for battery powered applications.
The series' wide impedance line-up ranges from 10Ω to 1000Ω. Operating temperature range is -55 to +125ºC.
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www.murata.eu

Laboratory power supply generates 175 W with silent cooling

The new EX355R from **TTi** is a compact laboratory bench-top power supply generating voltages from 0 to 35 V at currents from 0 to 5 A. Unlike other power supplies of similar power levels, it uses entirely convection-based cooling and is consequently silent in operation.
The EX355R costs £264 (plus VAT) in the UK.
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Making the Automotive Grade

Syfer Technology has successfully qualified several families of passive components to the AEC-Q200 qualification standard. Suitable for a wide range of under hood and general automotive applications, devices include surface mount, multilayer chip capacitors, balanced line and 3 terminal EMI devices, and a growing range of X2Y integrated passive components.
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Scientists at the University of Glasgow have developed the world's smallest diamond transistor

At just 50 nanometres in length the 'gate' of the diamond transistor developed by Dr David Moran, of the Department of Electronics & Electrical Engineering, is more than 1000 times smaller than the thickness of a human hair, and is half the size of the previous smallest diamond transistor developed by Japanese firm NTT.
Diamond is heralded as being an ideal material for the next generation of nanoscale electronic devices due to its amazing and unique properties and could help scientists develop nascent technologies such as Terahertz Imaging and Automotive Collision Detection.

The 'gate' of a transistor is used to control the flow of current between two electrical contact points, acting as a switch or an amplifier. The smaller the gate, the faster the transistor works.

Dr Moran said: "From its invention in 1947, the transistor has been the building block of many modern day technologies, from silicon based chips in your computer processor, to gallium arsenide based circuits in your mobile phone.

"These types of materials – silicon and gallium arsenide – are chosen upon what their strengths and weaknesses are. Diamond on the other hand is very much an excellent all-round performer, and has been described by many as a perfect material.

"By developing a diamond transistor technology, we aim to tap into the truly amazing properties of this exciting material which could prove fundamental to the development of several next generation technologies."
Such technologies include Terahertz Imaging and Automotive Collision Detection.

Terahertz imaging uses terahertz radiation (T-rays) – electromagnetic waves of a frequency range between that of microwaves and infrared which can penetrate a range of materials, including clothes and flesh – to create a picture.
Because it is non-ionising, it does not damage cells and has potential applications in security scanners to detect concealed weapons through clothes as well as safer medical imaging.

Automotive collision detection or automotive radar is an advanced safety feature currently being heavily researched by the car industry with which a car or other automotive vehicle will have an effective radar zone around it that will allow it to detect potential collisions from any side of the vehicle well in advance and take avoiding action.
Dr Moran added: "These applications require a very fast and ideally high-power transistor technology that needs to be able to operate in adverse weather/temperature conditions. This is where a diamond transistor technology would excel".

The diamond itself is artificially made by UK firm Element 6 through a process called chemical vapour deposition.
The creation of the tiny device is part of a five-year project funded by the Engineering & Physical Sciences Research Council (EPSRC) and is the result of a collaborative project between the University of Glasgow and Heriot Watt University. Its construction was only possible through the multi-million pound facilities within the James Watt Nanofabrication Centre at the University of Glasgow where electron beam lithography was employed to create patterns and structures on the miniscule sliver of diamond.

The University of Glasgow has one of the most advanced large area high-resolution electron beam lithography tools in the world.

Everything you always wanted to know about SPICE*

*But were afraid to ask.

By Colin Warwick, Agilent Technologies, Inc.

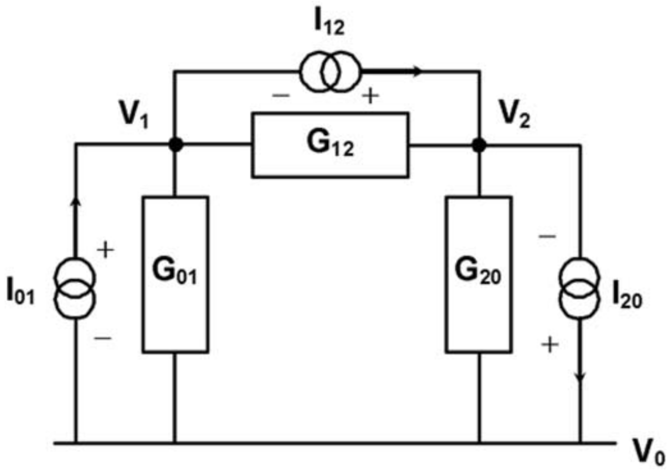
Adapted from several postings on my blog Signal Integrity: Tips, Tricks, and Tutorial for Multigigabit/s Chip-to-Chip Links

In his retrospective *Life of SPICE* (www.designers-guide.org/Perspective/life-of-spice.pdf), Larry Nagel the co-author of SPICE (an acronym for "**S**imulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis") noted:

> SPICE was announced to the world … in Waterloo, Canada at the Sixteenth Midwest Symposium on Circuit Theory on April 12, 1973. The paper was presented by none other than Professor Donald O. Pederson of the University of California, Berkeley. I don't think anyone had a clue of the impact of that paper or the computer program it described.

Well, impact it certainly had. So, in honor of SPICE's thirty-sixth "birthday", here is an article about how SPICE works.

Let's start simply with one time step (i.e. DC) solution of a circuit that consists of two unknown node voltages, V_1, V_2, a ground node V_0, three known ohmic conductances, $G_{xy} = 1/R_{xy}$ (where $I_{xy} = G_{xy} (V_y - V_x)$ and x and y are the node indices), and three known current sources.



You can solve a circuit using either Kirchhoff's current law or voltage law or both. These laws are named after a German physicist Gustav Robert Kirchhoff (1824-87). (The *ch* in Kir*ch*hoff is pronounced like the *ch* in the Scots word lo*ch*.) SPICE is a modified nodal solver and uses the current law: the sum of the currents into each node is zero. We'll talk about what the 'modified' bit means in a future posting on 'super nodes.' We'll also postpone a discussion about when Kirchhoff's laws break down for a future post (hint: Faraday's law trumps Kirchoff's law).

The nodes are joined by branches, so the other ingredients are the *branch constitutive equations* of the components that join them, for example V = IR if it's an ohmic resisitor, V = L dI/dt for an inductor, etc. In this simple example, we have three simultaneous equations, one each from node 0, 1, and 2:

$$G_{01}(V_1 - V_0) - G_{20}(V_0 - V_2) + I_{20} - I_{01} = 0$$

$$G_{12}(V_2 - V_1) - G_{01}(V_1 - V_0) + I_{01} - I_{12} = 0$$

$$G_{20}(V_0 - V_2) - G_{12}(V_2 - V_1) + I_{12} - I_{20} = 0$$

… with three unknowns, V_0, V_1, and V_2.

The same equations can be rearranged into matrix form, in this case the augmented (or indefinite) node conductance matrix relates the voltage and current vectors:

$$\begin{bmatrix} (G_{01}+G_{20}) & -G_{01} & -G_{20} \\ -G_{01} & (G_{12}+G_{01}) & -G_{12} \\ -G_{20} & -G_{12} & (G_{20}+G_{12}) \end{bmatrix} \begin{bmatrix} V_0 \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} I_{20}-I_{01} \\ I_{01}-I_{12} \\ I_{12}-I_{20} \end{bmatrix}$$

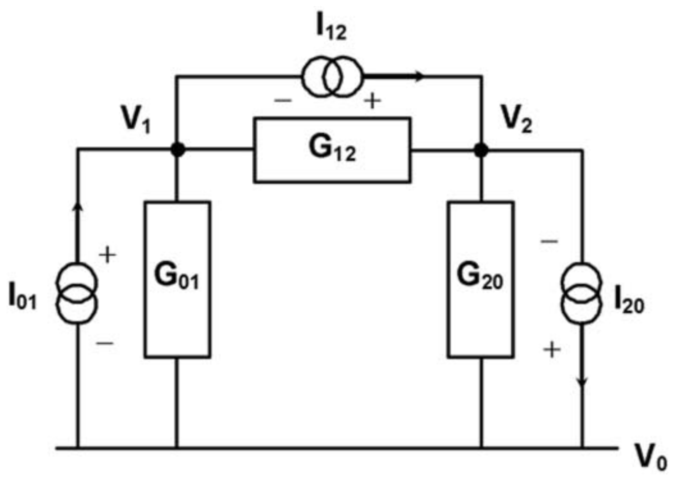
Note the 'pattern of four' that each conductance (e.g. G_{01} highlighted above) impresses into the conductance matrix:

	Column x	**Column y**
Row x	$+G_{xy}$	$-G_{xy}$
Row y	$-G_{xy}$	$+G_{xy}$

In SPICE parlance, making this 'pattern of four' impression is called 'stamping the matrix.' Conveniently, this 'stamping' generalizes for any number of nodes and two terminal components. In a future post, we'll show how a small modification to this method allows us to 'stamp in' a three- or four-terminal component like a voltage-controlled current source (and hence deal with transistors).

Pairs of nodes with no physical branch element connecting them have a conductance of 0. In practical circuits, the average number of non-zero conductance components per node is only ~3-4, whereas the number of nodes can be quite large: hundreds, thousands, even millions. Thus, practical circuits have sparse, not full, conductance matrices: SPICE can make use of the efficiency of a sparse matrix solver.

An n+1 by n+1 augmented matrix has rank n. (In our simple example n = 2.) The normal (or definite) conductance matrix can be obtained simply by selecting a datum node (e.g. define node 0 to be 0V) and deleting its row and column. The matrix equation GV = I can then be solved for the column vector of voltages ($[V_1; V_2]$) by matrix inversion: $V = G^{-1}I$.



Before we go on to see how SPICE deals with time-stepping ('transient analysis'), with reactive, four-terminal, and non-linear elements, and with shorts and voltage sources, let do a quick self-test:

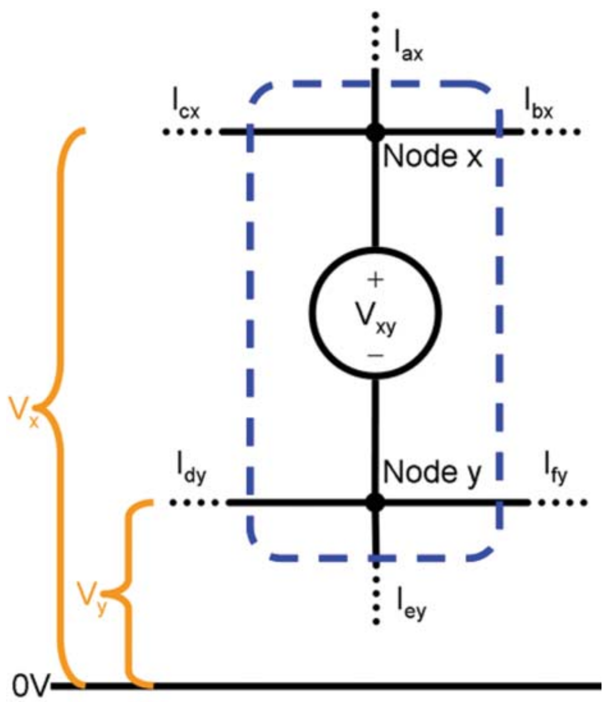
Which of these components *cannot* be modeled using a pure nodal circuit solver?

- Capacitor
- Non-linear resistor where $I = k_1V + k_2V^2 + k_3V^3$
- Open circuit
- Voltage source
- BSIM4 MOSFET model
- Voltage-controlled current source

To see the answer we need to explore beyond conductances and current source, and look at other analyses and components.

Voltage Sources and Other Infinite Conductances

It turns out that pure nodal analysis can't handle voltages sources because they have infinite conductance. So the answer to our pop quiz is *voltages sources*.

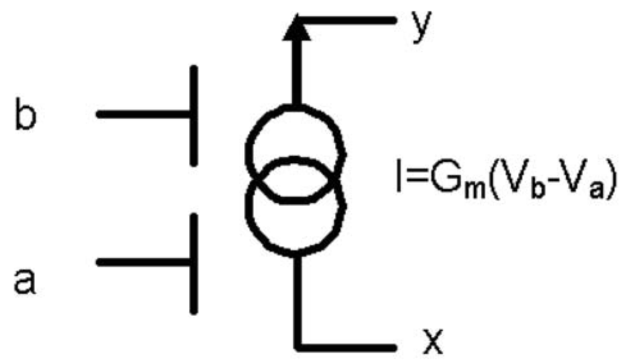


SPICE avoids the infinite conductance problem by modified nodal analysis (MNA). Nodes joined by infinite conductances are considered "super-nodes" whose constituent node voltages V_x and V_y move up and down in lock step. When SPICE creates a super-node the two individual KCL equations are eliminated and replaced by one KCL equation that sums all the currents into both nodes (into the blue dashed oval in the figure above) plus one internal constitutive equation, namely $V_x = V_y + V_{xy}$, where V_{xy} is the known value of the voltage source. Shorts and current sinks (i.e. the input ports of current controlled sources) can be treated similarly.

By the way, MNA isn't the only solution to the infinite conductance problem. For example Hachtel et al. proposed a sparse tableau method of where both branch currents and node voltages are considered unknown, both KCL and KVL equations are formulated. You then have to pick out a set of linearly independent equations.

Three and Four Terminal Devices

How about more than two terminals? It turns out that when the current source "stamped" its pattern-of-four into the conductance matrix, it was a special case of a more general four terminal "stamp." The general case is the *trans*conductance:



The "pattern of four" is simply displaced off-diagonal in the conductance matrix.

	Column a	Column b	Column x	Column y
Row a			$+G_m$	$-G_m$
Row b			$-G_m$	$+G_m$
Row x				
Row y				

Non-linear, Time-domain ("Transient") Analysis

For transient analysis, components are represented in differential or integral form. See the table below. SPICE performs numerical ordinary differential equation (ODE) solution. Non-linear elements are solved by an iterative method (e.g. Newton-Raphson) at each time step. An initial guess at the node voltages is created (usually all zeros). The slope and intercept of the tangent to the actual I-V curve is used to calculate a linear approximation of the non-linear element. The linear approximation (a conductance and a current source) is inserted into the conductance matrix as a proxy for the real device. Solution of the linear proxy yields better guess at the voltage vector. A new set of conductance/current source proxies is calculated using tangents at the new voltages. This is repeated until — hopefully! — convergence is reached for that time step.

SPICE uses variable time steps. The initial voltage vector guess for each time step is the converged solution of the previous step. If the time step causes accuracy problems, SPICE backtracks by disregarding that calculation and taking a small step from the previous time point.

AC Analysis

For DC analysis, reactive elements - inductors and capacitors - are treated as shorts and opens, respectively. For AC analysis, complex admittance is used in place of real conductance. For example admittance of a capacitor and inductor are jωC and 1/jωL, respectively. Again see the table below.

Table of branch constitutive equations for various components and various analyses in SPICE

Element	Mode	Branch constitutive equation
Resistor G=1/R	All	$I=GV$
Capacitor C	DC	$V=?,\ I=0$
	Transient	$I=C\dfrac{dV}{dt}$
	AC	$I=j\omega CV$
Inductor L	DC	$V=0,\ I=?$
	Transient	$I=\dfrac{1}{L}\int V dt$
	AC	$I=\dfrac{V}{j\omega L}$
Voltage Source	All	$V=V_s,\ I=?$
Current Source	All	$V=?,\ I=I_s$
Voltage Controlled Current Source	All	$V_{out}=?,\ I_{out}=g_m V_{in}$
Voltage Controlled Voltage Source	All	$I_{out}=?,\ V_{out}=AV_{in}$
Current Controlled Current Source	All	$V_{out}=?,\ I_{out}=AI_{in}$
Current Controlled Voltage Source	All	$I_{out}=?,\ V_{out}=I_{in}R_m$
Mutual Inductor M	DC	$V_1=V_2=0,\ I=?$
	Transient	$I_1=\dfrac{1}{L_{11}}\int V_1 dt+\dfrac{1}{M}\int V_2 dt$ $I_2=\dfrac{1}{L_{22}}\int V_2 dt+\dfrac{1}{M}\int V_1 dt$
	AC	$I_1=\dfrac{V_1}{j\omega L_{11}}+\dfrac{V_2}{j\omega M}$ $I_2=\dfrac{V_2}{j\omega L_{22}}+\dfrac{V_1}{j\omega M}$

Here's the link to the web page for the SPICE descendant in Agilent ADS:
http://www.home.agilent.com/agilent/redirector.jspx?action=ref&cname=PRODUCT&ckey=1486728&cc=US&lc=eng&cmpid=29280.

SPICE has its limitations. If there is a changing magnetic flux through a given mesh, Faraday's Law of magnetic induction $\nabla \times E = -\dot{B}$ affects the branch equations and breaks KVL by making the electric field non-conservative and the voltage undefined. At that point you need to switch to an EM solver, which is a topic for another day.

Colin Warwick, Signal Integrity/Power Integrity/EMC/EMI Product Marketing Manager, Agilent EEsof EDA
Check out his blog at http://signal-integrity-tips.com

EN 62233 replaces EN 50366

Harmonization of domestic appliance standards makes global exports easier for manufacturers

By Christoph Mühlhäuser, Narda Safety Test Solutions GmbH, and
Burkhard Braach, Freelance Trade Journalist

The domestic appliance standard EN 50366: Introduced in 2003, modified in 2006, obsolete since December 2008? This has caused some consternation, particularly among manufacturers who have invested in test equipment for EN 50366. However, there is no need to be anxious about this. EN 62233:2008 is technically equivalent. Manufacturers and importers can profit additionally from the harmonization of international standards.

Customs duties are not the only thing that can hinder global trading. Compliance with the differing safety standards applicable in different economic areas can also be a constraint. One example of this is the regulations governing human safety in the electromagnetic fields caused by domestic appliances. In this case the problem was the different standards that needed to be applied to demonstrate compliance with IEC/IEEE or CE regulations in order to be able to import and market appliances in the American and European markets respectively.

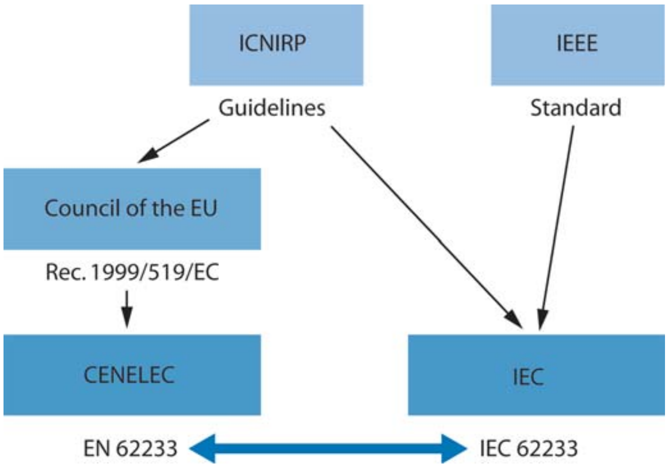
The harmonization of the international IEC standards and the European standards (EN) has greatly simplified matters here. As can be inferred from the identical numbering, the new EN 62233 is the adoption of IEC 62233 with only minor modifications. The "plus" for all Europeans is that EN 62233 is technically equivalent to the previous EN 50366:2003 + A1:2006.

The origins

EN 50366, the European standard for "Household appliances and similar equipment" was published in May 2003 by CENELEC. All EU member states had to incorporate the regulations of this standard into their national standards by February 1, 2004 and to withdraw any standards which differed from it by February 1, 2006. Since then, compliance with EN 50366 has been one of the prerequisites for awarding the CE mark to an appliance and for allowing the appliance to be marketed in countries belonging to the European Community.

In October 2005, the International Electrotechnical Commission IEC published its own standard, IEC 62233 – Ed. 1.0 [1], entitled "Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure". This standard was based on EN 50366.

The new EN 62233 [2] is effectively a retranslation of IEC 62233. It was adopted by CENELEC on December 1, 2007 and replaces EN 50366:2003 + A1:2006. All EU member states had to implement this European standard by December 1, 2008, by publishing an identical national standard or by formal acceptance. This resulted in the publication in the UK of BS EN 62233 [3], with the same content. Any national standards that conflict with the EN must be withdrawn by December 1, 2012.



Derivation of the harmonized domestic appliance standards EN 62233 and IEC 62233

IEC 62233 and EN 62233 – the difference

The two standards are identical as far as the measurement methods are concerned. There are, however, differences in the exposure limit values, which are specified as "Basic limit values and Reference values" in Annex B of each standard. EN 62233 only allows the values specified in Guideline 1999/519/EC [4]. These values are identical to the ICNIRP limit values [5]. In contrast, IEC 62233 provides two sets of basic and reference values, ICNIRP and IEEE [6, 7]. It is the responsibility of the user to apply the values that correspond to their national laws.

A further distinction within the standards should be noted. Whereas the definitions of the sensors, measurement methods, measurement distances, and test conditions are *normative*, the specification of basic limit values and reference values is *informative* in both the IEC and the EN standards. Those who consider the IEC and the EN to be the same are correct, at least in this aspect. This is because users in European countries are obligated to adhere to the limit values by the EC Guideline, and not by the European standard.

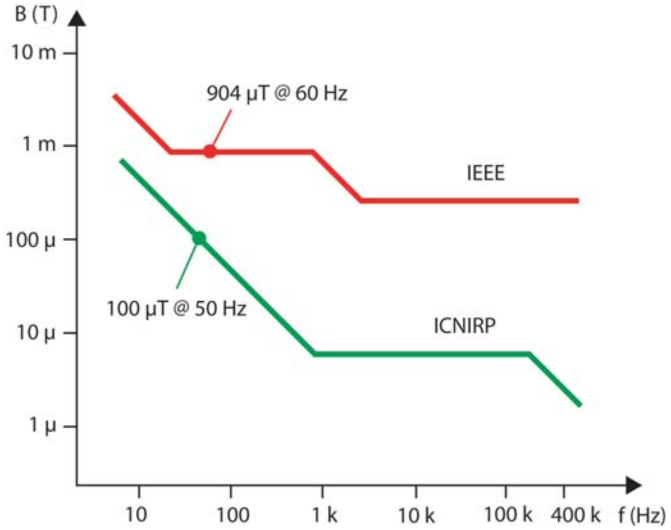
Basic limit values and reference values

These two terms must also be differentiated. The *basic limit values* are based on the effects of electromagnetic fields on the human body. At low frequencies it is the current density that can affect the function of the nervous system, and which therefore needs to be limited. At higher frequencies, it is the heating effect on human tissue, characterized by the specific absorption rate (SAR), which must be limited.

Sophisticated equipment is needed to measure both current density and SAR. For this reason, *reference values* for quantities that are easy to measure have been introduced: electric field strength E (V/m), magnetic field strength H (A/m), and magnetic flux density B (T). If the reference values are not exceeded, this guarantees compliance with the basic limit values.

Exposure to magnetic fields predominates in the case of domestic appliances. For this reason, the magnetic flux density, B, is usually measured. This is expressed in units of Tesla (T; where 1 T = 1 Vs/m^2). One Tesla corresponds to 10,000 Gauss, which was the unit used earlier. The measurement results for the usual domestic appliances are in the milli-Tesla to micro-Tesla range.

Even though the exposure limit values according to ICNIRP and IEEE are based on the same investigations in principle, the two still specify different basic limit values and reference values. This is due, among other things, to the approach used. ICNIRP considers the effects on the nervous system for the range 1 Hz to 10 MHz and the heating effect for the overlapping range from 100 kHz to 300 GHz. The corresponding ranges specified by IEEE are 0 Hz to 5 MHz and 3 kHz to 300 GHz respectively.



Limit value curves for magnetic flux density according to ICNIRP and IEEE

The practical solution

A practical solution can be derived from a comparison of the limit value curves. The ICNIRP limit values are lower than the IEEE limit values over the entire frequency range covered by the standard, i.e. the EN is stricter than the IEC. Anyone measuring according to EN 62233 will also comply absolutely with IEC 62233. Anyone measuring according to IEC 62233 will only comply with EN 62233 if the ICNIRP limit values are applied. It is therefore sensible for manufacturers who want to export their products globally to always use the ICNIRP limit values. A domestic appliance which passes the test will then conform to both EN 62233 and IEC 62233 and can therefore be declared as CE *and* IEEE compliant with regard to electromagnetic fields.

The main advantage of this harmonization is the standardization of the measurement methods. IEC and EN allow both time domain evaluation and spectrum analysis (line spectrum evaluation). In practice, results are obtained faster with time domain evaluation. This method was already adopted as the reference method in EN 50366. Test equipment that operates correctly according to EN 50366 can therefore continue to be used without restrictions.

Other standards

IEC and EN 62233 specify measurement methods for the frequency range from 10 Hz to 400 kHz. The standard indicates that the requirements are deemed to be fulfilled without test in the frequency range above 400 kHz and below 10 Hz in the case of devices that fall within the scope of the standard, unless otherwise specified in the IEC 60335 series of standards. This is a reference to the comprehensive set of standards IEC 60335 / EN 60335 [8, 9], which has also been harmonized. For example, IEC / EN 60335-2-25 should be applied to microwave cooking appliances or microwave ovens as they are more commonly known.

A further reference concerns devices that have a complete operating cycle of less than one second. These must be measured according to IEC 62311 [10] for pulsed fields. IEC 62311 covers all electrical and electronic equipment for which no product or product group specific standard with regard to electromagnetic field safety exists. Put simply, IEC 62311 applies to all non-domestic equipment. This, too, has a corresponding European standard in EN 62311 [11], which replaces EN 50392.

This harmonization reduces the test expenditure for manufacturers, simplifies conformance declarations, and thus removes export, import and trade barriers.

References

[1] IEC 62233 – Ed. 1.0 (2005) Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure

[2] EN 62233:2008 Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure (IEC 62233:2005, modified)

[3] BS EN 62233:2008 Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure (EN 62233:2008 Identical, IEC 62233:2005 Modified)

[4] Council Recommendation of 12 July on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC). Official Journal of the European Communities L 199/59, 30.7.1999

[5] ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Phys., 1998, vol. 41, no. 4, pp. 449-522

[6] IEEE C95.6:2002 IEEE Standard for Safety Levels With Respect to Human Exposure to Electromagnetic Fields, 0 - 3 kHz

[7] IEEE Std C95.1:2005 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

[8] IEC 60335 (all parts) Safety of household and similar electrical appliances

[9] EN 60335 (all parts) Household and similar electrical appliances – Safety

[10]IEC 62311 – Ed. 1.0 (2007) Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)

[11]BS EN 62311:2008 Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz) (EN 62311:2008 Identical, IEC 62311:2007 Modified)

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BOM cost and profitability

By Eur Ing Keith Armstrong C.Eng MIEE MIEEE, Cherry Clough Consultants

In the previous issue, in my article entitled: "When the going gets tough – smarter design wins" I wrote:

> "This is why most designers were brow-beaten into thinking it was vital to cut every last penny from the Bill of Materials, or BOM. (This was never true, just a symptom of lazy management, for rather obvious reasons that I plan to explain in a future article.)"

So here we are, reading that future article.

If you already know the reasons why the BOM cost has (almost) nothing to do with the profitable selling price, you are allowed to skip directly to the next article in this issue, or maybe peruse a few adverts and think about buying something.

Still with me? In the early 1980s I was working as an electronic designer, and found a new chip that would replace a whole circuit board containing about 60 components. I took it to my Technical Director (it was a small company) expecting to be patted on the back, but he asked me how much this IC cost.

I don't remember now, how much it was. But I do remember the TD saying that because it cost £1 more than the components it would replace, using this IC would mean we had to increase the selling price of the product by five times as much as the increase in the component cost – i.e. by £5.

Well, I stood there completely flabbergasted! After I had spluttered and made no sense for ten seconds, the TD explained that the profitable price for a product made by our company was calculated by taking the BOM cost and multiplying it by five.

I hadn't known that, and since then I have come across other manufacturers using the same stupid and totally-without-foundation basis for setting their selling price, all of them with different multipliers depending on the type of product and volume it was sold in, etc.

At the time of the above story I was in my early 30s, and – being a rather slow developer as far as assertiveness went – I felt unable to tell the TD that I had never heard anything quite so daft in my whole life.

I just mumbled a few things and left his office – my back sadly unpatted – and started looking through the jobs advertised in the engineering magazines, hoping to find an employer where some semblance of sanity might be found at board level.

(Now that I work for myself, I can say that I have finally achieved that goal – but then (as Mandy Rice-Davies (Google it)) would no doubt agree – I would say that, wouldn't I!)

Few companies have a system that accurately costs all the various things that go into making a product. It takes a lot of work, and some intelligence, to set up such a system, and keep it up to date as time goes on.

The BOM cost is about the only part of the product for which data is readily available, so – rather than do a proper calculation – many directors *pretend* there is a fixed relationship between the profitable selling price and the BOM cost, and guess at a multiplying factor. In the above (true) story, they had guessed the number five.

To show why this approach can't work, I'll list some of the things that need to be taken into account to set the profitable selling price of a product.

1. Corporate Overheads

This category includes the following, at least, none of which are related to the BOM cost:

- All wages and salaries, to everyone from the cleaners to the directors, including the engineering design department.
- Company vehicles.
- Costs of marketing and sales (exhibitions, brochures, websites, travel expenses and all those slap-up expense account dinners that it is hoped will make potential customers regard your products more favourably).
- Costs of product design and development, including all of the computers, test and simulation gear used by the design department to invent new products, plus the cost of manufacturing and testing prototypes.
- Rental or mortgage costs for the corporate buildings, and the maintenance and repair of same.
- Supplies of electricity, water, gas, and the treatment of waste.
- Payments of national insurance and pension contributions, local government taxes, and taxes on profits.
- Various insurance premiums, and bank interest on loans.
- Costs of machines, computers, hardware, automation, etc., that are used to manufacture the products, inspect and test them, and rework the (hopefully!) few products that need it.
- Cost of storing and shipping manufactured products.
- The christmas party.

2. Dividends it is hoped to be able to pay to shareholders...

- Plus performance-related bonuses it is hoped to be able to pay, to whoever is employed under such terms and conditions.

Not related to BOM cost.

3. The BOM cost

- The total cost of the materials and components used to make the product.

4. Cost of manufacturing and rework

- The total cost of fabricating things, assembling them with the other components, to make a product which is then tested.

  This depends upon the product's design, and the degree of automation used in fabrication, assembly and test.

- Rework costs depend upon the product's design, the skills of the fabricators and assemblers, and the degree of automation used in fabrication and assembly.

None of these are related to the BOM cost.

5. Warranty costs

- These depend upon the product's design. Pressure on the BOM cost and/or timescales causes designers to cut corners that could result in increased warranty costs.
- Many companies have failed, because – as the direct result of inadequate design – their warranty costs exceeded their profits.

None of these are related to BOM cost – except insofar as higher quality materials and more reliable components generally cost more. But the main determinants of reliability are design expertise and manufacturing quality.

Items 1, 2 and 5 in the above list are paid for by adding an amount to the cost of each product manufactured, called the "Gross Margin". In most manufacturing companies it is greater than the total cost of manufacturing a product (items 3 and 4).

So, more than half of the selling price of a product has nothing to do with what it cost to manufacture (and only a fraction of the manufacturing cost has to anything do with the BOM).

(Yes, we all know of sweatshops, and companies selling motherboards with the very first batches of the latest Intel processors, for which the above descriptions are not very accurate. But I'm talking about typical western European , Australian or American companies, that readers might find themselves working for.)

It's quiz time now for those hardy readers who have braved the many column-inches of graphics-free text above, and made it this far!

Question 1: (in your own time) — How many of the five categories above, bear even a slight relationship to the BOM cost?

Question 2: (in your own time) — There is no Question 2.

Those who answered: *"Just one - item 3 in the list (plus maybe a tiny bit of item 5)"* can go to the head of the class! You are smarter than the Technical Director in my earlier story (despite his Ph.D) and the rest of his fellow directors.

Of course, if you take an established product that is doing well and is clearly profitable, you can take its selling price and divide it by its BOM cost and get a number.

If every future product: used the same components designed in the same way to do the same functions; was assembled using the same skills and technologies; was purchased in the same quantities by the same customers, and *nothing else changes either* (e.g. salaries, rents, dividends, taxes, etc., etc., and the cost of the christmas party) – the same BOM multiplier will give you an accurate value for its profitable selling price.

But this <u>is based on totally unreasonable assumptions that are *never all true*</u>.

I've never worked on two sequential projects that used the same technology from one to the next, and my experience seems typical for electronic designers. For example since 1970 I've seen printed circuit board (PCB) manufacturing technology go from:

- Single-sided tracking (semiconductor devices no more complex than a single transistor), to
- Double-sided tracking with soldered pins to connect the two sides, to
- Plated-through-hole (PTH) technology with two layers (carrying opamps and TTL up to 16 pins), to
- PTH with four layers, with track-and-space at 230µm (9 thou) without cost penalty, to
- PTH with as many layers as you could want, with track-and-space at 100µm (4 thou) without cost penalty, carrying devices with 1,000 pins containing over 100 million transistors, to
- Microvia (High Density Interconnect, HDI, according to the IPC, www.ipc.org) with blind and buried vias, and as many layers as you could want.

At every technological step in the above progression, the PCB manufacturing and buying departments warned that the cost of the new PCB technology was higher than the old one, so the selling price of products that used the new technologies would inevitably have to increase.

But as we all know, having the benefit of hindsight, the cost of electronic products has continually *reduced* even while their performance and functionality has increased, *because* of the use of more costly new technologies.

Let's now look at a couple of quite reasonable scenarios:

A) A complex circuit that occupies a whole PCB can be replaced by a single IC.

Disadvantages: Increased BOM cost

Advantages: Fewer solder joints to fail, leading to smaller proportion of products needing rework; better reliability; lower warranty costs, plus a smaller (hence more attractive product) with smaller packaging and shipping costs, all leading to increased customer satisfaction; lower cost of future sales; increased sales volume and market share.

Would it be reasonable to deny using the new IC because of its higher BOM cost?

Would the selling price of the product really have to increase because of the increased BOM cost?

B) A 30p heatsink was omitted, due to pressure to meet the budgeted BOM cost.

The designer persuaded himself it would be OK, when he measured the temperature of the IC concerned and found that without the heatsink it was just below its maximum temperature rating.

But in most engineering undergraduate courses, they do not teach that semiconductor reliability typically halves for every 10°C rise in temperature. So the designer didn't realise that adding a 30p heatsink would have reduced the temperature of the part from 150°C to 90°C, increasing its reliability approximately 100-fold.

Since the IC in question was the most highly-stressed component in the product, the reliability during the warranty period turned out to be dominated by this IC, and the warranty returns rate was 25% during the winter months, 75% during the summer. Similar percentages of repaired products were returned under warranty a second time, when the same IC failed again. The reputation of the manufacturer's brand of products went into free-fall.

Finally they figured out what the problem was and added the 30p heatsink, reducing the returns rate to under 1%.

Do you think it was it reasonable to omit the 30p heatsink to meet the BOM budget, without consideration of the possible consequences for warranty costs; customer satisfaction; cost of future sales; market share, etc.?

Of course, the designer was only one year out of university and had never heard of Arrhenius or his famous curves. But – knowing that this was the situation – someone should have been watching out for this kind of problem. Without competent, experienced technical oversight, manufacturing companies become places where designers learn the hard way to design cost-effective and profitable products – at a potentially ruinous cost to their employers.

Well, if you read this far and *still* think that the BOM cost is the prime determinant of the profitable selling price – I just don't know what more I can do!

But I can suggest that you may enjoy a much more successful career in banking or politics, where consuming or losing huge amounts of other people's money doesn't seem to matter very much.

Keith Armstrong is the current President of the EMC Industry Association, www.emcia.org.

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Newsletter

The Institution of ***Engineering and Technology***
Electromagnetics Network

Meet the team

The Executive Team is responsible for the products and services delivered through the Electromagnetics Network. This issue features Dr. Richard Hoad, MSc. C.Eng, C.Sci, MInstP, MIET, MIEEE, member of the Electromagnetics Network Executive Committee.

Richard Hoad, QinetiQ

Richard Hoad is a principal consultant within the QinetiQ Electromagnetic and Environmental Services (EMES) team. His specific areas of interest include, Electromagnetic Environ-mental Effects (E^3), Electromagnetic Compatibility (EMC), and Electro-magnetic (EM) aspects of Information Security.

Richard has many years of experience in electromagnetics research including EM protection design and verification of large installations predominantly within the military/security environ-ment. Richard is the secretary of IEC SC 77C, and has recently been elected to join ACEC as the SC77C delegate. SC 77C is developing standards for the protection of installations against the effects of High Power Transient Phenomena including High altitude Electromagnetic Pulse (HEMP) and High Power EM environments. Richard is also an EMP Fellow of the SUMMA Foundation.

Community activities- what have we been up to?

In the Community Development department here at the IET we are looking to hold free to attend activities for the community such as site visits, quiz nights, awards and regional meetings. On May 6th the Electromagnetics Network supported a free to attend technical visit to TÜV Product Service's Fareham site. This visit was run jointly with the IETs Railway Network and attracted a mixture of IET members and non members.

Damon High, Railway Consultant at TÜV Product Service, gave his well received presentation 'The new EMC Directive – Its impact on the rail industry' to visiting delegates. Damon has been in the Railway Consultant group for three years. Given that, this Summer, the EMC Directive will have its second birthday the visit was an excellent opportunity to inform the community of its impact and implications.

Damon High, TÜV Product Service discussing ways of working with Roy Warden, Regional Development Manager, the IET.

TÜV Product Service are leading international experts in providing testing, certification, qualification, training and consultancy services to a range of industries. Their EMC testing is mainly based here in the UK. During the visit delegates were offered a networking lunch, tour of the site at Octagon House in Fareham, a presentation on the impact of the EMC directive and an overview of the company. Technical visits such as these allow the community to discuss with like minded individuals and find out information that the general public will not know. During the tour delegates had the privilege to see inside some of the hi-tech Anechoic Chambers and find out about the company's product safety testing, emissions testing, environ-mental testing and wireless equipment testing.

An Anechoic Chamber at TÜV Product Service

If you have any questions or suggestions surrounding community activity, or you would like to become involved with future activities please do get in touch.

Join the community – to get involved with the Electromagnetics Network (and to keep up to date with our activities) you can register online at www.theiet.org/electromagnetics and registration is free.

For more information regarding information in this article or the Electromagnetics Network contact Laura Cage, Community Development Manger by emailing lcage@theiet.org or calling 01438 765645.