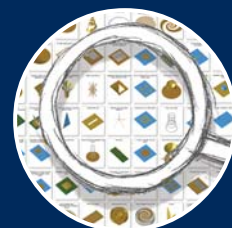


the



journal

Issue 88 May 2010



ISSN 1748-9253

**EMCIA announces PLT/PLC/BPL
competition**
See Page 5

**EMC Goggles
Unique Training Experience**
See Page 21

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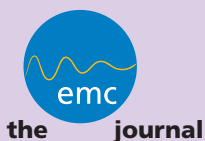
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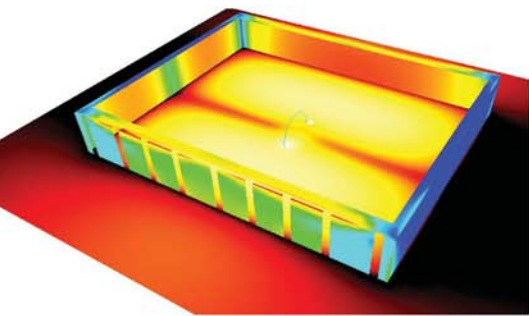
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CHANGING THE STANDARDS

PLT-Interference Range Contest

The EMC Industry Association announces a contest to identify the interference range of Power Line Telecommunications - otherwise known as PLC or BPL.

Competitors may be individuals or groups. They must demonstrate the presence of interference from a PLT installation - which might for example, comprise Comtrend or BTVision or Belkin Power Line Adaptors - at the greatest possible distance.

Two prizes of VR120 wide-band hand-held Scanner Receivers, kindly donated by Yaesu (UK) Ltd. are to be won:-

The "LDX" prize will go to the entry that, in the opinion of the organisers, best combines distance with technical excellence and credibility to Standards and Regulatory bodies.

The "MTY" - most typical - prize will be awarded to the entrant whose detection distance is closest to the average distance claimed by all entrants. The organisers

hope that this award will encourage everyone concerned to enter.

For details of the rules and how to enter go to <http://www.emcia.org/news.aspx>

For technical support and in-depth information about PLT go to <http://www.theemcjournal.com/>

Entries must be received by Monday 6th September 2010.

The contest is staged against a background of regulatory inertia that has resulted in the unfettered sale of hundreds of thousands of PLT devices that do not conform to the recognised international EMC standards or regulatory requirements. These cause serious - but sometimes difficult to identify - interference to short wave broadcast and point-to-point radio services. The problem has been brought into even sharper focus by the launch of the Belkin Gigabit PLA whose interference emissions extend into the VHF frequencies used by FM, DAB and mobile services.

Cheryl Watson appointed Managing Director at KEC



David Dyson hands over to Cheryl Watson

Cheryl Watson took over the position of managing director at KEC, the Aldermaston-based EMC specialist, on April 17th when founding managing director, David Dyson, became chairman.

Since joining Kern Electrical Components in 1980 Cheryl Watson has served in a number of capacities including PA, sales and office manager. She was appointed as administration director when KEC became a totally British owned, independent company in 1991.

David Dyson said of his successor: "Cheryl has long experience in all aspects of KEC business and over the past few years we have worked together on expanding the scope of the company from an EMC component manufacturer to one that is involved in the design and implementation of total EMC interconnect solutions."

Cheryl Watson said of her appointment: "I am looking forward to the new challenge. I have been closely involved in recent projects such as the Knowledge Transfer Partnership (KTP) between KEC and the University of Reading that will establish at KEC an EMC interconnect design and test facility based on computer simulated EMC test techniques. By following these and similar initiatives we plan to strengthen our position as a total EMC interconnect solution company."

AR RF/Microwave Instrumentation Receives ISO 9001:2008 Certification

ISO 9001:2008 Certified

AR RF/Microwave Instrumentation has passed the rigorous standards for quality management systems to earn recertification to the newest ISO standard, ISO 9001:2008.

Maintained by ISO, the International Organization for Standardization, and administered by accreditation and certification bodies, ISO 9001 is by far the

world's most established quality framework for companies of all kinds and sizes. It is currently being used by over 3/4 million organizations in 161 countries. It sets a global standard not only for quality management systems, but for management systems in general.

Having earned this latest recertification, AR has again demonstrated its commitment to continuous improvement and to bringing out the best in every facet of its operations.

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Front Cover

Hero image, TUV, page 28
Circle top, AR, page 20
Circle middle, CST, page 19
Circle bottom, Narda, page 18

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Rohde & Schwarz and Benetel present femtocell test and measurement solutions ranging from development to production

Rohde & Schwarz and Benetel Ltd. cooperate to supply comprehensive test and measurement solutions for Femtocell Access Points (FAP) from product development through pilot production to mass production. The relationship leverages test and measurement equipment from Rohde & Schwarz with experience from Benetel in test software and custom solutions. The BTS-114RS production test system is the first femtocell test system to utilize parallel RF testing to reduce the cost of test (COT). The design and verification system, FAST, helps shorten product development time during the R&D phase.

The BTS-114RS is a flexible hardware and software platform that implements a scalable solution capable of cost effective testing from pilot production through to volume production. It is the first FAP test system to apply throughput optimized parallel testing to volume manufacturing and has been successfully integrated into FAP production lines. Parallel automated highly isolated test fixtures allow over-the-air (OTA) testing of the Units Under Test (UUT). The system has a compact design to minimize floor space requirements. Other features include: Auto calibration, remote log-in capability, and a database with tools for analyzing production data. The platform can be configured to provide boundary scan, functional testing, RF calibration, RF test, and application code download; all of which is followed by final functional test. For the manufacturing test solution, Benetel has test profiles for UMTS, CDMA2000®, GSM and GPS available today, with LTE and WiMAX™ planned for later in 2010.

The BTS-114RS utilizes the R&S SMBV100A vector signal generator and the R&S FSV signal and spectrum analyzer. Both

units meet the requirements for volume production for accuracy and for speed. The multiple standards supported by the Rohde & Schwarz platforms make it possible to offer the wide range of standards for femtocell test provided by the BTS-114RS. The versatile and accurate R&S NRP-Z11 power sensors are used for TX testing.

Benetel's design verification system, FAST, also benefits from the cooperation. It helps femtocell developers shorten product development time by automating device verification. Test times can be reduced by up to 80% compared to manual testing. This has the benefit of allowing more time for rigorous stress testing of new products prior to compliance testing. The system utilizes Benetel's FAST software and Benetel's Test Set with two R&S SMBV100A signal generators, one R&S FSV13 spectrum analyzer and one R&S SMF100A microwave signal generator for blocking tests to measure according to 3GPP TS25.141 transmitter and receiver specifications.

The Benetel Test Set contains a series of filter banks which can be switched in and out of the RF path as required. This feature enables the automation of blocking and adjacent channel measurements. The software has a flexible GUI to simplify controlling factors such as tests performed, test limits, and frequency points. Results are stored in a database and a software package is provided to generate user-friendly reports in graphical and tabular format. The design and verification test system FAST can be utilized today for UMTS (WCDMA, HSPA, HSPA+), CDMA2000® (1xEV-DO) and TD-SCDMA. More information on Benetel and Rohde & Schwarz Femtocell Solutions: <http://www.rohde-schwarz.com/technology/femtocell-solutions>

EMV/AR UK Celebrate their 20th Anniversary!



Twenty years ago, two events of major importance occurred. First and most important, I married my wife Ethel. The other event was the founding of EMV Ltd. Ethel and I with the help of John Smith, Tim Hague, Kevin Hutchinson and many others, started a company dedicated to customer service. Our business model was to market RF products with local warranty service and customer support, while emphasizing the growing EMC market in our product coverage. Of course, the success of EMV was because of the high quality personnel that we started with, many of them are still with us today.

It all worked. The company grew substantially, actually making a profit the first year. And we have held to the business model. It still offers the best customer support available on hardware and software, as well as warranty and other repairs of RF equipment. Our system setup and support are the best in the industry.

During the twenty years AR has grown ten times over. Recently, AR Europe has been founded. EMV has become a part of it being renamed AR United Kingdom. This is not to change the business model, but rather, to start AR Europe on the same business model to enable its spread across Europe.

Congratulations on a job well done! We look forward to the next 20 years!

Oh, and the marriage is still wonderful!

Donald "Shep" Shepherd
Chairman, AR Group

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Demand for Syfer Technology capacitors is continually growing, but selecting the most appropriate MLCC for high frequency circuit

applications can be a difficult task for any Engineer. Syfer has now made that easier with a range of sample kits for its range of High Q chip capacitors.

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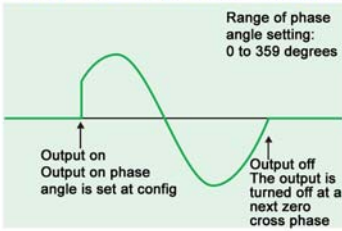
to FlexiCap™, Syfer's award-winning solution to reducing the possibility of mechanical cracking.

These kits will aid new circuit designs in the telecom infrastructure industry; in broadcast power amplifiers, high RF power circuits, filtering, diplexers and antenna matching applications.

For more information and to order a High Q sample kit, engineers should go to the website www.syfer.com

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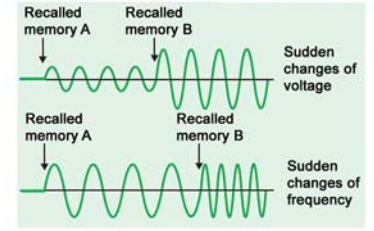
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12 & 13 October 2010

Every year we are told by Exhibitors we are coming back because we actually took orders on the stand or we were here “X” years ago and an enquiry has just resulted in a super contract. This is the strength of a single focus event, visitors come for a real reason not just to browse and collect literature.

Not surprising then that this is our 7th successful year. So don't be left out in the cold, if you are not there you will never know what you missed. But the competition will know what they gained.

Then of course there is the Networking. In an IET survey on last year's event delegates were asked: Did the event prove a valuable networking experience? 86.7% said Yes.

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Companies who have already Booked for 2010

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AR UK	MDL Technologies Ltd
BAE SYSTEMS (Rochester)	METECC
BAE SYSTEMS (Warton)	MILMEGA Ltd
BalSeal Engineering	Panashield (UK) Ltd
CST - Computer Simulation Technology	PPM Pulse Power & Measurement Ltd
Darchem Engineering Ltd	Q Par Angus Ltd
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Easby Electronics Ltd	Radio Society of Great Britain
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Conference and Training Sessions second to none



EMCUK 2010 Training Sessions

Tuesday 12th October 2010

Registration is from 08.30 for either Day.

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 OV 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

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

Wednesday 13th October 2010

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 anticipated 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.

We reserve the right to make changes as required.

EMCUK 2010 Technical Sessions

Tuesday 12th October 2010

08.30	Registration
09.00 - 10.30	Defence & Aerospace
	Chairman: Professor Nigel Carter Consultant
	The Environment Electromagnetic Pulse (EMP) and High Power Electromagnetic (HPEM) Environment and Assessment Methods <i>Dr Anthony Wraight & Dr Richard Hoad</i> QinetiQ
	Lightning Environment <i>Dr Chris Jones, BAE Systems</i>
10:30 - 11.00	Coffee and Visit to Exhibition Stands
11.00 - 12.30	Standards Implication of Changes to DO160 on Test Laboratories <i>Gavin Barber, QinetiQ</i>
	Read Across from Civil to Military CENELEC WG 9 <i>Dave Imeson, Compliance Europe</i> <i>Peter Dory/Simon Middleton, TÜV Product Services</i>
12:30 - 14.00	Lunch and Visit to Exhibitions Stands
	Chairman: Ian MacDiarmid BAE Systems
14:00 - 15.30	Protection Overview of Protection <i>Professor Nigel Carter, Consultant</i>
	Design Aspects including Modelling Modelling <i>Paul Duxbury, CST</i>
	Combat Corrosion in EMC <i>John Terry, Hitek Electronic Materials</i>
	Filtering <i>Chris Noade (or one of their engineering team), Syfer Technology</i>
	Shielding <i>Paper & Speaker TBC</i>
	Enclosures <i>Paper & Speaker TBC</i> Rittal UK Ltd
15:30 - 16.00	Tea and visit to Exhibition Stands
16.00 - 17.30	Testing Platform Testing of Military Vehicles <i>Roger Marson/Peter Lane - TBC</i>
	Challenges of meeting the HIRF Testing Requirements of DO160 <i>Gavin Barber, QinetiQ</i>
	Hardness Assurance <i>Tony Llewellyn, BAE Systems</i>
17.30	Finish

Wednesday 13th October 2010

08.30	Registration
09.00 - 10.30	Lightning
	Chairman: Ian MacDiarmid BAE Systems
	Defence & Aerospace Lightning Workshop <i>Dr Chris Jones, BAE Systems</i>
10:30 - 11.00	Coffee and Visit to Exhibition Stands
11.00 - 12.30	Defence & Aerospace Lightning Workshop (Continued) <i>Dr Chris Jones, BAE Systems</i>
	Lightning Strike Analysis on Modern Aircraft <i>Claudio Zizzo, Rolls Royce, Derby</i>
12:30 - 14.00	Lunch and Visit to Exhibitions Stands
14.00 - 15.30	Commercial EMC Workshop
	Chairman: Paul Duxbury CST
	Radio & Broadband <i>Papers & Speakers TBC</i>
	Digital Dividend TV, Audio Video <i>Papers & Speakers TBC</i>
15:30 - 16.00	Tea and visit to Exhibition Stands
16.00 - 17.30	Wireless On Board <i>Papers & Speakers TBC</i>
17.30	Finish

We reserve the right to make changes as required.

Fees for both Training & Technical Sessions:

One Day: £145 plus 17.5% VAT

Two Day: £260 plus 17.5% VAT

All fees include lunch, proceedings printed in colour, coffee and tea breaks. If you attend a Training Session you will be issued with an attendance certificate. Entrance to the exhibition is Free, as is all Parking.

To book go to www.emcuk.co.uk where you can download a booking form or book & pay securely Online.



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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 they are just the topmost 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. I'd need at least eight pages in every EMC Journal just to keep up!

570 Rail industry doesn't understand EMI

During a coffee break at the IET Seminar: "EMC in Railways 2009", held at Savoy Place, London, on 12th Feb 2009, I met an old colleague who I knew was a proper EMC expert (as opposed to what the rail industry seems to think is an EMC expert), and asked them why it was that most of the rail industry believes that only in-band EM disturbances can cause EMI? Given the safety-critical nature of railways, it seemed nothing short of astonishing to me that the whole industry should ignore (or deny) the many engineering issues that are responsible for most EMI incidents.

He said it was to do with the way dealing with EMC had evolved over many years on the railway and the historical focus on signalling equipment and a problem that he and his colleagues were trying to change, but were making slow progress. He then told me a story about a company that used very sophisticated coding to catch the incorrect data resulting from in-band interference and fail "right side" (railway-speak for fail safe).

Their calculations showed that this would occur so infrequently that it would not cause operational problems - the special coding was used "just in case", as a safety measure against what they thought of as the threats from EMI.

However, when their system was deployed in practice, the other kinds of EMI - the ones ignored or denied by most of the rail industry - caused their system to fail so often that it was never 'up' for long enough to be of any functional use. Needless to say an expensive investigation followed by remedial action was needed to render the system useable!

(Keith Armstrong, from a discussion during a coffee break at IET Seminar "EMC in Railways 2009", Savoy Place, London, 12th Feb 2009.)

571 EMI appears as error in calculation

This story is a relatively early one, from the development of the LEO computer. The quote is in the words of Mary Coombs, née Blood, who was the first female programmer on the software team.

"The engineers found us invaluable in helping to find faults. I remember spending hours and hours in the computer room - you could make little loops of instructions and put them in manually straight from the control desk. There was one fault that took us hours to track down - and it turned out to be electrical interference from the lift in WX block, the building in which LEO was housed. It didn't come out as a crackle like on the radio, it came out as something going wrong with a calculation."

The date of the event is not very clear in the book; probably 1951 or 1952. Source: Georgina Ferry, *A Computer Called LEO*, Harper Perennial, 2004, p. 107.

(Kindly sent in by Richard Pickvance, Engineer's Eye, London, on 8th February 2010.)

572 Radar interferes with early computer

Here's another early EMI anecdote, about Australia's first home-grown computer, the CSIRO Mark 1:

"Other problems proved more challenging than just keeping cool. One was the appearance of random digits in the acoustic-delay memory. The researchers were helped in tracing this one by realizing that when the random digits appeared they were spaced three seconds apart. After some head-scratching they found that a meteorological radar mounted nearby was rotating at one-third of a turn per second. Each time its signal passed the air-conditioning duct on the roof, some of it was reflected down into the guts of the machine. A suitably high-tech solution

was found - the mouth of the duct was covered with fine-mesh chicken wire that appeared impenetrable to radar of that wavelength, but didn't impede the flow of air."

Again the date is unclear, but certainly early 1950s, probably 1951 to 1953. Source: Mike Hally, *Electronic Brains: Stories from the Dawn of the Computer Age*, Granta, 2006, pp. 171-2.

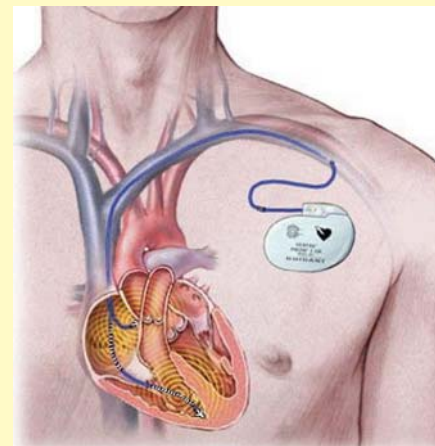
Somewhere I know I saw an account of life with a very early computer - either Colossus or another not much later - along the lines of "At some point in the small hours there was a loud explosion. Afterwards [the computer] worked considerably better than before." Not a banana skin, but a good story anyway. I'll keep looking.

(Kindly sent in by Richard Pickvance, Engineer's Eye, London, on 9th February 2010.)

573 RFID Tags Could Affect Pacemakers and ICDs

Background: The use of radiofrequency identification (RFID) systems is expanding and highlights the need to address electromagnetic interference (EMI) to implantable pacemakers and implantable cardioverter-defibrillators (ICDs).

Objective: This study sought to examine the electromagnetic compatibility (EMC) between RFID readers and implantable pacemakers or ICDs.



Methods: During in vitro testing, 15 implantable pacemakers and 15 ICDs

were exposed to 13 passive RFID readers in 3 frequency bands: 134 kHz (low frequency [LF]), 13.56 MHz (high frequency [HF]), and 915 MHz (ultra high frequency [UHF]).

Results: While being exposed to LF RFID, a reaction was observed for 67% of all pacemaker tests (maximum distance 60 cm) and 47% of all ICD tests (maximum distance 40 cm). During HF RFID exposure, a reaction was observed for 6% of all pacemaker tests (maximum distance 22.5 cm) and 1% of all ICD tests (maximum distance 7.5 cm). For both pacemakers and ICDs, no reactions were observed during exposure to UHF RFID or continuous-wave RFID. Pacemakers and ICDs were most susceptible to modulated LF RFID readers.

Conclusion: Although there is in vitro testing evidence for concern for implantable pacemaker and ICD EMI at LF and HF, the FDA has not received any incident reports of pacemaker or ICD EMI caused by any RFID system. We do not believe the current situation reveals an urgent public health risk.

(From *HeartRhythm Journal*: www.heartrhythmjournal.com/article/PIIS1547527109011461/fulltext, reported in *Interference Technology's on-line newsletter*: www.interferencetechnology.com/lead-news/article/study-rfid-tags-could-effect-pacemakers.html.)

574 Two infusion pump malfunctions apparently due to cellphones

MDR # 679280, Received 21 February 2006

The facility reported an infusion pump with over infusion. Reportedly a displayed rate changed during pt infusion. The pt's cell phone rang and the nurse at the bedside noticed that rate of pitocin was displayed at 120ml/hr rather than the prescribed rate of 20 ml/hr. The change was noticed in less than one minute and there was no harm to the pt. A new pump was put on the pt. According to the hosp. rep, the event history did not show any buttons being pressed for the rate change.

MDR # 736554, Received 19 June 2006
The facility reported a pump that stopped infusing during patient use. The pump was infusing heparin, at which time the patient's family member used a cell

phone in close proximity to the pump. The pump then stopped infusing. There was no patient injury or medical intervention according to the hospital rep.

(Presented by Jeff Silberberg (US FDA) to the 20th Annual AAMI/FDA International Conference on Medical Device Standards and Regulation, March 9, 2010.)

575 Interference between two medical devices means recall of one of them

Model X Extracorporeal blood circulation system. Recall date: March 17, 2008, No: Z-1902-2008

Recall reason: Use of Model Y Electrocautery Unit on the patient can cause Model X to stop pumping and alarm.

(Presented by Jeff Silberberg (US FDA) to the 20th Annual AAMI/FDA International Conference on Medical Device Standards and Regulation, March 9, 2010.)

576 New-generation mobile phones interfere with critical-care medical equipment

A total of 61 medical devices in 17 categories (27 different manufacturers) were tested and demonstrated 48 incidents in 26 devices; 16 were classified as hazardous, 20 as significant and 12 as light.

The GPRS-1 signal induced the most EMI incidents, the GPRS-2 signal induced fewer and the UMTS signal induced the least. The median distance between antenna and medical device for EMI incidents was 3 cm (range 0.1 to 500 cm). One hazardous incident occurred beyond 100 cm (in a ventilator with GPRS-1 signal at 300 cm).

(From: "Interference by New-Generation Mobile Phones on Critical Care Medical Equipment", van Lieshout EJ, van der Veer SN, Hensbroek R, Korevaar JC, Vroom MB, Schultz MJ., *Crit Care*. 2007;11(5):R98, Jeff Silberberg (US FDA) to the 20th Annual AAMI/FDA International Conference on Medical Device Standards and Regulation, March 9, 2010.)

577 RFID interferes with critical-care medical equipment

In 123 EMI tests (3 per medical device), RFID induced 34 EMI incidents: 22 were

classified as hazardous, 2 as significant, and 10 as light. The passive 868-MHz RFID signal induced a higher number of incidents (26 incidents in 41 EMI tests) compared with the active 125-kHz RFID signal (8 incidents in 41 EMI tests). The passive 868-MHz RFID signal induced EMI in 26 medical devices.

(From: "Electromagnetic Interference from Radio Frequency Identification Inducing Potentially Hazardous Incidents in Critical Care Medical Equipment", van der Togt, R., E. J. van Lieshout, et al, *JAMA* 299(24): 2884-90, 2008, Jeff Silberberg (US FDA) to the 20th Annual AAMI/FDA International Conference on Medical Device Standards and Regulation, March 9, 2010.)

578 EMC of Pacemakers and ICDs exposed to RFID readers

Implantable Pacemaker Reaction to RFID

At least one reaction was observed in 21 of the 22 pacemakers tested. While being exposed to each of the two 134 kHz RFID readers a pacemaker reaction was observed for 34 of the 44 possible tests (77%). While being exposed to each of the four 13.56 MHz RFID readers a pacemaker reaction was observed for 21 of the 88 possible tests (24%).

Implantable Cardioverter Defibrillator Reaction to RFID

At least one reaction was observed in 18 of the 19 ICDs that were tested. While being exposed to the two 134 kHz RFID readers an ICD reaction was observed for 27 of the 38 possible tests (71%). While being exposed to the four 13.56 MHz RFID readers an ICD reaction was observed for 8 of the 76 possible tests (11%).

(From: "Electromagnetic Compatibility of Pacemakers and Implantable Cardiac Defibrillators Exposed to RFID Readers", Seidman S, Ruggera P, Brockman R, Lewis B, Shein M., *International Journal of Radio Frequency Identification Technology and Applications*, Vol. 1, No. 3, 2007:237-246, , Jeff Silberberg (US FDA) to the 20th Annual AAMI/FDA International Conference on Medical Device Standards and Regulation, March 9, 2010.)

579 The strange case of the energy-saving lightbulbs and Virgin Media

Got a Virgin set-top box with a mind of its own? And energy-saving lightbulbs? Then you might find there is a surprising connection. Emma Clements was advised to switch bulbs when her TV kept changing channels.

If your television or cable equipment seems to have a life of its own, why not get rid of your lightbulbs? It might sound like a joke, but that's the advice Virgin Media gave to Emma and Alistair Clements when their cable TV receiver started behaving oddly.

The couple, who have two young daughters, have been Virgin Media TV subscribers since moving to their home in Carshalton, Surrey, in 2007. They had no problems with the service until a few months ago, when they first noticed their Virgin Media set-top box, manufactured by Samsung, started randomly changing channels and switching itself on and off.

"At first we thought it was the children's sticky fingers on the remote control and that the buttons were sticking," Emma says. "But the novelty soon began to wear off."

Emma called Virgin Media customer services, which promptly dispatched a technician to examine the box. "Before he'd even seen anything, the engineer asked us if we used Philips energy-saving light bulbs," she says. "He changed the box anyway, but said it would probably keep happening."

Unfortunately, the engineer's prophecy proved correct. "With the new box, it was worse, if anything," Emma says.

The Clements family had only one Philips energy-saving bulb in their living room, in a lamp sitting on a side table about 12 feet away from the TV.

A Philips Electronics spokeswoman confirmed the problem was known to the company, but expressed surprise users of its bulbs still experienced it. "Some very early compact fluorescent lamps, shortly after starting, could cause interference with TV controls due to the frequency of operation of the bulb and when placed near a TV," the spokeswoman said. "The frequency was quickly changed many

years ago and we have had no recent reported incidents."

Following Guardian Money's intervention, Philips's customer relations team contacted the family and asked them to return the offending bulb so it could properly analyse the problem, but said it wanted to monitor the issue on "a case-by-case basis". It advises other customers experiencing similar problems to contact its online support team. Virgin Media also acknowledged the problem but laid the blame squarely at the door of the bulb manufacturer. "This is an old problem," its spokesman said. "Some compact fluorescent bulbs flicker at such an imperceptible rate that they can interfere with infrared equipment. What our customer care chap said is kind of correct, but it's not the full answer. You can still use energy-saving bulbs, but we recommend trying an alternative brand."

Removing the offending lightbulb from the living room has helped, says Alistair, but the main light in his hallway still causes the set-top box to function erratically, despite being in a different room. "It's Virgin's box that causes the problem as much as the bulbs," he claims. "Energy-saving light bulbs aren't cheap. If we need to replace them all, why can't Virgin Media pay for them?"

The cable provider's spokesman denied the problem happened any more frequently with its Samsung boxes than others, but a browse through specialist cable TV forums online suggests it may be a more common issue than Virgin thinks – or cares to admit.

On cableforum.co.uk, a poster called Organ Grinder writes: "My light switch is controlling my Virgin TV box each time it is used ... anyone have any idea what is going on? Is my flat haunted? ... I don't think it's worth calling Virgin, as I understandably expect them to think I am raving mad." Monkey2468, a poster who lists his occupation as a technician, replied: "It will be energy-saving light bulbs. Seen it several times before with Samsung set-top boxes."

In the meantime, be it the fault of the box or the lightbulb, the Clements family just wants its TV to work properly again. "It would be very nice to get it sorted," says Alistair. "Virgin Media isn't particularly

cheap and if we can't get it fixed soon, it might be time to switch provider."

(Kindly sent in by Matthew Wilson, Product Design & Production Manager, GB Electronics (UK) Ltd., "The strange case of the energy-saving lightbulbs and Virgin Media", Graham Snowdon, The Guardian, Saturday 10 April 2010, www.guardian.co.uk/money/2010/apr/10/energy-saving-lightbulbs-virgin-media. This article appeared on p1 of the Money section of the Guardian on Saturday 10 April 2010. It was published on guardian.co.uk at 00.06 BST on Saturday 10 April 2010.)

580 Gas clothes dryer overheating incidents due to internal ESD.

A model of gas clothes dryer was recalled in 2008, after seven reported complaints that the dryers scorched clothes in them. The dryers were products of a well-known Japanese manufacturer, and 50,000+ units were shipped between 1997 and 1999. The cause of the incident, as I read from the announcement, is:

Clothes in the dryer's rotating drum caused ESD, and the ESD caused malfunction of a microprocessor which control the dryer. Then, the dryer's gas burner continued to heat the drum when the drum stopped rotation, caused overheating and scorched clothes in the drum. In all the known cases, temperature fuse in the dryer worked as intended and possible fire hazard could be prevented.

I don't know whether the product went through IEC/EN 61000-4-2 ESD tests. However, because the problem was caused by ESD inside the product and not by ESD outside the product as usually tested, and because maybe clothes dried and rubbed in the dryer could cause discharges stronger than that usually applied in ESD testing, I think we shouldn't be surprised even if product perfectly passed the IEC/EN 61000-4-2 tests still caused this type of ESD problem.

Reference: Recall notice from METI, http://www.meti.go.jp/product_safety/recall/file/080909-1.html

(Kindly sent in by our long-term correspondent in Japan, Tomonori (Tom) Sato, on 14th February 2010 <http://homepage3.nifty.com/tsato/>.)

581 Lubbock airport ILS suffers EMI, stops flights

There's a chance Lubbock Preston Smith International Airport will resume full service today, nearly a week after problems with the instrument landing system forced numerous flight delays and cancellations.

A Federal Aviation Administration flight check airplane is due to arrive today from Oklahoma City to test the airport's one working instrument landing system, which is essential for flights arriving in poor visibility.

An FAA spokesman said the system's equipment is operating correctly, but was being hampered by interference along the approach path. "It appears there is some electromagnetic and radio interference," said Lynn Lunsford, an FAA spokesman. "There was a spurious radio signal in the vicinity of the final approach path, doing just enough to cause our signal to be erratic."

FAA workers spent the weekend using radio and electromagnetic direction finding equipment to find possible sources of the interference. "We're reasonably confident we've identified the issue, but in aviation, 'reasonably confident' is not good enough," Lunsford said.

While he could not be specific about what was interfering with the ILS signal, he said causes could include unshielded electric lines or even a fluorescent light fixture with a ballast that is going bad.

FAA officials hoped to test the system Monday, but bad weather in Oklahoma City in the morning kept their airplanes grounded, Lunsford added.

Even if an airplane had been able to leave Oklahoma City, the weather at the airport Monday was not good enough to allow the tests. The flight check aircraft makes several passes along the airport's glideslope - the route an airplane would make on its final approach - to check the ILS signal.

Lubbock's airport has two ILS operations, but one is currently disabled because of runway construction. The airport also has an RNAV - area navigation - system that has allowed some carriers to keep flying.

Of the air carriers using Preston Smith, the situation has been hardest on Southwest Airlines, which has the most flights daily in and out of Lubbock. Southwest's airplanes are not equipped for RNAV.

(Kindly sent in by Dennis D. Swanson, Electromagnetic Effects Staff Engineer - Specialty Engineering Group, Lockheed Martin Mission Systems & Sensors, St. Paul, Minnesota, USA, taken from: "Landing system may be up today", by Walt Nett for AVALANCHE-JOURNAL, Tuesday, February 09, 2010, http://lubbockonline.com/stories/020910/loc_560323567.shtml. Story last updated at 2/9/2010 - 12:17 am.)

582 Bill includes \$800,000 for military EMI solutions

The U.S. Senate passed the \$636 billion Department of Defense appropriations bill that includes millions of dollars for military-related projects by Michigan companies, including an allocation of \$800,000 for research and development of optical interconnect technology for military aircraft.

The next generation data and communication management systems needed for weapons platforms will depend upon tightly integrated optical fiber solutions, which reportedly provide decreased weight, immunity to electromagnetic interference and other advantages.

(From: www.detnews.com/article/20091220/POLITICS03/912200301/1022/U.S.-Senate-OKs-bill-that-benefits-some-Michigan-companies-jobless,12/22/0901:49PM.)

583 PCB's solder resist layer causes hum interference problem

Over the years, I have improved the way we build our audio induction loop power amplifiers. When one niggle became unacceptable, I would try various means of dealing with it, then employ the best one.

Of interest to EMC design, I inherited the ancient strategy of star-wired earths, including several parallel earth tracks on the same power supply circuit board. My first revision of the power supply board was more like a transmission line from a.c. in to d.c. out, with one substantial earth track along the middle.

More recently, we have used a combined PSU and power amplifier board, with 2 power amp chips. A key feature of this design was a small angle bracket by which the large earth track in the middle of the p.c.b. was bolted firmly to a thick chassis plate.

A recent new batch of circuit boards came with solder resist, even though we had not specified this. It made soldering some components a little more difficult, due to the small solderable area, but we got used to it and carried on as normal.

However, we began having a hum problem, and this was variable, better on some amplifiers and worse on others. At first, I put this down to variations in the finished equipment, such as on which panel the mixer board was mounted.

Then it occurred to me that the solder resist was preventing the angle bracket from making good contact and providing a secure earth bond. Solution? A scrape and solder job, so that the bracket was soldered securely to the earth track of the pcb. Result? A good night's sleep since now I have no mains hum to worry about.

The lesson? An apparently small change, such as solder resist in the wrong place, is enough to cause EMI problems. And in case you're thinking mains hum is not an EMC issue, in this case it is because it is unwanted electrical interference on an otherwise high quality audio product.

(And I have modified the p.c.b. artwork so that solder resist would no longer be a problem.)

(Kindly sent in by Robert Higginson, of AREAC, manufacturers and installers of audio induction loop systems, on 17th February 2010. Robert has been contributing interesting anecdotes on EMI to Banana Skins for some years.)

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

By coincidence, I'm writing this just after returning from an IEC SC77AWG1 meeting, as was the case for the previous column. However, to avoid being accused of *crambe repetito*, I will mention only a few points that emerged from the meeting. Luckily, there is much to report on the latest happenings in the PLT field. There was a meeting of the CENELEC EMC committee, TC210, in mid-May, which hadn't happened at the time of writing, so 'latest' has to be interpreted with that in mind.

Low-frequency conducted emissions ('mains harmonics')

Grouping

This is about the change in Edition 2 of IEC/EN 61000-4-7 to increase the measurement bandwidth from 5 Hz to 50 Hz. It is suspended, under the terms of clause 7, because it would result in many products that are not found to cause EMI problems to fail the relevant provisions of IEC/EN 61000-3-2 or -12. It was introduced to take into account rapidly-varying harmonic amplitudes, which create sidebands around the harmonic frequency just as in AM radio. With the 50 Hz measurement bandwidth, these 'interharmonic' sidebands are 'grouped' with the adjacent harmonic. However, it has not explicitly been established that these rapid variations have any effect on the supply network or load equipment. What does happen is that the measured harmonic current is increased with the 50 Hz bandwidth, if interharmonics are present, often sufficiently so as to violate the stringent limits for some even, and high-order odd, harmonics.

Now we have load equipment that has switching circuits operating at low frequencies, directly connected to the supply. These generate individual interharmonic frequencies, not related to modulation of a harmonic amplitude. So the subject has to be re-examined in depth. Meanwhile, clause 7 remains in effect.

Lighting

Dimmable compact fluorescent lamps (CFLs)

Early examples of these have shown very undesirable input current waveforms, especially when dimmed, with very short, high-amplitude current pulses. Some lamps have been found to produce conducted emissions far above 9 kHz (the upper frequency bound of 'low-frequency' emission standards), in the tens of kilohertz range, which is also very undesirable. The technology is very dynamic, partly because of the search for solutions that meet requirements for low conducted emissions, high energy efficiency, long life and low cost. Another factor is that CFL technology itself has a limited life, being rapidly overtaken by LED technology.

There are two topics that affect the standards; a possible need to modify the requirements for the lamps themselves, and a need to reform the rather complex provisions relating to dimmers in IEC 61000-3-2. At present, it seems that there is no need to modify the requirements for CFLs, (but new requirements are needed for some LED-powering techniques). Also, dimmers for incandescent lamps are treated differently from dimmers for discharge lamps. The requirements for the latter were written in the context of the very complex and costly dimmers for linear fluorescent tubes, and cannot be met by simple phase-control dimmers. Manufacturers naturally want to be able to offer simple dimmers that work with either incandescent lamps or dimmable CFLs.

For all of the above, studies continue. The committee needs more detailed input data in order to come to firm conclusions on changes to the standards.

LED lamps and luminaires

Naturally, this technology is also very dynamic, for the same technical reasons as for CFLs, and the race is on to reduce costs so that LED products can compete on cost in the market. There is some way to go on this, but manufacturers are very confident that in a few years we shall all be buying LED lamps and luminaires by choice.

For these products, changes to IEC/EN 61000-3-2 are necessary. There is no problem for products over 25 W, but many products are, and will be, well below 25 W and even below 5 W. For such low power products, measurements of harmonic currents can be difficult. However, such products are likely to be used in very large numbers, so the cumulative effect of their emissions on the supply network and on load equipment may be significant. One proposed technique for products below 25 W has been called 'valley-fill'. It uses a diode, capacitor and resistor network in place of the normal filter capacitor in the on-line rectifier circuit. The committee meeting being in Mexico, it was immediately noted that the input current waveform resembles the outline of a sombrero, so that name may well replace 'valley-fill'. The technique has a good power-factor and produces fairly low harmonic amplitudes with a somewhat unusual spectrum, but it does not meet any of the limits currently applicable to lighting products.

PLT

Attempts to produce a standard (as an amendment to CISPR22/EN 55022) have failed in CISPR. The European Commission is determined to press ahead in Europe and the French national standards committee has made a proposal to produce a CENELEC standard. This is based on a rather complex CISPR proposal that has already been rejected. Notably, it does not correctly take into account the mode conversion, from differential to common, of the PLT signal caused by impedance discontinuities in the mains cables between the sender and receiver. There is also key data missing, which is necessary to verify some of the proposals, such as the inductance of a centre-tapped inductor in a proposed impedance-stabilising network (ISN).

However, there is dissent at other levels than the technical in the standards-making process. First, should the work be done in a CENELEC committee, a Working Group of CLC/TC210, or in a joint WG with ETSI? There are arguments on both sides. A liaison with ITU/R may also be necessary, which CENELEC doesn't really have as an operating process at present.

Then there is the question of what form the 'deliverable' - the publication - should take. There are four possibilities:

- a new EN standard (as proposed by the Swiss National Committee, although the next option would also satisfy their proposal);
- a second Part to EN 55022, cross-referring extensively to the current EN 55022, which would be come EN 55022-1 (suggested by me to the British National Committee) ;

- an amendment to EN 55022 (as proposed by the French National Committee);
- a self-contained Common Modification (probably a Normative Annex), converting CISPR 22 to a new EN 55022.

Naturally, there are supporters for all of the above, and there are supporters for 'none of the above' as well: they don't believe that PLT as it is conceived at present can ever meet the requirements for protection of radio services in the HF band. The rationale for a separate publication (a new standard or a Part 2 to EN 55022) is that it has already been very troublesome to maintain CISPR 22 and EN 55022, partly because of timing differences between IEC and CENELEC procedures. Adding in maintenance of rapidly-varying PLT techniques would make this problem much worse. However, the question does not have to be answered now: if it is prepared as a Normative Annex, it is purely an editorial matter to convert it into a Part 2 or a new standard, and this can be decided when the document is ready for voting (later this century, no doubt).

Meanwhile, the PLT industry sector is busy developing systems that work at frequencies well above 30 MHz, opening up ranks of new considerations. Cables are potentially much better radiators at VHF frequencies, due to being many wavelengths long, and impedance discontinuities of short physical length, which are less 'visible' to lower frequency signals, become more 'visible' at higher frequencies. Cable losses tend to be higher, too, which may well prompt the use of higher sending power.

To add exciting overtones to the mix, CENELEC TC205 has produced a 56-page report on cases of inadequate immunity of some products to PLT and PLT-like signals on the mains supply

in the frequency range 9 kHz to 150 kHz!


At least the UK National Committee has been able to reach a consensus (in a 90 minute conference call, because the CENELEC meeting is next week)! The principles are:

- The frequency range above 30 MHz should be included;
- No change to the test methods and limits above 30 MHz;
- Test methods and requirements for dynamic notching and adaptive power functions should be normative;
- All relevant information and inputs must be considered;
- A test method based on measuring the output of the modem, with no cable attached (as proposed by the French National Committee), would not be acceptable.
This latter point is important, because the balance of even a low-cost modem can be excellent, due to the need for a floating transformer coupling for safety reasons, so that the common-mode output, which is responsible for the emissions, is very small indeed.
- A new working group should be established specifically for this task (only). It should have a neutral chairman (i.e. not from the PLT industry)


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PRODUCT GALLERY

Real-time analysis of electromagnetic fields in hand-held format

Narda Safety Test Solutions has now equipped its frequency-selective measuring set for electromagnetic fields with a "Scope" operating mode. Using this, it is now possible to analyze the frequency content and time characteristics of signals from radar equipment, mobile communications services such as Wi-Fi, WLAN, WiMAX, and DECT, or radio control systems like ZigBee and Bluetooth.

The Selective Radiation Meter SRM-3006 from Narda Safety Test Solutions is now available with a "Scope" operating mode. The instrument displays the real-time characteristic of a signal recorded using frequency selection. It is possible to measure pulse widths and signal periods as well as set triggers, just as with an oscilloscope. The time intervals that can be set range from 24 hours down to microseconds, and the resolution goes down into the nanosecond range. It can therefore be used to make long-term observations of individual radio channels e.g. over the course of an entire day, as well as to detect even the shortest of impulses, such as from radar equipment.

This combination of frequency-



selective measurement and display versus time opens up possibilities that are not covered by either pure spectrum analysis or simple measurement over time:

- In unknown multi-frequency environments specialists can determine the type of field source by marking a frequency line displayed in "Spectrum" mode and switching to "Scope" mode to look at the time characteristic which exhibits specific features for various mobile communications services such as Wi-Fi, WLAN, WiMAX or DECT. The resolution bandwidth (RBW)

can be set between 40 kHz and 32 MHz – enough to capture an entire WiMAX channel.

- Where the signals are known, e.g. from GSM stations, operators can select a single 200 kHz bandwidth traffic channel (TCH) and measure the loading of the individual timeslots within the frequency channel using "Scope" mode.
- In "Scope" mode, the instrument records the real peak values of radio control signals in the industrial environment, such as ZigBee, or Bluetooth, or in the public and private domain – garage door openers, automobile keys, installation switches – even in complex situations where several signals are superimposed.

The SRM-3006 measures the average, RMS and peak values simultaneously; further conclusions about the type of field source can be drawn from the ratios of these values to one another. The instrument can be set to display all results in either physical quantities, such as field strength (V/m, A/m) or power density (W/m², mW/cm²), as logarithmic expressions (dBμV), or directly as a percentage of the

permitted limit value. For the latter, the weighting curves for all the current safety standards are stored in the instrument.

The SRM-3006 automatically takes the calibration data into account when Narda's proprietary antennas are used. The instrument also accepts measuring antennas from other manufacturers, such as so-called sniffer probes. In such cases, software can be used to upload the calibration data to the instrument.

About the SRM-3006

The Selective Radiation Meter SRM-3006 from Narda Safety Test Solutions has been specially developed for environmental and safety measurements in electromagnetic fields. Using isotropic measuring antennas, the instrument covers the entire frequency range from 9 kHz to 6 GHz. It can therefore be used equally well to investigate safety in the near field region of long wave transmitters, make measurements on radio and TV broadcast transmitters, and determine exposure levels caused by the latest generation of mobile telecommunications services.

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Bias tees make their mark in high frequency broadband

Just announced by **Admiral Microwaves**, the specialist supplier of RF and microwave components, is an expanded range of bias tees. Fabricated in the US by world-class manufacturer, Marki Microwave, the devices are available in surface mount, lead-free, RoHS compliant versions, or in traditional lead-solder packages for RoHS-exempt applications. Some units are also available with connectors.

Bias tees are used to supply DC currents or voltages to a wide range of RF and microwave devices, including field effect transistors (FETs) built into amplifiers, and triodes, as well as in photodiodes. Applications range from portable wireless products such as mobile phones, through test instrumenta-



tion, to equipment used in wireless/satellite telecommunications infrastructure, as well as medical, military and aerospace systems. The devices are expected to prove popular in upcoming 40Gbit/s and higher performance broadband applications.

A typical device in the surface mount, lead-free surface mount range, is the BT-0030SMG,

featuring an input frequency range from 10MHz to 30GHz, low typical insertion loss of 1dB (2.5dB maximum), maximum DC voltage of 30V and a 1W RF power handling capability. Other devices cover the frequency ranges from 500kHz to 34GHz.

For more robust applications, requiring connector fittings, the BT-0026 is typical of the range, with an input frequency range of 10MHz to 26GHz, low typical insertion loss of 1dB (2dB maximum) and 1W RF power handling. These devices are non-resonant with low leakage current, and normally supplied with 2.92mm connectors. The family also includes models with input

frequencies ranging from 40kHz to 65GHz.

The Marki bias tees are available in the UK exclusively from Admiral Microwaves. Prices are dependent on frequency and mounting options, with low frequency, surface mount units costing as little as £20 each, while high frequency devices with heavy duty connectors can cost £1000 each. Volume orders can be built to order and smaller quantities are generally available ex-stock, with delivery quoted in 4 to 5 weeks after receipt of order.

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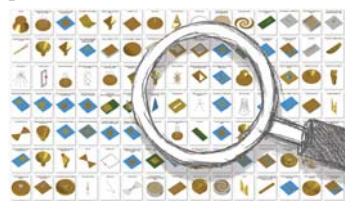
See Pages 8 to 11 for more information.

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PRODUCT GALLERY

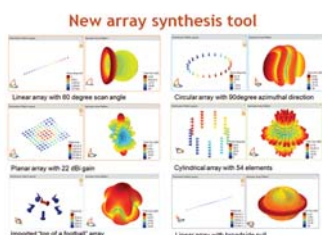
MAGUS (PTY), CST and EMSS announce the next major release of Antenna Magus, version 2.0 - the first antenna design software of its kind.

MAGUS (Pty) Ltd, CST - Computer Simulation Technology AG (CST), EMSS - EM Software & Systems-S.A. (Pty) Ltd announce the release of the second major version of Antenna Magus. The number of antenna topologies in the Antenna Magus database has almost doubled since the release of version 1.0. There are now 113 popular antennas available to be designed for a wide variety of objective values. Some of the more popular additions are the bi-quad, the axial choke horn, the travelling wave waveguide slot array, various patch arrays, the Vivaldi and the probe fed cheese.



Antenna Magus Version 2 features a database of 113 designed antennas which can be exported to CST MICROWAVE STUDIO® for further analysis and optimization

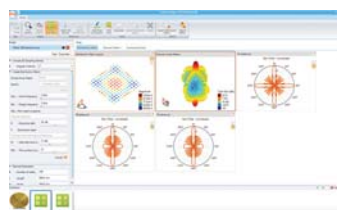
Many other aspects of Antenna Magus have been improved with additional functionality. One addition is the new Antenna Array Synthesis tool which was added to assist engineers with array synthesis. This tool designs spacings and excitation tapers for a variety of different array topologies, based on performance requirements such as gain, beamwidth or squint angle.



Antenna Magus Version 2 includes a new tool to assist engineers with array synthesis

The array design can be simulated with isotropic elements or with any one of several typical patterns. The designed spacings, excitation taper

and patterns are ready for export to FEKO and CST MICROWAVE STUDIO®.



An antenna array designed in Antenna Magus Version 2

"The response of the market to Antenna Magus Version 1.0 has been very positive. We have received a lot of valuable feedback from customers that has been used in developing the antennas and improvements implemented in Antenna Magus Version 2.0," stated Sam Clarke, Managing Director, MAGUS (Pty) Ltd. "We are confident that version 2 will add as much value to the end-user as the introduction of this tool did in version 1.0"

Highlights of Antenna Magus 2.0

- Antenna Array Synthesis tool
- 113 antennas in the database
- Major analysis speedups of over 50 antennas. A number of antennas run > 100 times faster
- Exporting reports and numeric graph data
- Side-by-side comparison of antenna "info docs"
- More modeling options when exporting to FEKO and CST MICROWAVE STUDIO
- Substrate library redesign
- Selection of antennas also export to TICRA's CHAMP, an additional CEM tool
- Major user interaction improvements

Availability

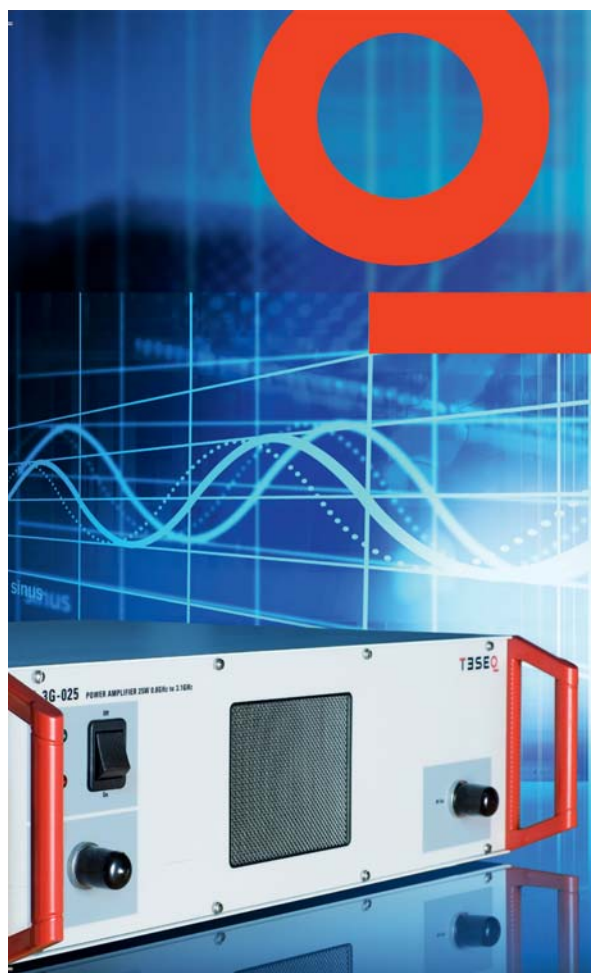
Antenna Magus Version 2.0 is immediately available and can be purchased through any CST or FEKO reseller.

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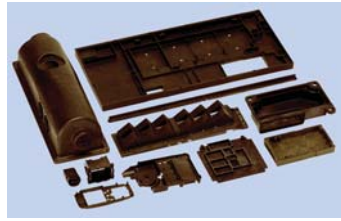
PRODUCT GALLERY

Chomerics offers new PREMIER conductive plastic material with enhanced thermal, shielding and mechanical properties

Chomerics Europe, a division of Parker Hannifin, has introduced a new version of its PREMIER™ conductive plastic shielding material that offers enhanced fuel resistance and heat deflection under load (HDUL) specifications. Complementing the existing range of Polycarbonate / ABS based materials, the new derivative uses a Polyether Imide (PEI) resin and is ideal for use in the most demanding applications such as those found in military and aerospace designs.

PREMIER conductive plastic shielding materials consist of nickel-plated carbon fibres integrated into an injection moulded thermoplastic resin resulting in finished parts with high mechanical strength. Developed for high performance EMI shielding and grounding applications, PREMIER allows greater design freedom and offers total cost of ownership savings of up to 65% compared to metal-based shields. Space and weight savings of 50 to 75% and significant space savings can also be achieved when using the materials.

The high HDUL of PEI based PREMIER conductive plastic allows stable performance at temperatures up to 180 °C (360 °F), shielding effectiveness is up to 85 dB. The robust material can be



moulded with sections as thin as 2.0 mm giving an exceptional strength to weight ratio. Complex features and geometries can easily be incorporated into designs.

Having the shielding functionality integrated into a moulded part means that significant cost and process savings can be made; the need for supplementary processes such as plating, painting and vacuum coating are all alleviated. Chomerics is able to support the design of PREMIER conductive plastics as a complete solution incorporating additional gaskets and inserts where required.

PREMIER PEI based materials are RoHS compliant and have a UL 94 flammability rating of V-0. Excellent corrosion resistance enhances suitability for long field life applications and the material is recyclable in line with WEEE EoVL TCO legislation.

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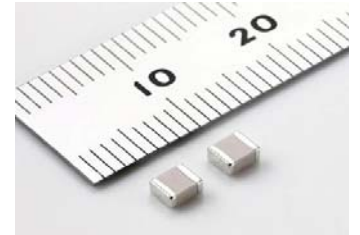
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Murata develops world's first 500V-rated MLCCs with low-loss base metal electrodes to improve Q-factor of high-frequency circuits

Murata has added a series of 500V-rated low loss monolithic ceramic capacitors for high frequency applications to the lineup of its popular GQM series, by integrating its low loss materials technology and its base metal electrode technology. The GQM22 series is the world's first 500V-rated MLCC with base metal electrodes, featuring high Q-factor, tight capacitance tolerance and excellent high frequency characteristics.

Although the use of base metal electrodes has been known to be effective in reducing loss and improving Q-factor, their use had until now been accompanied by problems involving characteristic adjustments and firing conditions, among other issues. With the addition of the GQM22 series, Murata has used its materials technology and co-fired ceramic technology to make the use of base metal electrodes possible.

The GQM22 series is ideal for matching or coupling circuits used in applications such as power amplifiers for mobile communication, WiMAX and LTE base stations, as well as other related high frequency RF modules. Together with Murata's existing 100V and 250V-rated products, the



introduction of the GQM22 series makes high Q and low ESR possible at VHF, UHF and GHz frequencies. The new devices feature a 40% improvement in Q at 1MHz over Murata's general-purpose medium and high voltage capacitors.

With dimensions of 2.8 x 2.8 x 1.15mm and capacitance ranging from 0.5pF to 100pF, the GQM series may be used for tight tolerance products (around capacitance tolerance ±0.1pF). DC withstand voltage is 1250V. Q-factor may be calculated as follows: $Q > 800 + 20C$ where C is the nominal capacitance of the product in pF and is between 1 and 30pF. Above 30pF, $Q > 1400$, measured at 1MHz. Operating temperature range of the GQM22 series is -55 to +125degC.

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AR Pulse Probe Approved For FORD-EMC-CS-2009 Specification

AR/RF Microwave Instrumentation has the distinction of having the only commercially available pulsed E-field probe that is approved by name in the new FORD-EMC-CS-2009 specification.

The new specification, which addresses the pulse e-field probe method calibration for ALSE method bands 6 & 7, singles out AR Model PL7004 (800 MHz – 3.6 GHz / 80 – 800 V/m) as the only commercial pulsed E-field probe capable of accurately measuring the high-field strengths needed to conduct the tests.

The PL7004 laser powered E-field



probe was created specifically for use in measuring E-fields found in radiated immunity testing and GMW3097 and FORD-EMC-CS-

2009 automotive radar pulse tests. It is designed to measure the RMS value of the "on" time of a pulsed electric field. Each probe is supplied with basic calibration data. A smart, fast, extremely accurate pulsed electric field probe, the PL7004 contains an internal microprocessor to provide linearization, temperature compensation, control and communication functions. Noise reduction and temperature compensation allow accurate measurements without zero adjustment.

The probe is laser-powered to allow for continuous operation without

battery recharging or replacement. It communicates and is powered through glass fiber optic cables, up to 100 meters long, connecting to the FI7000 interface. X, Y, Z, and composite readings can be returned through the FI7000 in 20 milliseconds. This probe can measure pulsed electric fields with pulse rates as low as 200 Hz and pulse widths as short as 1µs. The PL7004 is not designed to respond to CW fields. AR offers an extensive line of field probes for CW measurement.

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emc goggles

John Davies

*Blackwood
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“I am convinced there is a wide audience out there who need to learn about EMC and just don’t know the first thing about it. There is no true, well rounded and simple, all encompassing, beginners course for EMC until now... EMC Goggles. Also an excellent precursor to the EMCUK Training courses.” John Davis.

Almost without exception people improve their performance when they dedicate themselves to years of practice and training. This is true whether it is in the arts or the sciences, or in sport, in hairdressing even, and in countless other professions or pastimes.

As we all know experience counts for a lot. For any given situation, if you’ve come across it before, you’ll not be surprised when it crops up next time and you’re much better equipped to deal with it. With experience you are free from concentrating on the complex realities of the issues and you can simply deal with them. With experience, problems are expected and even what the layman cannot foresee can be anticipated.

The experienced EMC engineer is no different.

For the last 20 years I have worked in six accredited EMC test laboratories. I’ve been involved in actually building three of them. In recent years I’ve had increasing involvement in laboratory management, accreditation issues, EMC consultancy, staff training, and there’s my involvement in standards development, through both BSi and the IEC. Of course I still assist Blackwood Labs customers in understanding their requirements, I help them to fix their failures and I regularly perform internal technical audits. The hands-on testing has eased up for me in recent years, but I maintain that my EMC testing experience remains intact. And with my other EMC experiences, I would say that I now have an extremely well rounded knowledge of the world of EMC.

Of course, I don’t profess to be alone here. There are many highly experienced EMC test engineers and consultants out there, each of us having different experiences, each of us having different specialities, of course.

What my experiences have given me is a broad understanding of the requirements for products; the Directive, the Law, the routes to compliance, etc. I also have a very good understanding of the standards and the tests (*and if you can understand the nature of the tests then you are half way to meeting them*). From just looking over products I can see where the troublesome areas are, where the failures are likely to be, prior to testing. I am also able to diagnose and fix failures in the laboratory

quickly and effectively because over the years I have learnt what works and what doesn’t for almost any given situation.

In essence I have a different view of the product compared to the product designer. I and others with similar experience to me are looking at the product through what I call “EMC Goggles”.

It sounds magical but it’s not. EMC Goggles is only a metaphoric phrase. I certainly do not have a pair of tangible EMC Goggles in my pocket that enable me to actually see the emissions. EMC Goggles is simply a phrase I use to sum up what I have got from my 20 years in EMC. As I said they allow me to see things differently and I don’t need to trouble myself with all the complexities of the science.

EMC itself is often considered to be magical. How many times have you heard it referred to as a “black art”? Well I say it’s not magical and it’s not a “black art”! I say EMC is *simply* a complex science. The calculations and algorithms needed to predict EMC performance of even a very basic product are a massive mathematical undertaking. And even then, in the laboratory the actual results will almost certainly be different to that which was expected. I know that the EMC performance of a product is far too complicated for me to calculate! I certainly don’t understand Maxwell’s equations and I don’t think I ever will. There’s nothing wrong with Maxwell’s equations as far as I know, and I’m sure there is absolutely a place for them in our wider industry. But they’re certainly not needed in seeking EMC product compliance.

An athlete doesn’t need to understand the science of propulsion and gravity when he competes in the 110m hurdles. He just needs to know how to deal with them and how to maximise his performance with them there.

A product designer doesn’t need to fully understand the deeper complexities of EMC. He just needs training in how to deal with it, what he must address and overcome to get his product to market to make money.

I have created a training course called EMC Goggles through which I intend to present my understanding of EMC with tips and tricks on how I have helped many thousands of products through EMC compliance.

Yes, there are plenty of EMC training courses out there. But there are no true, easily understood, yet all encompassing, courses for EMC. I am convinced that there is an audience out there who need to learn about EMC but just don't know the first thing about it.

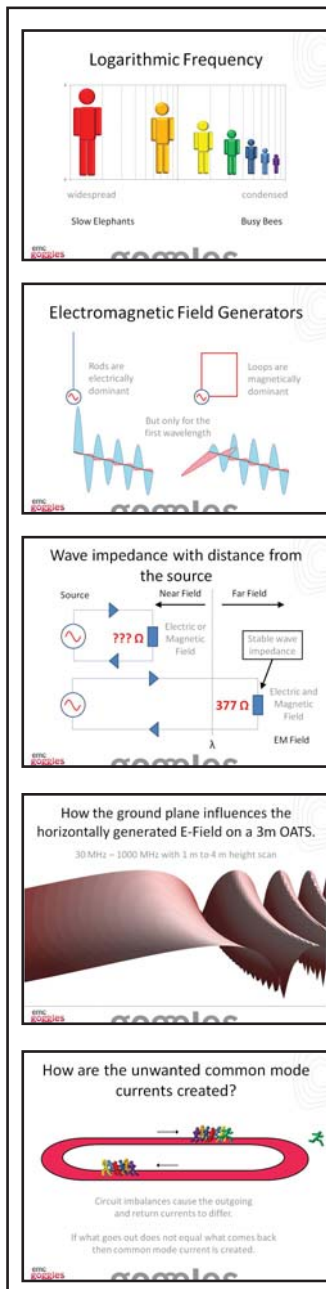
If existing EMC training courses were intended to train a hurdler then they would concentrate on propulsion and gravity. EMC Goggles teaches budding hurdlers how to run and jump!

EMC Goggles was created to fulfil a training need. EMC Goggles is about giving the attendee a clear understanding of the fundamentals of EMC such that their eyes are opened to the whole science. When you can see and understand the fuller picture, then you can choose to delve into the deeper

complexities within. EMC Goggles is therefore an excellent precursor to the more technical, specialised training courses, as those courses offered at EMCUK.

I am convinced that any design engineer or compliance manager who has attended the EMC Goggles course will have the tools to get a compliant product to market much more efficiently and at less cost. Design engineers and compliance managers with EMC Goggles will become even bigger assets to their companies.

In essence then, EMC Goggles is a visualisation training course. It's about seeing and understanding EMC as experience has taught me to do. It's about not getting bogged down in the complex realities and terminology that give it the "black art" tag. Anyone with any level of understanding of engineering will thrive on the EMC Goggles training course. EMC Goggles uses nothing more complex than Ohms Law, but that simplicity doesn't belittle the course at all. This course doesn't use equations, yet it is packed full of "aha" moments and jargon busting which opens up the science of EMC like no other existing training course.



emc goggles

An exciting new approach to Training for EMC beginners

Coming to a Venue near you soon

EMC Goggles is a visualisation training course. It's about seeing and understanding EMC. It's not about getting bogged down in the complex realities and terminology that give EMC the "black art" tag. The course uses nothing more complex than Ohms Law, but that doesn't belittle it, the simplicity just makes it easier to understand.

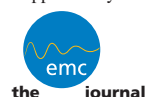
Anyone with a basic level of engineering will thrive on this course. Although no equations are used it is still packed full of "aha" moments and jargon busting which opens up the science of EMC like no other existing training course. All supported with superb Graphics, as samples illustrate.

Any product designer who attends EMC Goggles will have the tools to get a compliant product to market much more efficiently, and at less cost.

"EMC is not a "black art"... it's simply a complex subject.

If you would like more information and notification of Venues and Dates please email: info@emcgoggles.com

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Ambient Cancellation... reality or fiction?

By David Mawdsley, Laplace Instruments Ltd

The issue of the effectiveness of ambient (background) noise cancellation has been long debated. However, there seems to be little published evidence to justify the claims made by either side of the debate. In the absence of a screened room, test cell or chamber, we have to work in a very noisy environment, so any technique that can help would be welcome. The problem could be likened to trying to listen to the guy with the triangle at the back of the orchestra when all the other instruments are playing at full volume!

The original study was done some years ago, but the work is now updated and is published again as it covers a topic of key importance to the self testing community.

This paper is the result of some simple experiments that were performed by the author in an attempt to provide a clear answer to the question 'Does ambient cancellation work?'. The conclusions were (at least to me) unexpected and surprisingly clear cut!

There are two situations in which cancellation may be used..., identification and measurement. Identification techniques are used to simply locate EUT emission frequencies and/or source locations in the presence of high ambients. In both cases the use of near field probes provides a very effective answer. Those who have attempted to locate emissions reliably in the far field without some kind of ambient cancellation will know how frustrating this can be.

Measurement techniques go one step further and are able (potentially) to measure the EUT emission levels with some degree of accuracy.

This paper addresses this second, more demanding requirement.

Two approaches to the problem of ambient cancellation are currently on offer from EMC test equipment manufacturers...

1. To measure just the ambient first, then to take a second measurement with the EUT switched on and use software to subtract the first from the second measurement (difference technique).
2. To use a twin channel analyser that can either:
 - a. correlate a near field probe input with the far field antenna input. The assumption being that any significant emission must be detectable in the EUT near field and that near field probes are 'blind' to ambient signals.
 - b. use two far field antennas, one at a significant distance from the test site, and use difference techniques to extract the EUT emissions.

Each technique has its pros and cons. None are perfect! For instance technique 1 suffers in the presence of fluctuating ambient (and ambients **always** fluctuate to some extent) but has the advantage of potentially being accessible to any standard EMC receiver or analyser. Both options 2 require the use of a specialist twin channel EMC analyser and 2(a) exposes as false the assumption that near field probes are immune to ambient. In reality, strong ambients are induced into any cabling associated with the EUT and re-radiated as a near field signal. Both 1 and 2(b) depend on the validity of the 'difference' technique, and it is this technique which is the subject of this paper. The validity of using some kind of 'difference' trace to calculate the emission levels from an EUT in the presence of ambient is based on the assumption that the field strength will increase when a second source with a frequency within the RBW is switched on. This seems obvious, and is confirmed by the behaviour of OATS sites. It is well known that the ground-reflected signal combines with the direct signal on a standard site to increase the field strength by almost 6dB, which on a linear scale is a x2 factor. Reasonable enough, given that the two signals will be of similar strength. Of course, the signals in this case are strictly coherent (from the same source) and are in phase. Changing the phase relationship (for instance, by varying the height of the antenna) will completely 'undo' this happy result. So phase matters. But does it matter when we are considering an EUT emission with an ambient signal?

This is one of the aspects for investigation in the following experiments.

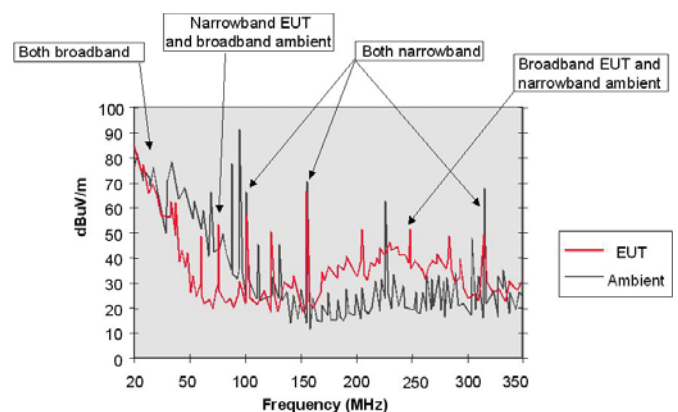


Fig 1. Typical situation. A mix of broadband and narrowband signals.

Identify the main issues.

Signal types, broadband and/or narrowband?

Signals of both types are common, both from EUTs and in the ambient. We should not assume that any cancellation technique will work equally well (or badly) for all combinations of these two signal types.

It seems sensible to break down the problem into manageable sectors. One way to achieve this is to consider the four combinations of narrowband and broadband signals.

The easy situations... Where the ambient is broadband and the EUT is narrowband, use of the QP detector will usually result in suppression of the broadband signal, leaving the EUT narrowband signal dominant, therefore easy to measure. This is because broadband signals are by definition, impulsive, and will therefore often be attenuated by the QP detector. Narrowband signals are generally continuous and are therefore not reduced by this detector.

Similarly, if the EUT is broadband and the ambient is narrowband, it is obvious that by looking at the EUT broadband level either side of the ambient peak, the level is easily measured.

These two situations described above are therefore not included in the following work. Instead we concentrate on the narrowband/narrowband and the broadband/broadband situations as being potentially 'difficult'.

Table 1 shows the potential combinations.

Possible combinations	Narrowband ambient	Broadband ambient
Narrowband from EUT	If frequency separation <IF B/W then peaks merge together. Phase issues may add complications. Possible 'worst case' scenario.	Choice of detector can suppress broadband but leave narrowband (continuous) signals unaffected.
Broadband from EUT	Broadband emissions clearly observable either side of narrowband ambient. By definition, broadband emissions have relatively flat characteristic.	Another potentially 'worst case' scenario.

The Method

It seems from the above that the toughest challenge for any cancellation techniques is when both EUT and ambient signals are of the same type of signal. Therefore our experiments modelled these two situations.

We created a known 'ambient' and a known 'EUT' signal and studied how the field strength as measured by an EMC analyser was affected when both were on together. The type of signals to create were in line with the above analysis, ie two narrowband sources and two broadband sources.

The narrowband experiment

The test involved the use of two emissions reference sources (ERS) from Laplace Instruments Ltd, one to simulate the background (ambient) level, the other to simulate an EUT. These are 'comb' generators, essentially narrowband sources with a continuous (in time domain) emission output. They radiate a signal with 2MHz spacing and the two units have a very close

frequency matching (actually within 40ppm), well within the resolution bandwidth of the analyser. Thus presenting an almost 'worst case' scenario. The close frequency matching prevents the use of frequency discrimination to separate the signals and the steady state nature of both prevents the use of averaging techniques.

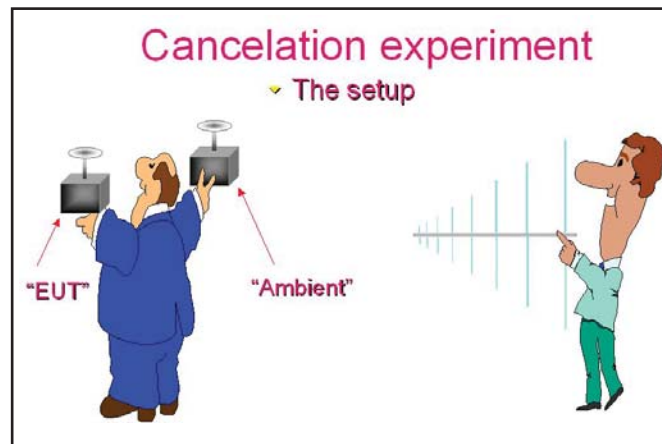


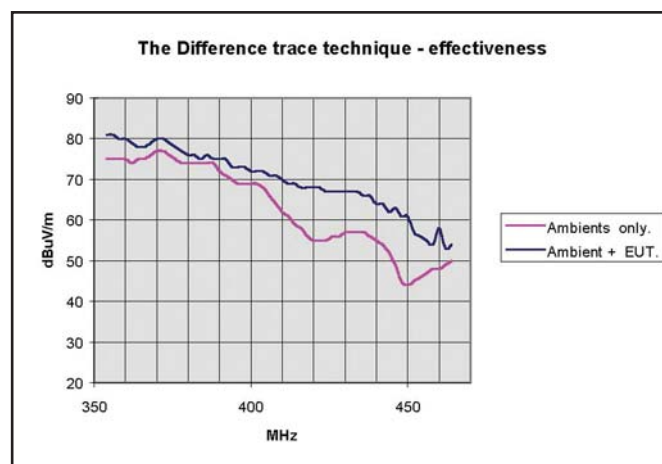
Fig 2. Test configuration

The ERS units actually give very similar radiated output levels, but they were located in different positions in the test site (the laboratory) so that the signals received at the measurement antenna were different from each. The difference is due to the change in 'site attenuation' at the two locations.

The frequency range 350 - 450MHz was chosen as this range was relatively free of other background signals. (note that this test was done before Tetra arrived!).

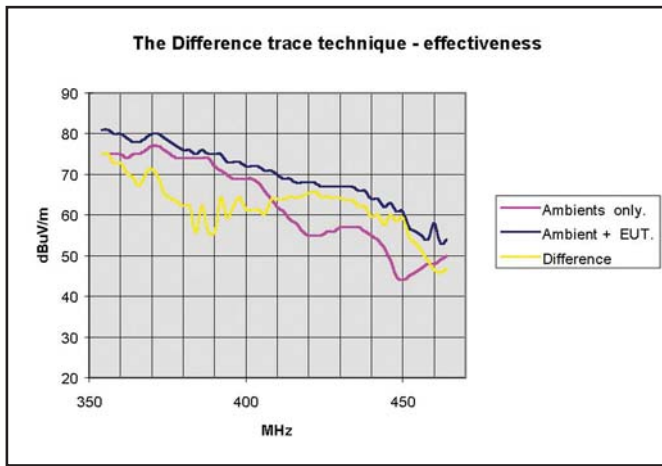
Each ERS was initially measured separately. The one which gave the lowest levels (as measured by the antenna) was chosen to represent the EUT. This we called unit A. The other (unit B) then represented the ambient.

A sequence was then followed to represent an real EMC test...



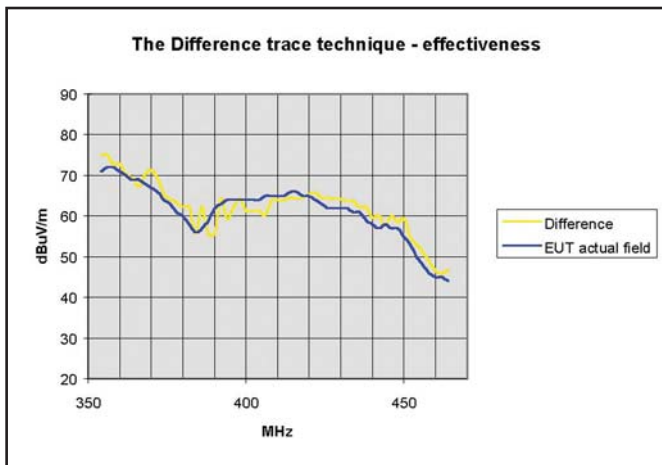
The first plot shows the 'ambient only' (unit B) spectrum and the increased level when the EUT is switched on, (units A and B)

Note that for clarity, we have plotted the level of only the 2MHz peaks, and omitted the intervening background.



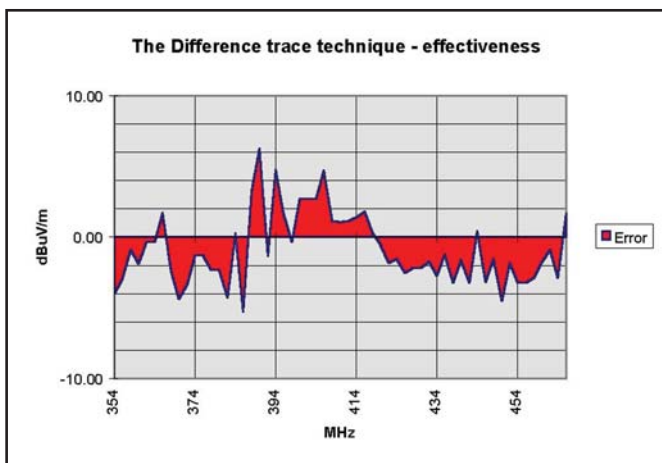
The second plot shows the calculated difference trace.

Note that this is NOT the simple difference (A-B) but one that takes the log scaling into account (see below). This is the estimated level of the emissions from the EUT.



The third plot is a comparison of the estimated level and the actual level of emissions from the EUT.

As can be seen, the difference technique has delivered a remarkably good measurement of the actual emission level.



The fact that at 380MHz, the difference trace is within 4dB of the actual even though the EUT is over 15dB below the ambient level, shows that this technique can be remarkably effective.

The difference calculation

To calculate the signal which caused the field to rise from level XdBuV/m to level YdBuV/m we cannot simply subtract the to

numbers to find the difference. Subtracting two log values is the equivalent of dividing one by the other. So these values must be converted back to linear values first using the formula $X(\text{lin}) = 10^{(X(\text{log})/20)}$ and similarly for Y. Then the difference $Z(\text{lin}) = X(\text{lin}) - Y(\text{lin})$. Finally, $Z(\text{lin})$ is converted back to log (dB) values. $Z(\text{dB}) = 20\log(Z(\text{lin}))$.

Phase

This experiment has used two independent sources, hence the signals are incoherent. Incoherent signals are not phase locked. This will be the reality when dealing with EMC applications when an ambient signal is to be 'cancelled'. There will be a phase relationship between the EUT and each ambient source, causing the combined field to fluctuate in level at the difference frequency. So for example, a 253,456,789Hz ambient and a 253,456,800Hz EUT signal will mix to create a resultant that fluctuates at 211Hz. When using a QP detector with a band C time constant of 550msec, it is obvious that these fluctuations will not affect the resultant. Indeed, for any phase effect to be observed, the two frequencies will need to be totally stable to within a couple of Hz, (within 0.001ppm). Possible, but highly unlikely, especially over any meaningful period of time.

Ambient variation

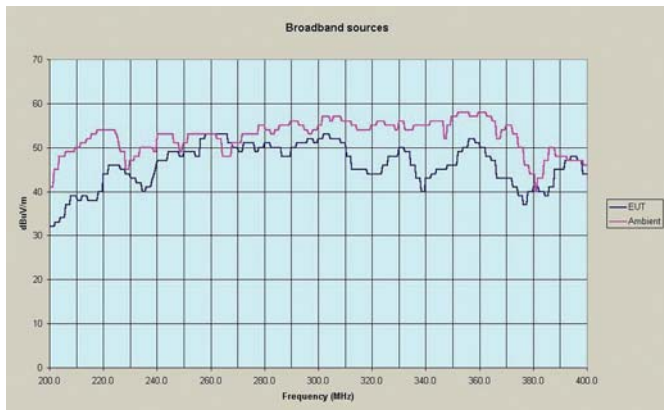
The only problem that would affect the results is that of an unstable ambient. A technique has been routinely used by the author and others is to stabilise the ambient by using an averaging technique when acquiring both the ambient result and the ambient+EUT result. This is not the same as using an 'Average' detector. It involves repeated scans and then at each frequency, calculating the average level across all the scans. Typically, using this technique on a set of 8 scans produces a stable result. The difference trace then produces a relatively 'clean' measure of the emissions from the EUT. Naturally, there is often some rogue transmission that is timed so as to appear as an EUT emission, but simple 'common sense' investigations soon identify these as not originating from the EUT.



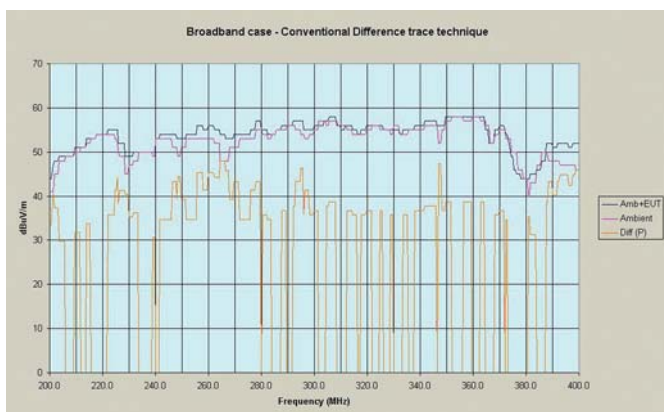
Fig 3. ERS (left) and CNE

The Broadband experiment

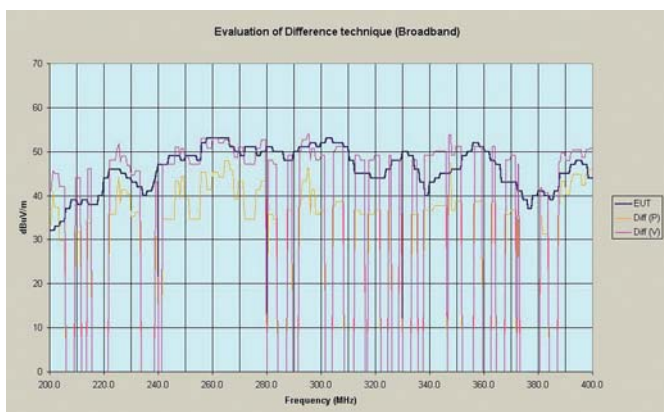
The above procedure was repeated, but this time using two broadband sources, the York Electromagnetics CNE (Comparison Noise Emitters). These produce a relatively flat output spectrum with high bandwidth impulsive noise sources.



Again the emissions from each were plotted separately at first.



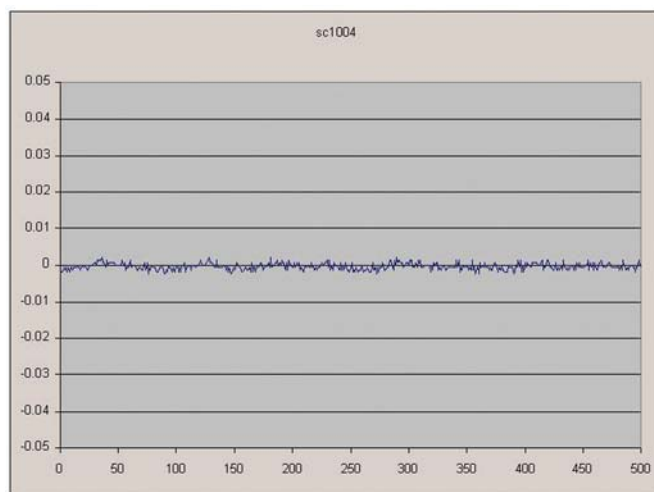
Then plots were taken with first one then both sources switched on. The plot shows the results. The difference trace includes intermittent excursions to minus infinity where the calculation attempts to find the log of zero! The cause of this little difficulty is at frequencies where the ambient result and the ambient + EUT result are the same (or negative).



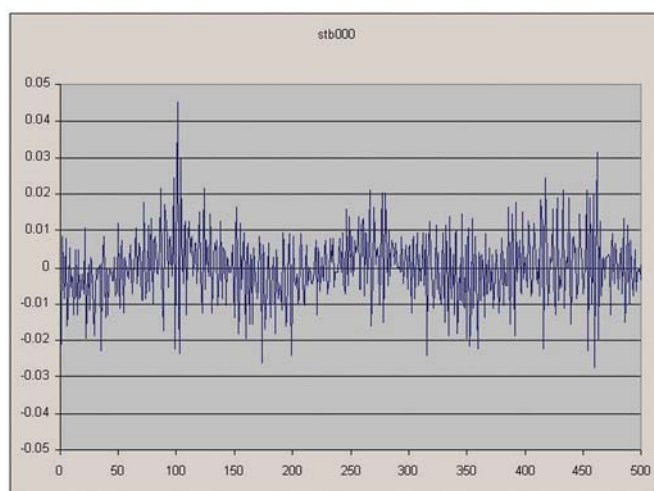
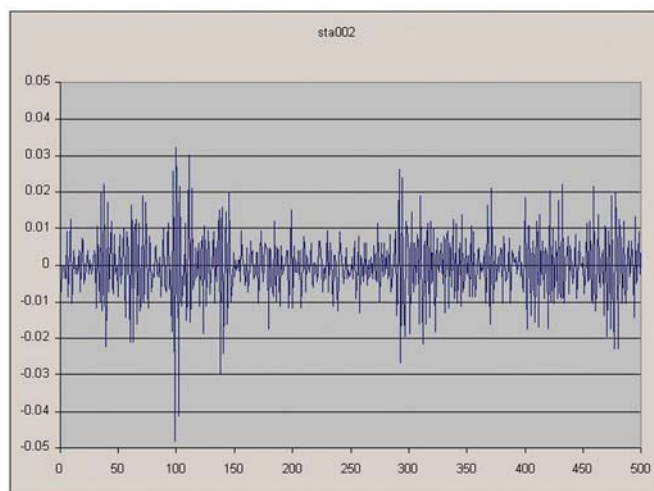
The final plot shows the actual EUT level (orange trace) and the difference trace as calculated for the narrowband experiment. The results show that the technique has failed to provide even a rough estimate of the levels from the EUT. Clearly the signals were not interacting together in the same way as the narrowband sources. In an attempt to improve the result, the difference was recalculated using a voltage base (V) rather than a power base (V²). The magenta trace shows that whilst it is better, there are still wide inconsistencies.

Use of the QP and Average detectors did not significantly improve matters. In an attempt to resolve why the two signals apparently did not 'sum' together, the signals from the receiving

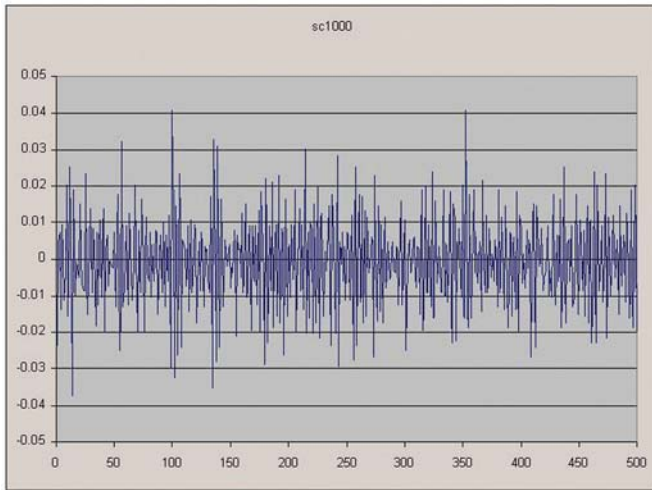
antenna were plotted in the time domain. The following 4 plots are all acquired on a fast digitising DSO (500MHz sampling rate). The time axis is in nanoseconds and the vertical scale is identical for all these plots.



Plot sc1004 shows the ambient as output from the log periodic antenna with no sources switched on.



Plots sta002 and stb000 show the signal from the antenna with each source switched on independently. The impulsive nature of these sources is immediately evident. Fourier analysis shows that for a flat (ish) spectrum in the frequency domain, the time domain must have a transient nature. The signals are completely random in nature, as expected from noise sources.



Plot sc1000 shows the two sources radiating simultaneously. The frequency of the impulsive spikes has increased, in fact doubled, but the peak levels are unaffected.

Thus a peak detector will generally maintain the same level as the strongest source, unaffected by the presence of any source with a lower level of impulsive peaks. This assumes that the spectral bands of the two sources overlap. If this was not the case, identification of the EUT emissions would be simple!

A calculation to show the level of signal in each waveform was undertaken by summing the absolute values of all the DSO samples in each frame.

Ambient only	0.3696V
Source 1	3.7744V
Source 2	3.6467V
Both sources together	5.1472V

This shows that there is the expected increase in signal in the time domain.

It was thought initially that the use of an average or QP detector would improve the performance of the difference technique. This was not observed. Further thought regarding the average and QP detectors as specified by CISPR16 shows why. The output from these detectors is critically dependant on the repetition rate of the incoming impulses. Time constants within these detectors are such that for repetition rates above 10KHz, the detector output will be equal to that of a peak detector. In other words, once above 10KHz, increasing the repetition rate will have no effect. A study of the waveforms shows that significant impulses occur at a median interval of approximately 300nS, equivalent to a repetition rate of 3.3MHz. Well above 10KHz!

Clearly, the above analysis holds true for the noise sources we used (the CNEs). Other noise sources with different characteristics may behave differently. For instance, many sources in the 'real world' are caused by mains frequency switching devices (such as phase angle controllers). These have an impulse repetition rate of 100Hz (or 120Hz). Doubling the rate by introducing a second source would increase the QP level by some 3dB and the average level by approximately 6dB. This suggests that a difference technique would work, but factors such as relative timing (ie relative phase angles) and duty cycle would influence the results.

Coping with the real world

Overall, this experiment has shown that in real world situations where both the background and the EUT emissions are broadband with overlapping spectra, and the nature of the noise sources is unknown, (this must be particularly true of the background), the use of any difference technique should be avoided where possible. In practice however, a modified difference trace technique has been successful in detecting the general spectrum of broadband emissions from an EUT, even in situations of high level ambient. This modified technique involves the use of an average scanning technique coupled with a peak detector.

1. With the EUT off, free run the analyser and invoke trace averaging to provide the average level at each frequency point over the several sweeps.
2. When the resultant has stabilised, cease scanning and store this as the background trace.
3. Switch the EUT on and repeat the average scanning process until the resultant has stabilised.
4. Plot the difference between the two results.

Although not recommended for accurate measurements, this technique does seem to give an excellent estimation of the EUT emissions for pre-compliance purposes.

Summary

Where the ambient and EUT sources are of different signal types (narrowband and broadband) the measurement of EUT emissions is generally possible with common sense judgement. The difference trace technique works well in the narrowband / narrowband situation, provided that the background is stable. However, additional techniques are available (ie averaging of scans) that have proved very effective in coping with unstable backgrounds.

When both ambient and EUT emissions are broadband, measurements become less reliable and the difference technique may fail even to provide an approximation of EUT levels. However, the nature of the sources used in the experiment may not be typical of the real world. Experience has consistently shown that the difference trace technique does provide a useful guide for EUT emissions even in worst case situations. This is probably due to the lower repetition rates (100s of Hz) that are typically causing the 'real' broadband emissions. In addition, experience shows that emissions from EUTs are usually (but not exclusively) narrowband in character above 30MHz.

In practice, measurement of EUT emissions in the presence of ambient has proved to be very effective. The combination of trace averaging, difference trace processing and test technique has consistently provided results that are within 8 dB of test lab results.

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Keeping EMC on Track

By Jean -Louis Evans, Managing Director, TÜV Product Service

Keeping EMC testing on-track

Electromagnetic interference occurs when electrical or electronic equipment malfunctions due to electromagnetic disturbances. Indeed, Electromagnetic Compatibility (EMC) is defined as ‘the ability of a device, equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable disturbance to anything in that environment’.

Poor EMC management and control can result in operational problems, which in extreme cases can have a direct effect on the safety of the rail network. Safety-critical systems, such as signalling and rolling stock equipment, must therefore be designed, manufactured and tested prior to service introduction to ensure all EMC compliance and health and safety requirements have been met.



The EMC Directive

The EMC Directive was fully adopted in July 2009 and the implementing regulations in the UK are the ‘EMC Regulations Statutory Instrument 2006 No. 3418’.

The essential requirements of the directive states that the equipment shall be designed and manufactured so as to ensure that:

- The electromagnetic disturbance it generates does not exceed a level above which radio and telecommunications equipment, or other equipment, cannot operate as intended.
- It has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use.

Under the EMC Directive, manufacturers of apparatus must prepare and maintain technical documentation and usually carry out an EMC assessment. This process is then followed by them making a declaration of conformity and affixing the CE marking.

The directive defines ‘apparatus’ as ‘any finished appliance or combination thereof made commercially available as a single functional unit’. The directive also addresses the EMC compliance requirements for larger, complex apparatus which can be moved and used in various locations, defining these as ‘mobile installations’. This means that the compliance requirements for rolling stock are the same as those for apparatus.

Meeting the standard

Manufacturers of apparatus must also take into account the Harmonised European Standard EN 50121 relating to railways. This has five parts which cover emissions of the whole railway system to the outside world, rolling stock, signalling and telecommunications apparatus, as well as fixed power supply installations and apparatus.

By testing to the appropriate standards, apparatus for use on-board trains, signalling and telecommunications equipment, and power supply apparatus can be declared to comply with the EMC Directive as this provides a presumption of conformity.

For apparatus there is only one route to compliance – self declaration with internal production control. It is now at the manufacturer’s discretion to involve an EMC Notified Body to assess all or part of his technical documentation. This requires the manufacturer to:

- Produce Technical Documentation
- Perform an EMC Assessment
- Provide Additional Information (for identification of the apparatus)

For apparatus where the EMC harmonised standards can be applied in full, the resulting EMC test report will form the basis of the technical documentation that the manufacturer is required to keep under the EMC Directive. Where harmonised standards cannot be applied in full (e.g. for rolling stock) then an EMC assessment will need to be made in conjunction with the limited testing that can be performed.

Exceptions to the rule

Ideally EMC testing will be performed in an EMC test facility and conform with the applicable test set-ups. In cases where logistics are an issue for large or complex equipment, these can be tested in-situ either at the manufacturer's premises or the final point of installation.

Much of the technology being used in the railway sector is tried and tested and available as commercial off the shelf (COTS) equipment. However, these may have a lower EMC performance than that specified for rail use. Where COTS equipment is used, a gap analysis should therefore be performed against the standards to which the equipment has been tested and the standard that best represents the final point of installation. If a gap is identified, then additional testing may be required unless a technical rationale can be used to demonstrate compliance.

Bespoke approach

The EMC Directive also contains requirements for 'certain apparatus', bespoke equipment intended for permanent incorporation in a fixed installation, which would not otherwise be commercially available. In this case, such apparatus will not require CE marking or the raising of a declaration of conformity, with the directive specifying additional documentation requirements.

Unique considerations

Rolling stock has unique power supply characteristics and these low frequency emissions can interfere with signalling. Furthermore, as modern rolling stock uses a wealth of communication and control electronics, it's vital that these perform reliably and safely.

Due to health, safety and operational issues caused with conducting Radio Frequency (RF) immunity testing outside of an EMC test facility, no testing of this type is conducted on new or modified rolling stock. RF emissions measurements should be made trackside, with the test site meeting the 'free space' requirements as far as practically possible. The type of rolling stock under consideration will determine if emission measurements are made with the rolling stock stationary or slow moving and what systems are to be operational.

The electromagnetic characteristics of rolling stock will also change if it has been modified or updated. Unfortunately for a great deal of rolling stock running with 'grandfather rights', the existing EMC characteristics are unknown. Before the modification commences, an RF survey should therefore be performed, with a further survey being conducted once all modifications are complete. This will allow a gap comparison to be made.



Documenting complexity

The railway industry has such a long history that older safety-critical equipment running alongside more bespoke new equipment is commonplace. It is therefore important that in order to meet all regulatory and customer requirements that the control of EMC throughout a product development project is documented and agreed upfront with all involved parties. Testing should be conducted against all of the relevant standards and where this is not possible, a technical rationale and assessment produced to confirm how compliance has been achieved.

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CISPR 16 Detectors

Issues regarding the application of CISPR Average, RMS-Average detectors and APD measuring function with respect to product emissions standards

Teseq - Advanced Test Solutions for EMC

Abstract

Changes to detectors specified in CISPR 16-1-1 for EMC measurement receivers are described and related to the requirements of each CISPR-based product standard in the EMC Directive regime that refers to CISPR 16-1-1.

Introduction

RF emissions tests to CISPR, and hence EN, standards, invariably require that the instrumentation complies with CISPR 16. Changes in the last few years to the base standard CISPR 16-1-1 take some time to ripple through to the product standards which reference it. Therefore there is a period during which the instrumentation requirements in product standards are in transition. This note identifies the timescale that results for detector specifications in respect of particular product standards.

The standard for instrumentation in the early 2000s was CISPR 16-1 Edition 2. This was re-organised in 2003 to separate it into initially four, and now six, sub-parts. The relevant sub-part for measurement instrumentation is CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Radio disturbance and immunity measuring apparatus: Measuring apparatus*.

Old and new detectors within CISPR 16-1-1

Quasi-Peak, Peak and Average

These three detectors appear in CISPR 16-1: 1999 clauses 4.1, 4.2 and 4.3 respectively and have been well established for many years. The first two are carried through to CISPR 16-1-1 clauses 4 and 5. The average detector has changed, as noted below.

The CISPR Average detector

Where the disturbance is not steady, the reading of the measuring receiver is observed for at least 15 s for each measurement; the highest reading is recorded, with the exception of isolated clicks, which are ignored. If averaging is applied throughout the period of 15 s, then intermittent narrowband disturbances will be suppressed or at least averaged so that the measured value does not correspond with the interference effect of the disturbance. This was regarded as unacceptable, and CISPR 16-1 was consequently amended to specify clause 4.3.4.3 (6.4.3 in CISPR 16-1-1), "Response to intermittent, unsteady and drifting narrowband disturbances". This amendment specifies a meter time constant following the envelope detector. The amendment appeared as Am 1 to CISPR 16-1 in 2002. Receivers designed before the amendment was published will probably not implement this time constant. The effect is only relevant for pulsed or intermittent disturbances with a low pulse repetition frequency, in which case the measured amplitude increases with respect to the un-amended detector.

To distinguish between the two versions, the later, amended detector is usually called the "CISPR Average" detector, while the earlier version is called the "Average" detector. However, product standards which make reference to average measurements do not usually make this distinction.

The RMS-Average detector

From the introduction to CISPR/A/680/CDV, "Weighting of interference according to its effect on digital communication services":

"The transition from analogue to digital radio-communication services has happened in many areas and is still proceeding. The introduction of a new detector type may follow this transition, which may be regarded in terms of frequency ranges: Above 1 GHz, the use of digital radio-communication systems is more common than below. This is because frequency ranges above 1 GHz were available for new techniques. Also, CISPR 16-1-1 currently only defines the peak and the average detectors for use above 1 GHz. The use of the average detector as a weighting detector is questionable because its pulse response does not agree with the results of investigations; the peak detector does not consider the minimal effect of lower pulse repetition frequencies at all."

Thus a new weighting has been proposed. This is achieved by employing a weighting detector that is a combination of the RMS detector (for pulse repetition frequencies above a corner frequency f_c) and the average detector (for pulse repetition frequencies below the corner frequency f_c) thus achieving a pulse response curve with the following characteristics:

- 10 dB/decade above the corner frequency and
- 20 dB/decade below the corner frequency.

This is described as the "RMS-Average" detector and it has been implemented in CISPR 16-1-1 by replacing the pre-existing Clause 7: "RMS measuring receivers for the frequency range 9 kHz to 1 000 MHz" with a new Clause, "Measuring receivers with RMS-average detector for the frequency range 9 kHz to 18 GHz". Product standards have up till now avoided calling up this new detector type and so although it is now available in CISPR 16-1-1, it has yet to be used in practice. However, it will appear as an alternative in CISPR 13 Edition 5, about to be published.

The APD measuring function

The "amplitude probability distribution" of a disturbance is defined as the cumulative distribution of the "probability of time that the amplitude of disturbance exceeds a specified level". It can be measured at the output of the envelope detector or the succeeding circuits of an RF measuring receiver or a spectrum analyzer. The amplitude of disturbance is expressed in terms of the corresponding field strength or voltage at the receiver input. Usually, an APD measurement is carried out at a fixed frequency.

The APD measuring function will be an additional function of the measuring apparatus and may be attached to, or incorporated in the measuring instrument.

Proposed in 1997 to CISPR/A by the Japanese National Committee, the APD function was eventually implemented in the second edition of CISPR 16-1-1. Product standards do not yet reference it.

Changes to CISPR 16-1-1 with respect to these detectors

CISPR Average detector

This was implemented in Am 1:2002 to CISPR 16-1:1999, and has been a requirement in all subsequent editions of CISPR 16-1-1. The peak and CISPR Average detectors (not the QP detector) were extended above 1GHz to cover the frequency range from 9kHz to 18GHz in the second edition, CISPR 16-1-1:2006.

RMS-Average detector

This was implemented in Am 2:2007 to CISPR 16-1-1:2006, the second edition.

The APD measuring function

This was implemented in CISPR 16-1-1:2006, the second edition.

Revisions to CISPR product standards that reference CISPR 16-1-1

The mandatory requirement to actually have a particular detector version or function in a receiver in a test laboratory depends on the product standard(s) to which that laboratory is testing. A product standard will make reference to various parts of CISPR 16 in its “Normative references” section. If the reference is dated, only that specific document is to be used; subsequent amendments and new editions are to be ignored. If it is undated, the latest amendments and/or new editions are to be applied.

In the European regime, CISPR product standards are not used directly. Instead, their equivalent EN versions must be used, with dates of application set out in occasional listings published in the Official Journal of the EU (OJEU). Each EN product standard includes an “Annex ZA” at the back which translates the CISPR normative references into EN equivalent references; the dates in the EN references are the relevant ones for application under European Directives.

Therefore, to arrive at the applicability of specific versions of instrumentation in the context of product standards used for European Directives, it is necessary to consider:

- The mandatory dates of application of the EN product standards, published in the OJEU;
- The Annex ZAs of the specific product standards, at the back of the EN document, and whether they make dated or undated reference to the CISPR 16 series;
- From what version of CISPR 16 a particular instrumentation change is required.

Also, of course, the required detector depends on what tests the product standard mandates, over what frequency range.

Table of product standards versus detector requirement

The following table relates the European dates of application in the case of 7 product standards, to the requirement for the CISPR Average detector. Both the base CISPR and equivalent EN product standards are considered, as in one case (CISPR 13) there is a difference. Note that neither the RMS-Average detector nor the APD functions are yet referenced in these product standards.

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Product standard: EN	Mandatory from	Refers to CISPR 16-1 version	CISPR Average detector required?
EN 55011: 2007 + A1 + A2	1.11.2009	CISPR 16-1: 1999, dated	No *
EN 55012: 2007	1.9.2010	EN 55016-1-1: 2007, dated	Yes
EN 55013: 2001 + A1 + A2	Expired	CISPR 16-1: 1999, dated	No *
EN 55014-1: 2000 + A1 + A2	Expired	CISPR 16-1:1993, dated	No *
EN 55014-1: 2006	1.9.2009	EN 55016-1-1: 2004, dated	Yes
EN 55015: 2006	1.9.2009	EN 55016-1-1: 2004, dated	Yes
EN 55022: 1998	1.10.2009 for amendments	CISPR 16-1:1993, dated	No *
EN 55022: 2006	1.10.2009	EN 55016-1-1:2004, dated	Yes
A1: 2007 to EN 55022: 2006	1.10.2010	No change from the above references, but adds tests above 1GHz **	
Product standard: CISPR			
CISPR 11: 2003 + A1 + A2		CISPR 16-1: 1999, dated	No
CISPR 12: 2007		CISPR 16-1-1: 2006, dated	Yes
CISPR 13: 2001 + A1 + A2		CISPR 16-1 undated	Yes
CISPR 14-1: 2000 + A1 + A2		CISPR 16-1: 1993, dated	No
CISPR 14-1: 2005		CISPR 16-1-1: 2003, dated	Yes
CISPR 15: 2005		CISPR 16-1-1: 2003, dated	Yes
CISPR 22: 1997		CISPR 16-1: 1993, dated	No
CISPR 22: 2005		CISPR 16-1-1:2003, dated	Yes
A1: 2005 to CISPR 22: 2005		No change from the above references, but adds tests above 1GHz **	
CISPR 25: 2008		CISPR 16-1-1:2006, + A1:2006 + A2:2007	Yes

* Note: the European standard EN 55016-1-1: 2004 has a dow (date of withdrawal of conflicting standards) of 1st September 2007. This implies that earlier European versions, if they had existed, should not be used after this date. However, the EN product standards that make dated reference directly to CISPR 16-1:1993 or :1999 should not be affected by this.

** Note: it may be concluded that, for CISPR22: 2005 + A1: 2005, the CISPR Average detector is now necessary on test receivers both below and above 1GHz; however the document makes a *dated* reference to the *first* edition of CISPR 16-1-1 (EN 55016-1-1), which refers only to reduction of spectrum analyser video bandwidth for detector weighting above 1GHz.

Fundamentals of RTCA/DO-160F, Section 22: Lightning Induced Transient Susceptibility

By Louis A. Feudi and Robert Given, Thermo Scientific

Over the past few years, the standard RTCA/DO-160, Section 22 has undergone multiple revisions. As a member of the Aerospace Test Industry, I regularly receive articles and news informing me of the latest changes being implemented to the standard. However, for others who are new to the requirements, many questions are left unanswered. In my travels, I am often asked the same fundamental questions. This article is intended to introduce the requirements of DO-160, Section 22, and to address some of those fundamental questions.

What is the RTCA?

To better understand the RTCA as it applies to Section 22, let's take a look at the Foreword for DO-160 Version F.

Who is RTCA?

The Radio Technical Commission for Aeronautics, organized in 1935 and now known as RTCA, Inc. includes roughly 335 government, industry and academic organizations from the United States and around the world. For a clear understanding of the organization we refer to the Foreword: RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus based recommendations on contemporary aviation issues.¹

Author's Commentary: This means that the requirements in RTCA DO-160 F are Advisory requirements, not Mandatory requirements.

What are RTCA's objectives?

Again, let us refer to the Foreword for DO 160F to answer this question. RTCA's objectives include but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;

Author's Commentary: They mediate requirements between Aircraft part manufacturers, aircraft manufacturers, and Airlines.

- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

Author's Commentary: They come up with requirements that try to keep the planes in the air under adverse environmental conditions.

- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational

performance standards for electronic systems and equipment that support aviation;

Author's Commentary: They get both airplane manufacturers and component manufacturers to agree on a minimum operational performance standard while the product is being stressed (immunity).

and;

- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunications Union and other appropriate international organizations can be based.¹

Author's Commentary: Worldwide Organizations adopt these requirements as their positions on issues that arise.

How important are RTCA's standards?

Looking again at the Foreword for DO-160F, we learn that the organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration technical Standard Orders. Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the U.S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.¹

Author's Commentary: When an aircraft manufacturer (Boeing, Airbus, DeHavilland, Embraer, Fairchild, General Dynamics, Goodyear, Grumman, Gulfstream American, etc.) is deciding on purchasing criteria for its Tier one, two and three vendor parts, it can use any or all of the requirements in the standard as part of its buying criteria. That means almost all of the electronics incorporated into an airplane need to meet some part of this standard.

Who else uses these standards?

We find the answer to this question also in the Foreword of the standard: These standards were coordinated by RTCA SC-135 with the European Organisation for Civil Aviation Equipment (EUROCAE) Working Groups (WGs) 14 and 31. EUROCAE concurs with RTCA on the environmental conditions and test procedures set forth herein. When approved by EUROCAE, this document will be identified jointly as RTCA DO-160E/EUROCAE ED-14E.¹

Author's Commentary: The Europeans have similar if not identical requirements, when the standard is adopted as RTCA DO-160E/EUROCAE ED-14E.

What is the SAE?

SAE International is a global technology information and standards-setting resource for the aerospace, automotive, and commercial vehicle industries. In addition to standards development and publication, SAE holds annual and biennial conferences and tradeshows, periodic industry seminars, student Collegiate Design competitions, all focused on all facets of transportation.

SAE Aerospace is a sub group of SAE International. Their focus is on writing Aerospace Standards (AS), which apply to missile, airframe, ground support equipment, propulsion, propeller and accessory equipment; Aerospace Recommended Practices (ARP), which provide recommendations for engineering design and provide background information and research to support those recommendations; and Aerospace information Reports (AIR), which contain generally accepted industry engineering data and information.

AE-2 is the SAE Lightning Committee established by the Aerospace Council of SAE. They draft and publish the recommended requirements for Indirect Lightning Strikes, based largely on industry and SAE research and knowledge. These requirements are very often adopted into RTCA by the RTCA SC-135 subcommittee, who is responsible for the content of DO-160.

The fundamental document that defined the environment and test waveforms used in DO-160, Section 22, and accounted for the lightning data and analysis necessary to support these requirements, is SAE ARP5412, "Aircraft Lightning Environment and Related Test Waveforms," originally published in 1999, and revised to Revision A in 2005. This document explains where the concepts of Multistroke, Multi Burst and the current test waveforms originated.

Changes in requirements over the past few years

Many airplane components have to keep working under environmental stress conditions. One of those conditions is lightning. So many airplane manufacturers specify Section 22 as one of the requirements for critical systems, like guidance, radar, communications, engine control, heat and air controls, etc.

We sometimes think of avionics as being the navigation and communications equipment, but it also includes engine controls, servo motor controllers for control surfaces like ailerons, rudder and flaps, landing gear controls, radar, even satellite TV, Wi-Fi, and entertainment systems.

Revisions E and F of DO 160 are driven by the use of composite materials used for airframe construction on recent planes like the Boeing 787 Dreamliner and Airbus A380 (Figure 1).

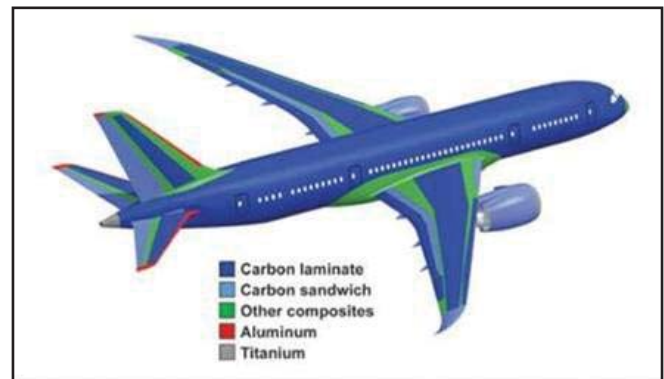
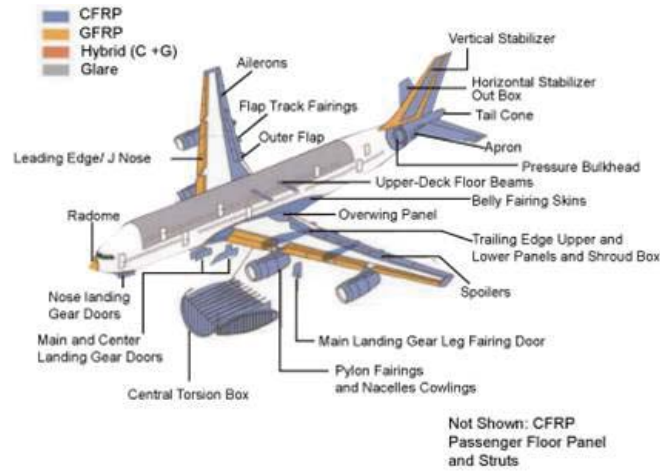


Figure 1 shows current and intended uses for composite materials in the construction of airplanes

Carbon Fiber (CF), also known as graphite fiber, or carbon graphite, is a material composed of ultra-thin fibers (0.005-0.010mm diameter) of aligned crystalline Carbon atoms (see Figure 2). The crystalline alignment makes the fiber extremely strong for its size. Thousands of fibers are twisted together to form a yarn, which is often woven into a fabric material. The fiber, combined with a polymer, and heated through various processes, forms a composite material that is extremely strong for its lightweight construction. This lightweight property makes the use of Carbon Fiber Composite (CFC) very attractive to the aerospace industry where weight/thrust ratios are critical for operation, manoeuvrability, and fuel efficiency.

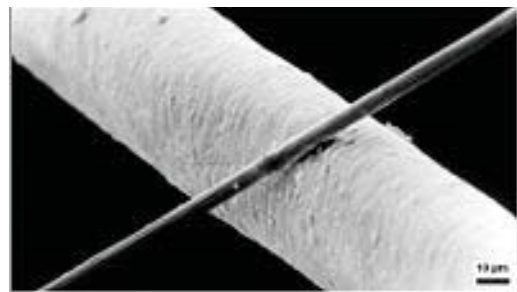


Figure 2 shows a single carbon filament (bottom left to top right) laid across a human hair

Prior to CFC materials, the airframe and most other parts of the airplane were made of metal. Thus, if a lightning strike occurred at the nose of the plane, during takeoff for instance, the lightning would travel outside the plane to the tail, exit the surface of the plane, and continue to ground. The solid metal construction of the airframe acted as a Faraday cage, with an

extremely low impedance path. This prevented coupling of voltages and currents on the internal wiring of the plane, which usually was routed along the side of the plane, between the inside of the outer skin and the interior bulkhead. This also greatly reduced the susceptibility of the mission critical components located in the plane.

CFC materials, however, don't conduct lightning currents the way metal airframes do. As a result, the increased impedance of the outer skin as a path for the lightning increases the possibility of higher voltages and currents coupling directly onto internal cables and into the avionics equipment on the aircraft.

RTCA's Multi Stroke, Multi Burst and SAE's ARP5412 revision A

For the newly initiated, DO-160F currently calls out six individual waveforms. Understanding why these waveforms were incorporated into DO-160 comes from referencing the previously mentioned Aerospace Recommended Practice (ARP) 5412 rev. A. Under the scope of the document, the "standardized external current waveforms have in turn been used to derive standardized transient voltage and current waveforms which can be expected to appear on the cable bundles and at equipment interfaces. The test waveforms are considered to be adequate for the demonstration of compliance for the protection of an aircraft and its systems against the lightning environment." ²

ARP5412 rev A (hereafter referred to as ARP5412) devotes an entire section to the description of lightning and the variety of forms that lightning can occur. Lightning flashes are the discharging of strong electric fields, or charge centers, within cumulonimbus clouds (Cumulonimbus clouds can form alone, in clusters, or along a cold front in a squall line. They create lightning through the heart of the cloud). There are three types of lightning flashes which may occur:

- Flashes between cloud regions of opposite polarity within the same cloud called intra cloud discharges
- Flashes between cloud regions of opposite polarity in different clouds called inter cloud discharges
- Flashes from clouds to ground or the reverse (in instances of high ground locations like mountains and towers)

When a negative cloud to ground flash occurs, the discharge process starts with the formation of a 1-10m wide ionized column that travels in zigzag steps toward the earth. The leader may form branches on the way down to the ground. When the leader gets close to the ground, it causes buildup of high fields near trees and buildings. These then send up leaders to meet the tip of the downward leader. When they meet, a return stroke is initiated, retracing and discharging the leader channel, resulting in a bright flash and high current pulse. After the initial return stroke, subsequent strokes can occur from higher regions of the cloud through the downward leader stroke. These subsequent strokes are usually of lower amplitude than the initial return stroke.

This is the idealized basis for the Multi Stroke Test parameters of DO-160, Section 22. An illustration from the standard is

shown in Figure 3. The initial stroke is the highest amplitude of the Multi Stroke application, with subsequent strokes (up to 14) at a lower but repeated amplitude.

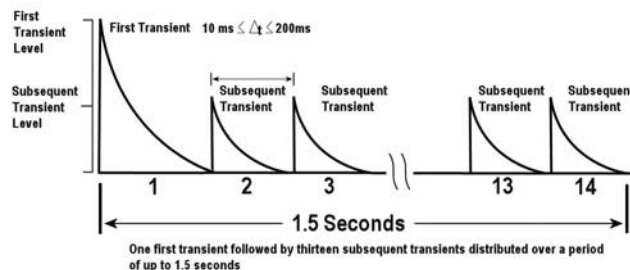


Figure 3. Multi Stroke Application of a Waveform

Inter- and Intra- cloud discharges behave differently than cloud to ground (and vice-versa) discharges. Most of the data recorded for inter- and intra- cloud discharges come from instrumented aircraft employed in the USA and France to record the characteristics of these types of flashes. Although cloud flashes are less severe than flashes to the ground, it was noted that the rise time of the cloud flashes were significantly shorter (less than 0.4 us) and often occurred in grouped pulses during the initial attachment and final detachment phases of the discharges. These short duration, lower amplitude initial and final phases are the basis for the Multi Burst application of Waveform 3. An illustration of the Multiburst Waveform set is shown in Illustration 4. One burst is normally composed of 20 pulses.

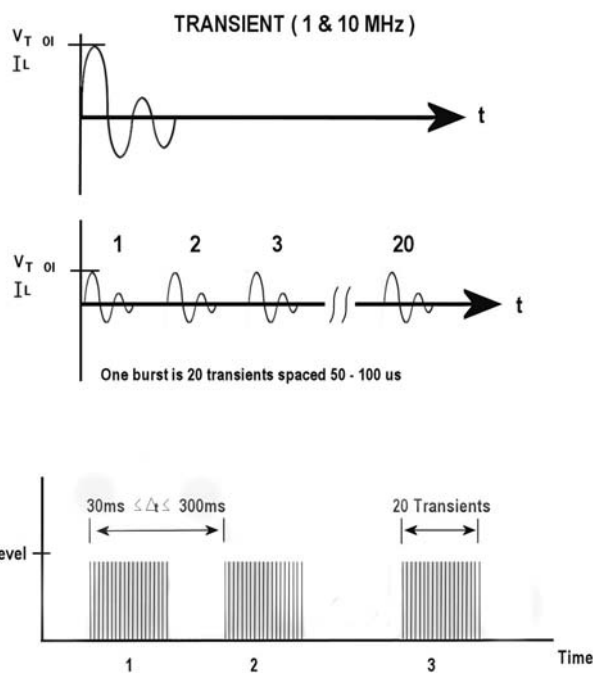


Figure 4. Multiburst Waveform Set

Waveforms 1, 2, 3, 4, 5A and 5B

We now jump to section 7 of ARP5412, which describes the idealized transient waveforms intended for verification of adequate protection of systems and equipment from indirect lightning effects. This section states that there are multiple mechanisms that can induce lightning transients inside the plane from the external lightning environment, but broadly divides

them into 2 categories: Aperture Coupling and Resistive Coupling.

Actual induced transients are complex waveforms that result from both coupling methods, but for test purposes, they have been kept separate. ARP5412 states that magnetic fields penetrating through apertures (electromagnetically transparent openings) will induce:

1. a current waveshape in conductors or shields terminated to the structure through low impedances at each end.,(Figure 5)

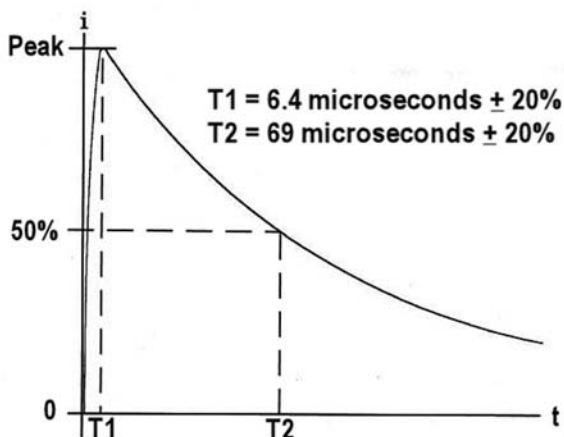


Figure 5 - Waveform 1 - Current
Double exponential 6.4us X 69us (to 50%)

2. a voltage waveshape in loops existing between cables and the structure (Figure 6)

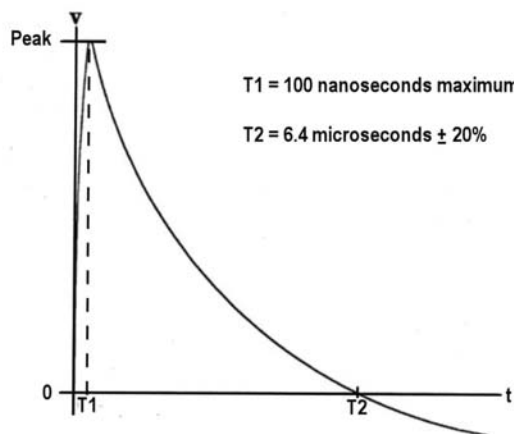


Figure 6 - Waveform 2 - Voltage
Double exponential 100ns X 6.4us (at zero crossing)

3. damped oscillatory voltage and current waveforms resulting from excited resonances on coupled interior cables. 1MHz and 10 MHz frequencies representing long and short cable lengths, respectively. (Figure 7)

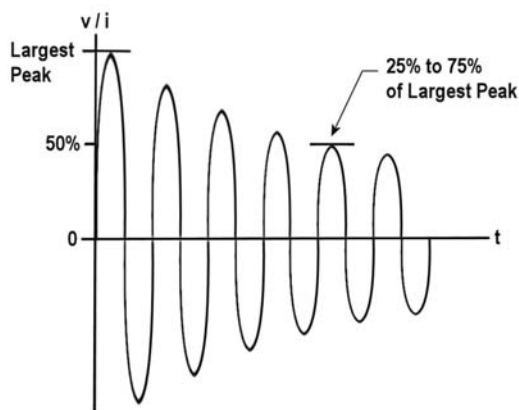


Figure 7 - Waveform 3 - Voltage/Current
Ringing wave, sine or cosine 1MHz and 10MHz

Resistive Coupling will produce :

1. voltages in conductors within shields due to shield current and shield transfer impedance (Figure 8) and

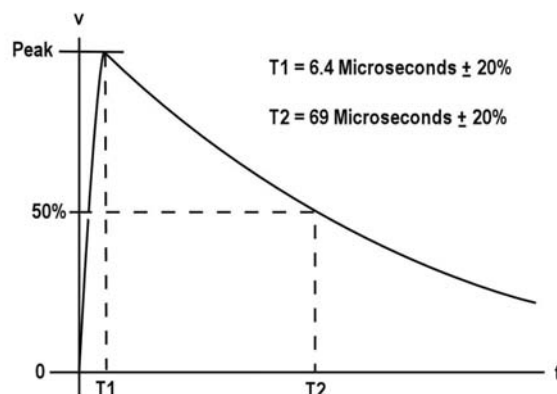


Figure 8 - Waveform 4 - Voltage
Double Exponential 6.4us x 69us (to 50%)

2. voltages produced by loops existing between cables and the airframe structure (resulting from variances in voltage from the endpoint locations of the cable at different locations on the airframe) and voltages resulting from diffused fields through the structural material (Figure 9). Figure 9 shows 2 different waveforms to cover the wide variance of frame resistance represented by metal and carbon fiber composite airframes.

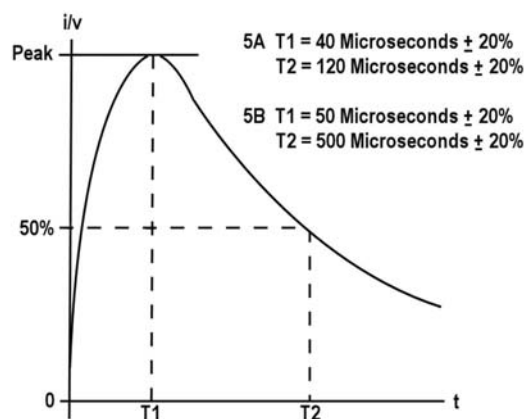


Figure 9 Waveform 5A - Voltage/Current
Double Exponential 40us X 120us (to 50%)

Waveform 5B - Voltage/Current
Double Exponential 50us X 500us (to 50%)

Waveform Power Levels

There are five Test Power Levels, where Level 1 is the lowest and Level 5 is the highest.

- Level 1
 - Equipment and wiring are installed in a *well* protected environment
- Level 2
 - Equipment and wiring are in a *partially* protected environment
- Level 3
 - Equipment and wiring are in a *moderate* electromagnetic environment
- Level 4 and 5
 - Equipment and wiring are in *severe* electromagnetic environments

Power levels specified in DO-160 Section 22 are often based upon how critical the component is for flight operation and/or where the unit is located within the aircraft. Greater resistance or spacing from apertures will result in lower power levels. Power levels can also be dictated by the component purchaser or plane manufacturer, based upon other factors. An example is a plane manufacturer may wish to increase the immunity level of entertainment systems on long range aircraft, with the idea that they are more likely to experience multiple lightning strikes and more likely to fail during a 14 hour flight.

Testing methods

There are three primary methods of testing aircraft components

Pin Injection – This method is used to directly inject the waveform into connector pins of both cables and printed wiring boards.

Cable Bundle Induction – This method uses a coupling transformer to inductively couple the waveform onto the cable bundle.

Ground Injection – This method is often used as an alternate method to inject the waveform onto the ground wire of the unit under test, referenced to the Ground plane that is located on the surface of the test table.

Methods of testing are often dictated by the purchaser, using categorizations defined in DO-160, and involving specific waveform sets for different coupling means. Figure 10 shows the Table for Pin Injection for both aperture coupling and resistive and aperture coupling, and specifies which waveforms are to be applied.

Table 22-1.1 Pin Injection Test Requirements

Waveform Set	Test Type	Test Levels	Test Waveform Nos. (Voc/Isc)
A (aperture coupling)	Pin	Table 22-2	3/3, 4/1
B (aperture and resistance coupling)	Pin	Table 22-2	3/3, 5A/5A

Figure 10

Figure 11 shows the table for Cable Bundle Induction Testing, and indicates the categories for various Aperture and Resistive Couplings. Figure 12 shows an example of a Cable Bundle Injection Transformer.

Table 22-1.2 Cable Bundle Test Requirements

Waveform Set	Test Type	Test Levels	Test Waveform Nos.
C (unshielded, aperture coupling)	Single Stroke	Table 22-3	2, 3
D (unshielded, aperture and resistance coupling)	Single Stroke	Table 22-3	2, 3, 4
E (shielded aperture coupling)	Single Stroke	Table 22-3	1, 3
F (shielded, aperture and resistance coupling)	Single Stroke	Table 22-3	3, 5A
G (unshielded, aperture coupling)	Single Stroke	Table 22-3	2, 3
	Multiple Stroke	Table 22-4	2, 3
	Multiple Burst	Table 22-5	3
H (unshielded, aperture and resistance coupling)	Single Stroke	Table 22-3	2, 3, 4
	Multiple Stroke	Table 22-4	2, 3, 4
	Multiple Burst	Table 22-5	3
J (shielded aperture coupling)	Single Stroke	Table 22-3	1, 3
	Multiple Stroke	Table 22-4	1, 3
	Multiple Burst	Table 22-5	3
K (shielded, aperture and resistance coupling)	Single Stroke	Table 22-3	3, 5A
	Multiple Stroke	Table 22-4	3, 5A
	Multiple Burst	Table 22-5	3

Figure 11



Figure 12 – Injection Transformer
For Waveforms 1, 5A and 5B

As defined in the tables above:

- a. A, C, E, G and J are for aperture coupling
- b. B, D, F, H, and K are for resistance coupling
- c. A and B specify Pin Injection
- d. C through F specify cable bundle single stroke

- e. G through K specify cable bundle single, multi-stroke and multi-burst
- f. Z means other tests were conducted

These letters (A-K, Z) are used as part of a classification code often provided by the buyer (Airplane Manufacturer) who determines what coupling may occur and what induced conditions may be expected on their airplane, based upon construction materials, unit location and expected coupling zones.

Mil Std 461

The content presented above represents an explanation of the fundamentals of DO-160 Section 22 Testing for Indirect Lightning effects. Understanding the origins and justifications of the requirements often help in determining the course of action needed to test a product. Current expectations are that the requirements listed in DO-160 Section 22 will be adopted by Mil Std 461 in 2011.

References

1. RTCA/DO-160F Environmental Conditions and Test Procedures for Airborne Equipment
2. SAE ARP5412-RevA-2005 Aircraft Lightning Environment and Related

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The Affects of the New ESD Standard on ESD Simulators

By Bruno Straumann, Senior Development Engineer, Haefely Test AG

Introduction

The new IEC 61000-4-2 Edition 2 standard which replaces IEC 61000-4-2 Edition 1 1995 was initially announced in December 2008.

Based on the revised IEC standard, the identical European standard EN 61000-4-2:2009 was also released.

The new EN standard can already be applied for ESD immunity testing, and testing according to the new standard will be mandatory starting 1st of March 2012.

The following article focuses on the effects the new standard has on ESD simulators and the corresponding calibration procedures of such generators.

Misleading first impressions

While comparing the previous and new standard ESD simulator specifications, one may easily get the wrong impression.

The tolerance levels (table 1) along with the rise time (t_r) and current peak values (I_p), are clearly higher in the new standard.

One would assume that the ESD simulator requirements would now be reduced with the new standard, something which is not actually true.

On one hand, the enhanced lower tolerance limit of the rise time only takes into account the lower measurement values, which results from the increased measurement bandwidth. On the other hand, the new standard requires that per measurement level, 5 impulses are recorded at a time and individually evaluated.

Every single measurement (i.e. t_r , I_p , I_{30} , I_{60}) of each impulse must meet the required tolerance levels.

It is now not permitted to use average values from several impulses, although the previous standard permitted using averaged measured values, a procedure which is often used.

	61000-4-2 Edition 1	61000-4-2 Edition 2
Rise time t_r	0,7ns – 1,0ns	0,6ns – 1,0ns
Peak value I_p	±10%	±15%
Current at 30ns I_{30}	±30%	±30%
Current at 60ns I_{60}	±30%	±30%

Table 1: Permitted ESD impulse tolerance levels according to previous and new standard.

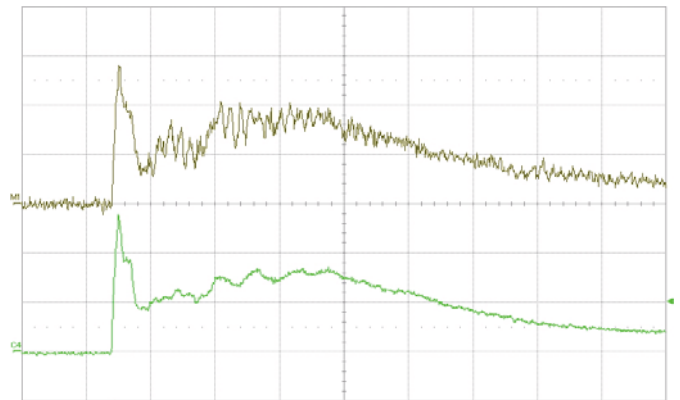
Correct measurement becomes more difficult

Previously, if random measurement errors (in terms of measurement uncertainty) occurred, it was very likely that they would not appear in the final measurement results. The reason for this is because random measurement errors were averaged. With the new standard, random measurement errors are no longer averaged, and thus random errors will now clearly be shown in the final measurement results.

An important source of random measuring errors could be an insufficiently shielded measuring system.

In other words, the reason why the measured ESD impulse does not meet the standard specification could be due to the measurement system itself, and not the actual ESD simulator.

Picture 1 shows the possible effects of a badly shielded measurement system.



Picture 1: non-conforming measurement (above) and correct measurement (below). Insufficient shielding can lead to measurement errors of $\pm 20\%$ magnitude or more.

Higher measurement bandwidth and defined test setup

To calibrate an ESD simulator according to the new standard, the following equipment is necessary:

- Digital Oscilloscope, analogue Bandwidth $\geq 2\text{GHz}$ / Sampling rate $\geq 10\text{GS/s}$
- Measurement target, Bandwidth 4GHz / Impedance $\leq 2,1\text{ Ohm}$
- Attenuator, 20dB typically
- Reference ground plane, dimensions $\geq 1,2\text{m} \times 1,2\text{m}$
- Suitable shielded housing for the measurement system

It is important to note that the new measurement target no longer has the 50 Ohm series resistor. Therefore, there is no halving of the measurement voltage.

While the amplitudes of ESD impulses remain constant, the measured voltage at the oscilloscope is doubled.

The shielded housing has to damp interference frequencies of up to GHz levels.

To go without saying, all wiring leading into the shielded housing must be filtered accordingly.

A possible data transfer should be done via fibre optics. The position of the grounding connections on the ground reference plane is now exactly defined, i.e. 0.5m vertically below the measuring target.

The position of the ESD simulator earth cable is now also defined. This is very important and should not be ignored because it influences the measurement values of I30 and I60.

Consequences for ESD Simulators

Experience shows that there are significant differences between various ESD models. Because the new standard demands more from ESD simulators, it is clear that some ESD simulators will no longer be compliant to the new standard.

Testing with such non-compliant ESD simulators can lead to over-testing or under-testing of EUTs. In praxis this is not a desirable result.

A decision on whether an existing ESD simulator meets the new requirements can only be made following calibration to the latest edition of the IEC standard. When purchasing a new ESD simulator, one should ensure that the new simulator meets the exact requirements.



Picture 2: Modern ESD-Simulator built to meet exact requirements of the latest standard.

Verification and calibration.

In the previous standard, the term verification and calibration was used incorrectly, while the revised standard now correctly differentiates verification from calibration.

Calibration is the exact measuring technique of the measurement values, and verification means verification of the ESD simulator.

The verification is carried out before the actual testing takes place, whereas calibration period of the ESD simulator needs

to be determined by the user, and is typically every 1-2 years.

The new standard suggests that to determine whether the simulator is functioning correctly, the length of the spark should be checked during an air discharge.

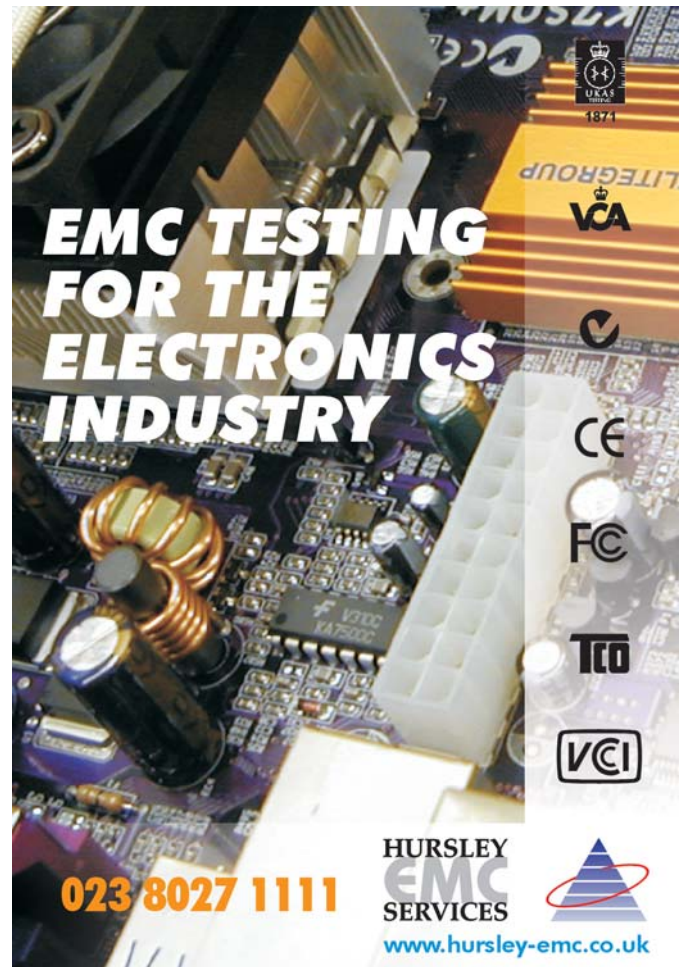
However, this is an insufficient method as the length of the spark depends on the geometry of the discharging electrodes, the polarity, and the environmental conditions. Furthermore, a defective discharge relay will not be detected.

This is the reason modern ESD simulators include self test routines, which within seconds can diagnose potential defects.

It can generally be said that the new IEC/EN 61000-4-2 Edition 2 standard demands more from ESD simulators as well as from the measuring equipment used for calibrating the ESD simulator itself.

If the ESD simulator meets the standard can only be determined through proper calibration.

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The Physical Basis of EMC — Part 4

Eur Ing Keith Armstrong CEng FIET SMIEEE ACGI, Cherry Clough Consultants

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8 Crosstalk and “internal EMC” issues inside a product

For EMC compliance we are only concerned with the EM interactions between an item of equipment and its external EM environment.

But EM interactions also occur between devices, components, traces and wires *inside* a product or item of equipment, and we care about these because they affect the number of design iterations and time-to-market. We also care about them because they can easily affect reliability and hence warranty costs, and customer perceptions hence future sales.

Banana Skins [9] includes many examples of companies that lost a lot of money, maybe even their whole company, because of poor EMC engineering. These examples can help engineers encourage their managers to take the subject seriously.

We might call this issue “Internal EMC”. EMC consultants worldwide have been trying for decades to get designers to use good EMC engineering from the start of any project, to save money and time overall and reduce financial risk, and they have usually had a very poor response – causing them to stop trying.

Well, I have been banging this particular drum for 20 years now, and still haven't given up [26]. Maybe Figures 43, 44 and 45 will add to [26] and help get the message across. Like all businesses today, all that matters is money [27] and so – as an engineer – to get anywhere in discussions with your managers you have to bring it down to terms they can understand – money, time, and probability. Strangely enough, it is just as if you were discussing the odds of various gambling methods.

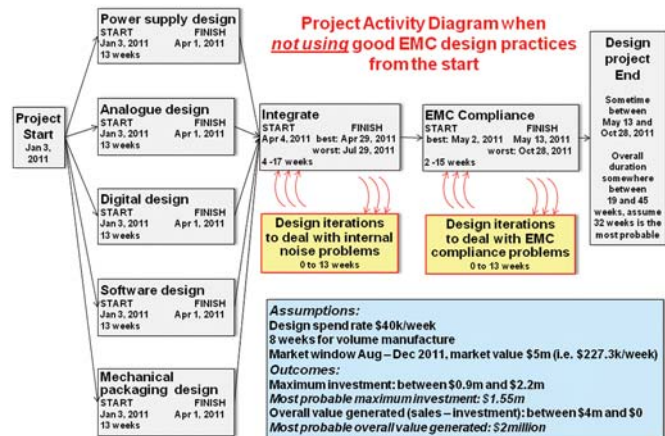


Figure 43 Example Project Activity Diagram when not using good EMC design practices

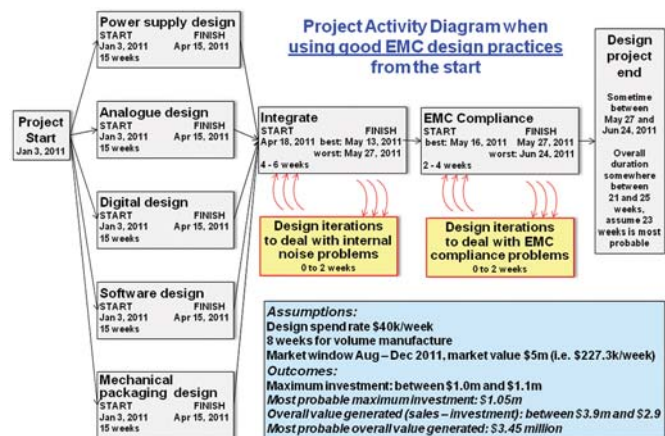


Figure 44 Example Project Activity Diagram when using good EMC design practices

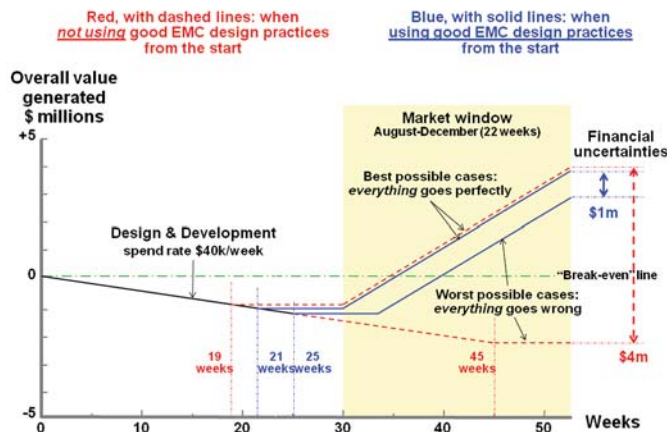


Figure 45 Comparison of financial risks from the projects of Figures 43 and 44

Now I must get back on course again and discuss the physics of EMC. The material in this little series of articles applies equally well whether the issue is “external” or “internal” EMC.

Internal EM interactions are traditionally called crosstalk and analysed in terms of stray capacitance and stray mutual inductance, i.e. a Lumped Analysis approach (see Section 3 of Part 1 [8]). But this only works when the victim is in the near-field of the E of H-field emissions from the noise source.

Traditional crosstalk is often inadequate for modern designs, because the high frequencies we now employ (e.g. clock harmonics) have such short wavelengths that parts of the inside of the equipment we are designing are in their far field, and the wires and cables inside an equipment; PCB traces; heatsinks and even devices themselves, can behave as very efficient accidental antennas.

Remember that far-field and resonant EM interactions cannot be estimated by lumped analysis methods.

But there is more to internal EMI than crosstalk: noise, signal-to-noise ratio; noise margin; eye closure; overshoot; ringing; double-clocking, etc. are also aspects of it, as sketched by Figure 46.

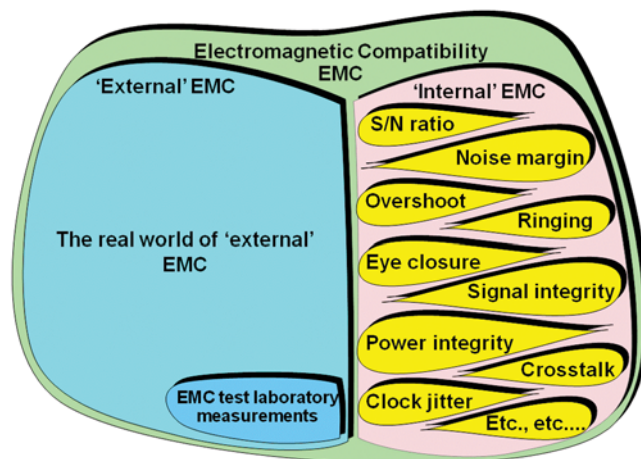


Figure 46 Aspects of Internal and External EMC

9 Types of EM phenomena and how they can interfere

A guide to assessing EM phenomena is one of the many very useful Technical Guidance Notes (TGNs) issued by the EMC Test Labs Association, as TGN 47 [28].

9.1 EM phenomena that couple into all metalwork and conductors

When I write the word “conductors” in this series on the Physical Basis of EMC, I always mean anything that can possibly conduct electricity, for example, metal structures, brackets, chassis, wires, cables (power, data, signal, control, etc.), PCB traces, water (except when distilled), etc.

9.1.1 Surge transients

All conductors pick-up noise currents and voltages from transient over-voltages, in IEC standards-speak these are called “surges” (which term in the USA means what the IEC calls

voltage fluctuations, so be careful) or more colloquially “spikes”, sometimes just “transients”.

These are generally caused by nearby thunderstorms, even by cloud-to-cloud lightning when there are no thunderstorms, by reactive load switching (e.g. electrical motors, relay and contactor coils, solenoids, capacitors, long power cables (especially HV transmission lines) etc.), fault clearance (e.g. fuses, circuit-breakers, etc.).

Surges can be directly injected into conductors (e.g. when de-energising a relay coil or solenoid) or coupled into them by one or more of the four coupling effects described in section 5 of Part 2 [17]. Figure 47 shows a surge waveform induced into a wire that is bundled together with a pair of wires that were powering a relay coil, when that coil was switched off.

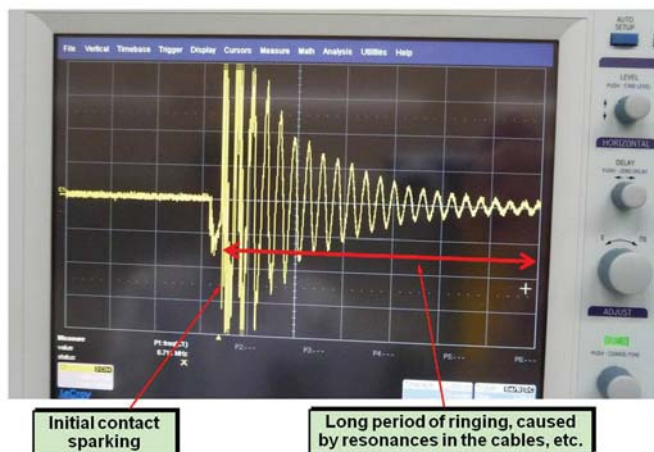


Figure 47 Example of induced surge from wires powering a relay coil

There is an infinite variety of surge wavelshapes, all having different effects on electronic circuits, but IEC test standards only use three: Unidirectional; Oscillatory Wave, and Ring Wave, all sketched in Figure 48.

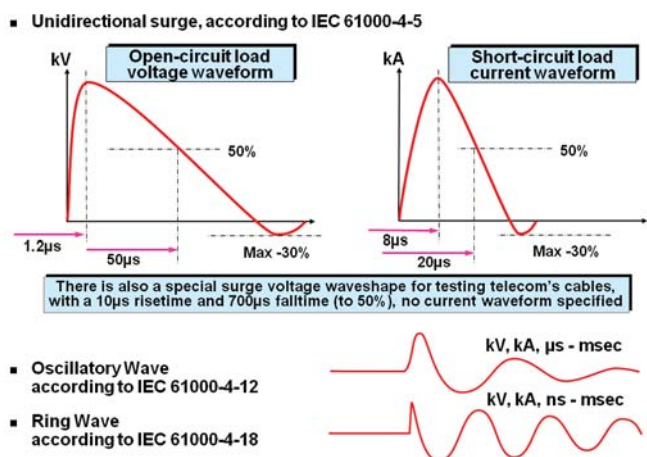


Figure 48 The IEC’s three kinds of test surges

All power supply systems are plagued with transients, and some of them are related to the type of equipment that generates the power or is powered from it. So there are special test standards (e.g. ISO 7637, for motor vehicles) that specify a few types of transients that are different from the IEC ones, to try to simulate

the infinite variety of transients that they can experience. Older motor vehicles used to suffer surges of up to $\pm 200V$ (maybe more) on their 12V dc battery supply systems, but modern vehicles have lower levels due to the large numbers of surge protection devices fitted to help protect all their electronics.

Surges occurring in AC power distributions that are not protected by surge arrestors correctly-installed as part of a lightning protection system (see Section 5.13 in [29]) are only limited in voltage by insulation breakdown, usually spark-over in the rear terminals of power sockets. Single-phase sockets in almost all countries worldwide tend to spark-over at around $\pm 6kV$ (can be more) but three-phase power networks with only larger three-phase sockets and no single-phase sockets might spark-over at $\pm 12kV$ or more.

Of course, most product standards only test with mains surges to $\pm 2kV$, because of the “economic/technical compromises” that were “agreed upon” by their standards committees.

9.1.2 Electrical fast transient bursts

These are fast random transients occurring in bursts lasting from a few microseconds to several seconds, caused by sparking. Sparks emit noise across the entire electromagnetic spectrum, from almost DC to beyond the visible range, and we can see this broad bandwidth if we measure very close to them with a broadband close-field probe. See Figure 49.

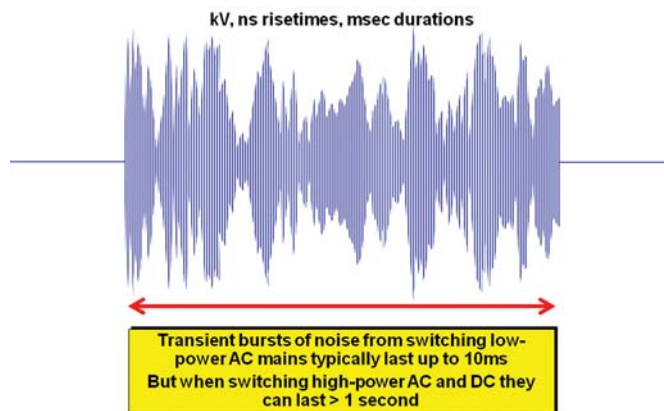


Figure 49 Fast transient bursts from sparking

However, at some distance from the spark, what we tend to see is the accidental antenna behaviour of the cables carrying the current that has been interrupted to cause the inductive flyback that caused the spark, energised by the random noise of the fast transient burst, upon which is superimposed the accidental antenna behaviour of the conductor picking up the noise.

Figure 50 shows an example of a fast transient burst from an unknown sparking event measured with a GHz broadband antenna and 1.5GHz 8Gsa oscilloscope in a larger server room, taken from [30].

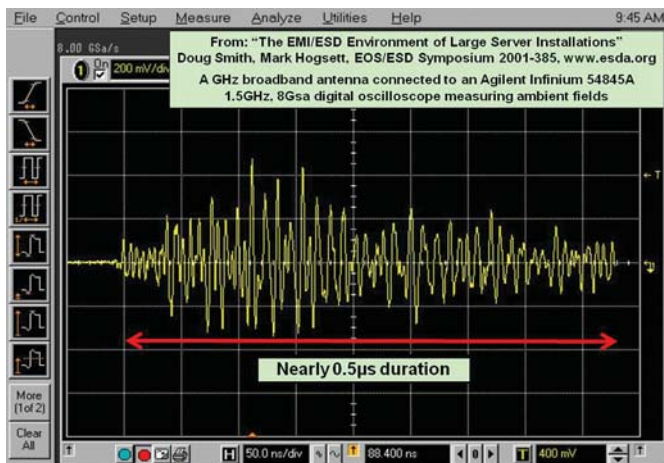


Figure 50 Example of a fast transient burst from an unknown sparking event

Any/all sparks caused by switching electrical power cause such fast transient burst noise, but the power does not have to be very high. I once had a mains indicator light that consumed 15mA from 230V, enough to cause the on/off switch to cause the product to fail the CISPR 14-1 (EN 55014-1) limit for discontinuous emissions.

The pantographs and sliding shoe contacts used in electrical traction vehicles with remote power supplies (e.g. trains, trams, etc.) will spark from time-to-time, causing electrical fast transient bursts. They are usually worse in bad weather, especially when there is icing.

Recently I saw a video of a French TGV travelling at 300mph or some such incredible speed (it was an experiment, with no paying passengers). Apart from the spectacle of all those hundreds of tons travelling at that speed on land, I was particularly struck by the fact that its pantographs were continually spraying huge sparks as it rocketed past. I remember thinking that if they planned to run this as a regular service, they would probably need to improve their technique for picking up power from overhead cables.

Poor connections in power conductors can cause continuous low-level sparking, which may be audible nearby as a slight fizzing noise. This causes *continuous* electrical fast transients, which have been known to interfere with satellite communications at GHz over a very large area (see Banana Skin No. 5 [9]).

9.1.3 Very fast transients

These tend to be single events, often caused by electrostatic discharge from people. But they can also be caused by tribocharging effects during materials processing (a big problem in photocopiers and printers) or when insulating materials that are part of some machine are rubbed (e.g. the plastic bearings of a motor; rubber drive or conveyor belts; plastic pulleys, etc.).

Figure 51 shows the noise emitted by allowing a charged up coin to touch another coin. Notice that the ringing caused by the event lasts very much longer, caused by the resonances/reverberation of the metal cabinets in the server room where this event was measured [30].

Doug Smith, the author of [30] and very much else that truly excellent on EMC and ESD, jingles a plastic bag of coins to create a low-cost near-field broadband GHz noise source. He keeps the cost low by only using low-denomination coins, but you can use gold Sovereigns or Krugerrands if you prefer.

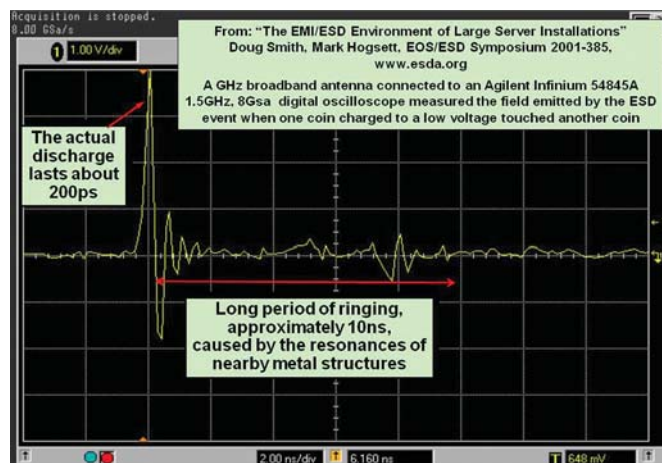


Figure 51 Example of very fast transient from a small metal discharge

Notice that the rise-time of the ESD event in Figure 51 is measured at 200ps – but it is almost certainly shorter than this because of the rise-time of the measuring system (the theoretical rise-time of 1.5GHz oscilloscope is 212ps). Normal ESD test equipment (e.g. to IEC 61000-4-2) have rise-times no faster than 700ps, but it is clear that real-life rise-times can be much less than this.

This is important, because the latest ICs, using sub-130nm silicon processes, can switch in 100ps or so (e.g. PCI Express drivers) and so can respond to ESD events with similar (or longer) risetimes, and at 45nm or less can be upset or even permanently damaged by voltages of less than 100V [31].

ESD events that discharge directly into conductors can have voltages of up to ± 35 kV (in very dry climates). I remember speaking to one poor designer who was having a problem with ESD punching through a 0.5mm polycarbonate layer on his membrane keyboards, which means it must have been at least ± 20 kV. And Banana Skin No. 418 [9] describes a popular choice of footwear causing ± 25 kV in a hospital and interfering with medical equipment.

However, ± 8 kV is more typical when the relative humidity of the air is more than 25%, with a statistical distribution that favours smaller voltages. Peak ESD currents can be 10s of Amps.

People generally do not notice personnel ESD events (usually from their fingers) when they are less than about ± 3.5 kV, but larger voltages usually elicit an involuntary muscular response, larger still often causing involuntary vocalisation with possibly embarrassing consequences. This means that we can all be walking around zapping electronic products and equipment, and charging up portable electronics, with up to 3.5kV without even being aware of it.

Computer keyboards are all made of plastic, and ESD tests directly applied to them usually fail to achieve a discharge at up to ± 8 kV. However, the PCB traces connected to the

keyboard's IC have been measured as experiencing $\pm 100V$ very fast transients, due to the traces coupling with the E and H fields from "indirect" discharges during IEC 61000-4-2 testing to nearby vertical or horizontal metal sheets. This shows us that nearby ESD events that are not direct discharges, can still couple noise into circuits that can cause upsets and even damage.

9.1.4 Continuous low frequency voltage and current noises

In EMC parlance, the term "Low Frequency" usually means everything less than 150kHz, but I have worked with microwave engineers who called everything less than 5MHz "DC".

All AC mains power supplies now have distorted waveforms and carry harmonic and interharmonic currents. Interharmonic currents are low frequencies that are not related to the mains frequency, and are mostly caused by variable-speed AC motor drives.

These voltages and currents couple into other conductors via the common-impedance of the protective bonding structure (often called the "safety earth"), E and H fields.

Figure 52 shows a noise current waveform I found caused by the lighting scheme in a road tunnel under a major river. This is dominated by the harmonics of the megawatts of fluorescent and discharge lighting equipment being used. Interestingly, although all of the lamps met their harmonic emissions limits in IEC/EC 61000-3-2, the aggregation of their harmonic currents caused overheating in the lighting control switchgear (the reason I was there at all).

This is one reason for why we should never assume that all we have to do for an easy life is to buy products that are CE marked, even if we take the trouble to check the manufacturers compliance documentation and ensure that his products actually do comply with what we might assume from their CE marking (quite a lot of products do not [32]).

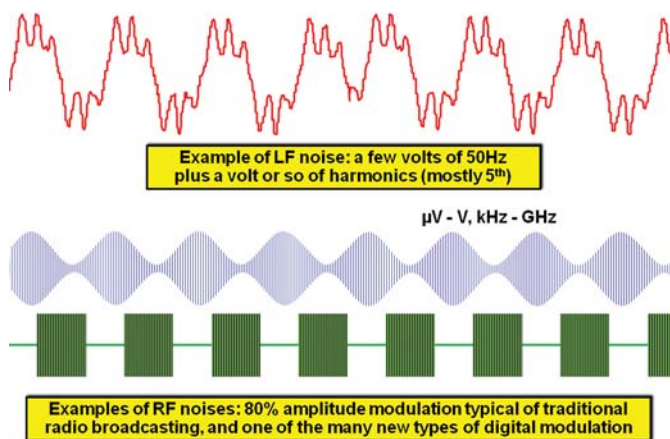


Figure 52 Example of low-frequency and RF noises

Where power is used at other frequencies (e.g. high-power audio in entertainment venues) continuous low-frequency noise will also arise in nearby conductors, at those frequencies.

When there is an insulation failure between a mains conductor and the protective bonding, or during the "follow-on" period

of conduction following the discharge in a gas-discharge-tube surge protection device that is connected between an AC supply and the protective bonding, the level of mains-frequency noise induced into conductors can be as high as the mains voltage itself (e.g. up to 240V rms), and last until the fault is cleared (could be several seconds).

If the insulation fault occurs in a high-voltage mains distribution, the low-frequency noise level can reach kV for a few seconds. [33] provides some more information on the causes of low-frequency noises in conductors, and their effects.

Trams and light rail systems are becoming quite popular in some cities, and it is unfortunate that they insist on using electrical technology that would have been familiar in the late 1800s – I mean electrical power delivered by rails or cables, with sliding connections to the vehicle. Since traction currents for one vehicle can easily reach 1000A, the H fields produced can be very large, and because the send and return conductors are so far apart, they can spread widely.

This is particularly a problem in the case of overhead power cables with a rail return. The send/return spacing is very large, and the H field sprays out sideways – straight into buildings alongside the route. Any equipment sensitive to low-frequency magnetic fields, such as cathode ray tube (CRT) displays, had better be fitted with hi-permeability metal or "active" H-field screening or be located at least 40m away from the line of the track. More sensitive scientific and medical equipment, like electron microscopes, had better be fitted with appropriate H-field screening (not cheap!) or located at least 200m away.

Since the current return rails for electrified traction systems are usually connected to earthing electrodes in the soil, heavy currents can flow through the ground and interact with other metal structures nearby – usually structures associated with buildings, increasing corrosion and adding to the low-frequency common-impedance noises in their protective bonding and other "earthed" metal structures.

9.1.5 Continuous radio frequency (RF) voltage and current noises

As was discussed earlier in Parts 1 [8] and 2 [17], all conductors (or slots in metal sheets) act as accidental antennas for E, H and EM waves (and their associated fields). So they pick up all the radio and TV broadcasts, mobile phone transmissions, etc., that are present in their environment – many frequencies and types of modulation – all at once.

Any conductor can be connected to a radio receiver and used as an antenna, although it might not be much good over certain frequency ranges. Wire coathangers make good antennas for FM broadcasts (around 100MHz) and it used to be quite common to see them used as car antennas when the old antenna had broken off. (In fact, I was surprised to find that the FM antenna mounted in the loft space of the house I moved into recently, and which works quite well, was a wire coathanger.) To help save paper and hence the planet, Figure 52 includes some examples of RF noises in conductors.

9.2 EM phenomena associated with the mains power supply (Power Quality)

9.2.1 Waveform distortion

Harmonic distortion is caused by the harmonic currents drawn by non-linear loads, such as fluorescent and discharge lighting, and especially (these days) AC-DC rectifiers. Interharmonic distortion is caused by mains currents that are not related to the mains frequency, and are mostly caused by frequency-changing power converters (e.g. for variable speed AC motor drives). Total harmonic distortion (THD) can be up to 10%, with 8% considered the limit beyond which electronic products and equipment not specifically designed for highly-distorted mains might malfunction.

It is becoming increasingly common to see THD of up to 30% for ships and offshore installations, because of the recent large increase in use of “thrusters” (variable-speed AC motors driving propellers) and even electrical propulsion. This is made worse than similar loads would cause on land, because marine vessels generate their own electricity, and since the source impedance of a generator is about three times higher than that of a HV-grid supplied distribution transformer of the same VA rating, a given non-linear load causes three times the distortion.

Figure 53 shows some examples of distorted mains waveforms from my own files. The top left hand one is from an industrial lighting installation, and the voltage waveform shows the sort of “flat topping” that is characteristic of supply networks that are heavily loaded by AC-DC rectifiers.

These sorts of voltage and current waveforms are not untypical of light industrial, commercial and domestic premises. Of course, the currents tend to be lower than the 108A shown in Figure 53 but the mains source impedances tend to be correspondingly higher, so the waveform distortion often stays much the same.

The top right hand waveform was provided by Dr Nick Maroudas, from an oscilloscope measuring the mains in his house in Israel in 2000, see Banana Skin No. 104 [9].

The bottom right waveform is from a generated supply feeding a 1MW AC motor drive switching at about 1.7kHz. The measuring equipment had a bandwidth of only 5kHz (typical of power quality instrumentation) and if it had a wider bandwidth the depth of the notches in the waveforms would have been much deeper than their already very excessive magnitude.

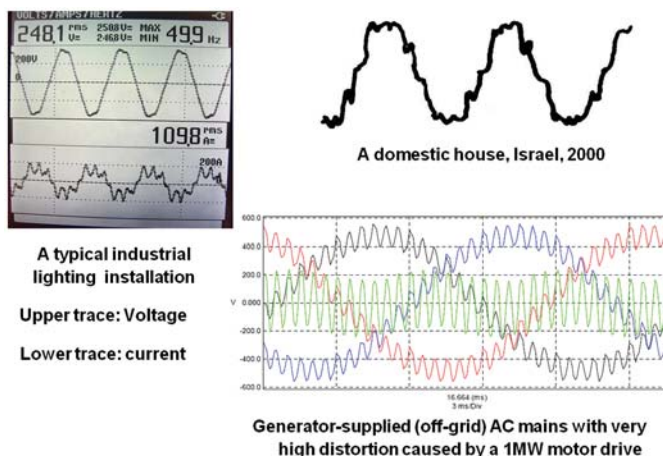


Figure 53 Examples of AC mains distortions

Harmonic and interharmonic currents, and the voltage waveform distortions they cause, are just an EMI problem. They can cause overheating with very costly, if not dangerous consequences. [34] and [35] provide more information on harmonic and interharmonic currents, waveform distortion, and their effects.

Of course, waveform distortion is a problem only for AC supplies, whether 50Hz, 60Hz or 400Hz (aircraft). There are many other power quality problems that afflict both AC and DC supplies (e.g. the 48V supplies used in telecommunications rooms, and by blade servers [36].)

9.2.2 Fluctuations in the supply voltage

Rapid fluctuations in supply voltage are caused by rapid load fluctuations (assuming there is not some instability in the network voltage control system). Up to $\pm 10\%$ is possible; higher levels usually indicating a serious problem with the supply impedance.

Voltage dips and flicker from power distribution network control and fault-clearance can be of any depth and any duration, with a statistical distribution in favour of smaller depths and durations.

Dropouts and interruptions are also caused by power distribution network protection and fault-clearance, and of course interruptions can last for weeks (especially in the case of a natural disaster).

Figure 54 shows some rather clean versions of these three power quality issues. In real life, they are unlikely to look as simple. For example, when an insulation fault causes a fuse to blow or a circuit breaker to open, there will generally be a dip or dropout at first, combined with a significant increase in mains-related noise in the protective bonding structure (also appearing on earthed neutrals), plus a locally intense increase in H-field emissions due to the very high levels of current in the fault. There may also be some continuous broadband RF noise if the fault includes some sparking.

Then when the faulty circuit is eventually disconnected by the overcurrent protection device, there will be a larger burst of RF noise (an electrical fast transient burst) due to the sparking as the large amplitude of the fault current is interrupted. This will be followed by a surge of up to double the nominal mains voltage, caused by the flyback of the energy stored in the mains network's wiring during the gross overcurrents that occurred during the fault.

Of course, when tested in a lab, for all products except critical telecommunication infrastructure (and maybe not even then), they test with just one type of EMI at a time.

9.3 High Power Electromagnetic threats (HPEM)

The topic of HPEM includes:

- Lightning
- Powerful radio and radar transmitters creating High Intensity Radiated Fields (HIRF), for example at airports and harbours.
- Nuclear electromagnetic pulse, which comes in various “flavours”: EMP, NEMP and HEMP
- Intentional EMI (IEMI) – using a variety of powerful EM devices often originally intended for military use, some of which can be purchased for private use, or constructed by a reasonably competent engineer, making IEMI a real possibility for some applications.

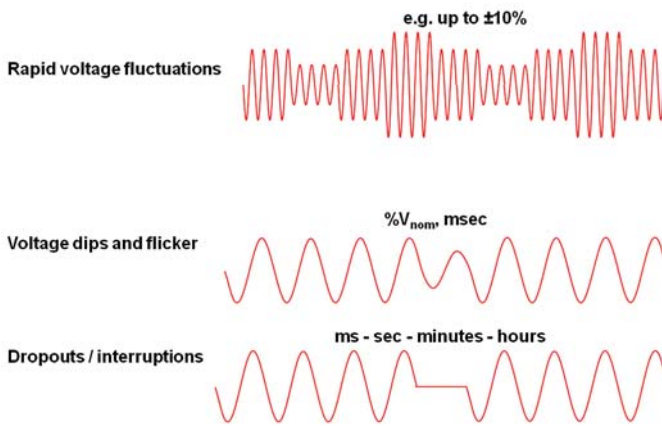


Figure 54 Examples of some more power quality issues

Figure 55 sketches some more power quality issues:

- Slow variations (called sags and swells in IEC-speak, surges and brownouts in the USA) caused by long-term load variations.
- Three-phase voltage unbalance, in voltage and/or phase, caused by unbalanced loads or insulation failures in three-phase systems.
- Frequency variations caused by significant load fluctuations on generators. For national-grid-supplied power, frequency variations usually do not exceed $\pm 0.5\%$ (except for a few seconds before load-shedding to protect the grid causes a whole area to lose power).

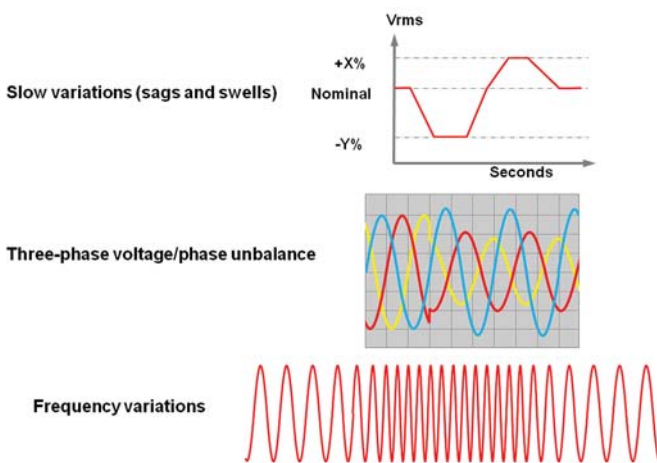


Figure 55 More examples of power quality issues

Don't forget that because AC and DC power distribution uses cables, all of the EMI issues discussed in 9.1 apply – often to a larger extent because many of the electrical noise sources are directly connected, rather than induced, and because mains cables can be very long indeed and so pick up higher levels of lower-frequency noises.

And when running from a generator, for example a hospital running on its emergency mains supply, most/all power quality issues are made much worse.

[37] provides more information on a wide range of power quality issues, including how to deal with them.

Figure 56 shows some examples of HPEM, and is taken from IEC 61000-1-5. Figure 57 shows an example of an IEMI weapon in a suitcase.

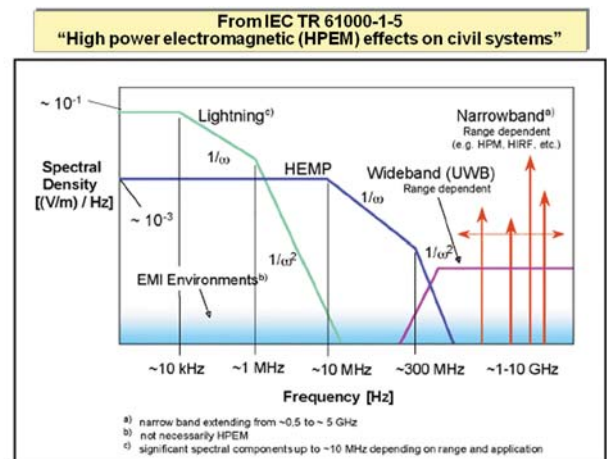


Figure 56 Examples of HPEM threats

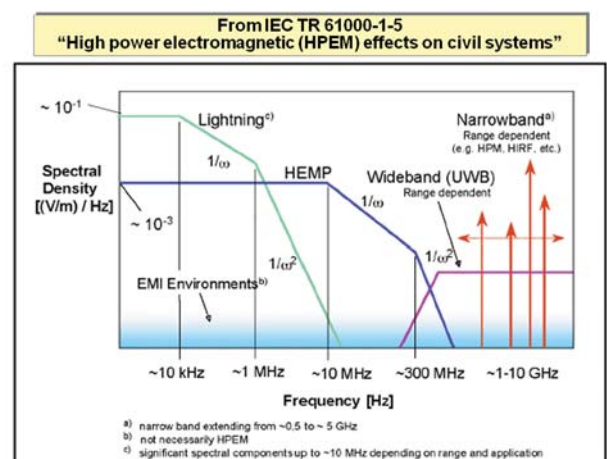


Figure 57 Examples of an IEMI weapon

A number of IEC standards have recently been written, describing various HPEM threats, and how to harden systems against them, in the 61000-5 series [38].

9.4 Mechanically or climatically induced EMI

This issue concerns electrical connections, and electrical insulation. Poor-quality connections can have a variable contact resistance, and even make intermittent connections. The quality of their contact resistance and whether they are intermittent (temporarily open-circuit) is frequently affected by mechanical vibration, and temperature changes (because of coefficients of thermal expansion).

So we can get modulations in supplied voltages and signals, caused by mechanical shocks, vibration, and temperature. Sometimes they can mimic real signals, for example when an engine vibration causes a poor connection in the cable from a vehicle's speed sensor to produce noise that can be mistaken for a valid speed signal [39].

Poor quality electrical insulation can cause corona discharge (broadband RF noise), maybe even spark-over occasionally (causing electrical fast transient bursts) due to shock, vibration, or climatic effects such as condensation or conductive dust.

And all these problems get worse with ageing and corrosion (whether fretting, oxidative and galvanic).

9.5 High voltage power distribution using overhead cables

The high voltages in the conductors cause local corona discharges in the air – continuous broadband noise at the frequency of the mains supply, plus all of its harmonics up to 100s of GHz. In the case of HVDC, it is just random noise all the way from DC to 100s of GHz.

9.6 EMI Victims: Analogue circuits

The effects of EMI on analogue circuits include noise and/or distortion and/or zero-shift errors of up to \pm full-scale. This causes problems particularly for measurement and control of physiological parameters; chemical reactions; temperature; pressure; weight; mass; flow; velocity; movement; level; etc., which often use analogue sensors that need signal conditioning, amplification, and analogue-digital conversion.

Analogue semiconductors are easily destroyed by overvoltages and overcurrents, although they are generally not as vulnerable to this problem as digital devices, because they usually larger silicon processes that have thicker insulation layers.

However, there are some analogue devices that use very small features indeed, whether in silicon (e.g. RF power devices) or other materials (e.g. giant magneto-restriction (GMR) devices used for reading data in computer hard drives) – these could be permanently damaged by just a few volts above their nominal supply rating.

9.7 EMI Victims: Digital circuits (including software)

A well-designed digital circuit has a significant noise margin – a voltage gap between the peaks of its self-generated circuit noise (e.g. due to ground/power bounce) and the thresholds at which its devices each decide whether they are being supplied with a signal that is either 1 or 0.

External noise (which could be from other parts of the same product, or from the ambient EM environment) “fits into” this

threshold, so that normal levels of EMI do not cause a device to mistake a 1 for a 0, or vice-versa.

So, in a well-designed digital circuit, functional performance errors tend only to occur when the EMI's magnitude passes a threshold, but then a variety of malfunctions can occur – often quite unpredictable. Sometimes, when testing digital circuits with various EMI threats, we see the following escalation in functional errors:

- False key-presses, errors in communications, data and control, which could be quite dangerous, for example changing operational mode (e.g. from crawl speed to full speed). These errors are caused by the accidental antenna behaviour of the long cables or PCB traces usually associated with manual controls, keyboards, and datacommunications.
- As the level of the EMI is increased, smaller cables and PCB traces start to pick up enough noise to cause all sorts of incorrect software operation, not just limited to controls and datacomm's, for example continually repeating an inappropriate activity (stuck endlessly repeating a section of the program) and of course also being able to change the operational mode.
- At higher levels of EMI still, stopped operation (often called a “freeze” or “crash”) will occur. This is usually detected by a “watchdog” circuit that reboots the software process after some time has passed, resuming normal operation (or some default state). But while the processor is rebooting, its control outputs will assume random combinations of states, which can possibly include those with undesirable or unsafe results for whatever is being controlled.
- At higher levels still, digital devices can be permanently damaged. Modern processors and memory ICs are very easily destroyed by overvoltages, maybe by as little as 10V, because of the very small silicon processes they are made on, e.g. 60nm or less. At these levels, the insulation layers are films of silicon nitride whose thickness is measured as a (small) number of atoms, and incapable of handling more than a few volts.

In the past, ICs were protected by ESD diodes connected to their I/O and power pads, but with these smaller silicon processes and the huge number of I/Os they support, there simply isn't the room for such high levels of protection, so as well as the chips being much more susceptible to overvoltages, they are less well protected.

9.8 EMI Victims: Power switching semiconductors

These include IGBTs, SCRs and PowerFETs. They can all be permanently damaged by overvoltages, surges, ESD and overcurrents. Being large devices intended for high voltages and frequencies of up to only a few 10s of kHz, they generally have large internal capacitances, lots of insulation and heavy-duty conductors, so are not easily damaged by most types of EMI.

In most high-power switching applications, very high levels of “internal EMI” are created anyway, and if the devices were not

very immune they would not survive. Even so, care must be taken with their design if they are to be reliable and not blow themselves up, and some types of power switching devices use optical fibres instead of conductors to control their gates, to make them more immune to noise.

However, all power switching devices are driven by lower-power circuits, in turn controlled by microprocessors or similar low-power ICs, which can be fairly easily interfered with or damaged. If the control terminals of the high-power switching devices are triggered at the wrong time, cross-conduction can occur, shorting the power supply out through the devices and causing malfunctions, and/or actuation of protective devices, and/or actual damage.

When high-power devices cross-conduct, they can explode like hand-grenades, with similar energies and shrapnel.

9.9 EMI Victims: latchup can affect all semiconductors

Latchup is an extremely important factor in determining product reliability, and affects NMOS, CMOS, Bipolar and all variations and combinations of these technologies, whether they are used for analogue or digital processing [40]. A negative or positive voltage transient on any input or output pin of an IC, that exceeds either supply rail voltage by more than one diode drop, is a common cause of latchup.

Latchup can also be caused by high temperatures, and by ionizing radiation, and the presence of either increases the susceptibility of latchup to voltage transients.

During latchup, parasitic SCR-like structures in the IC turn on and short-out the power rails. If the power current is not limited by external components, the IC will overheat and could be permanently damaged.

Where overheating is prevented by the external power supply circuit (as it may need to be, for safety reasons, to prevent fire) and the IC is not damaged, it can only be restored to normal operation by removing the power, waiting a few seconds for the device to cool, then reapplying the power – when the IC will work normally again.

Clearly, all types of EMI transients can cause latch-up, but they are also often caused by non-EMI effects such as hot-plugging, or switching products on or off when they contain multiple voltage rails, when those activities can cause a voltage that is more than one diode drop above or below the instantaneous values of an IC's power rails to be applied to one or more of its input or output pins.

9.10 EMI Victims: Electromechanical devices

Many designers seem to assume that electromechanical devices are totally immune to all EM threats, but dips and dropouts in their electrical power supply can cause relays, contactors and solenoids to drop out. What it will take to make them drop out is hard to predict because susceptibility varies individually, depending on their make and model, age, and temperature.

Few, if any, “relay logic” designers ever test for susceptibility to power quality issues, which is surprising when the main use of electromechanical devices these days is in “hard-wired”

safety systems, possibly protecting the lives of dozens of people. The US Nuclear Inspectorate discovered, many years ago, that the relays used in safety systems in nuclear power plants, would drop out with mains dips that were rather common when compared with the reliability required of the safety systems. So they made the plant operators fit “coil hold-up” devices to the supply to each relay. These would keep the relay operating as usual even when the mains had dropped to less than 50%, indefinitely, and would hold-up through most dips and dropouts to lower voltages. (Since generating plants create electrical power all the time, a total loss of power, such as the rest of us might expect and have to protect against, is not a problem.) There are at least two common relay logic practices that can cause particular problems when power quality issues cause relays, contactors or solenoids (e.g. in safety door interlocks) to become de-energised.

One is when relays or contactors are “held-in” by a normally-open contact. They are usually energised by a momentary contact, such as a push-button, and then hold-in by power applied through the normally-open contact, which is now closed. If the relay or contactor drops out through its supply falling momentarily below its hold-in level, it will not recover to normal operation when the dip, dropout or voltage fluctuation, which might only have lasted a few milliseconds, has passed.

The other is when the relays, contactors or solenoids are pulled-in at full voltage, but then kept energised by a reduced “hold-in” voltage, to save power. Depending on the way in which their reduced voltage is supplied, they may drop out during a dip, dropout or voltage fluctuation – and not pull back in again when power is back to nominal.

Other EMI problems with electromechanical devices include:

- High levels of shock and vibration can make electrical switch contacts “chatter”, causing sparking that generates broadband RF noise (see 9.1.2) that can interfere with electronic devices. This is an example of mechanically-induced EMI.
- Overvoltages due to surges and fast transients can make open contacts spark-over, which is the same as closing them momentarily – applying power more-or-less at random to circuits which should be off, causing who knows what kind of functional errors or safety problems.
- And surge currents can weld closed contacts together, so that they won't open when they are supposed to.

This is a problem for most types of switches, relays and contactors, because they can change their mechanical state from ON to OFF without their electrical state changing at all (or only partly changing). Once again, power may be supplied to circuits that are meant to be off.

Also, despite instructions to isolate at the mains supply before removing any covers, most operators and maintenance engineers would assume that a circuit was safe because they can see that the switches, relays or contactors that supply power to it are in the OFF position, not realising that some or all of its electrical contacts might still be ON. Clearly an electric shock hazard.

Switches, relays and contactors are available with “positively-guided” or “forced” contacts, that cannot change state mechanically unless they also change state electrically, but choice is very limited and they are larger and more costly. An alternative might be to use devices fitted with low-current contacts that provide feedback of actual contact position.

One of the problems with electromechanical components, is that their manufacturers often try to improve or add to their functionality by adding electronics to them.

For example, I saw an advertisement some years ago for a motor control contactor (MCC) that said this new model had an “electronic brain” (i.e. a cheap microprocessor) that provided an extra dozen motor protective functions to the few normally provided by the bi-metal strips, coils and magnets used by traditional MCCs.

What the advertiser should have added, was a bold warning that you should not use their new “brainy” MCCs near to any high-power switching converters; on very noisy supplies; within 5 metres of any walkie-talkie or 3 metres of any cellphone– if you wanted your motor to remain protected, and not to stop working at random times. Of course, these are all places where the traditional design of MCC would have been perfectly happy, and in fact were often installed.

So it is a good idea to ask about the electronic content of any electromechanical device, and if it contains even one rectifier, transistor, or IC, treat it as an electronic device and not as an electromechanical one.

9.11 EMI problems are worsening all the time

This is happening because:

- Traditional electrical, electromechanical, pneumatic, hydraulic and mechanical technologies are continually adding (or being replaced by) electronic technologies.
- Electronic technologies are emitting more noise (e.g. wireless communications, switch-mode power conversion, digital processing, etc.) whilst also becoming more susceptible to EMI due to the use of ever-smaller silicon processes
- The complexity of both hardware and software is continually increasing, making it harder to understand and perform risk analysis upon.

It surely can't be long before the first question asked of any candidate for an electronic design or design management position (hardware, software, PCB, cabling, enclosure design, etc.) is “What do you know about EMI and EMC?” It simply won't be worth the financial risk of employing anyone who does not understand how to apply good EMC engineering in everything they do.

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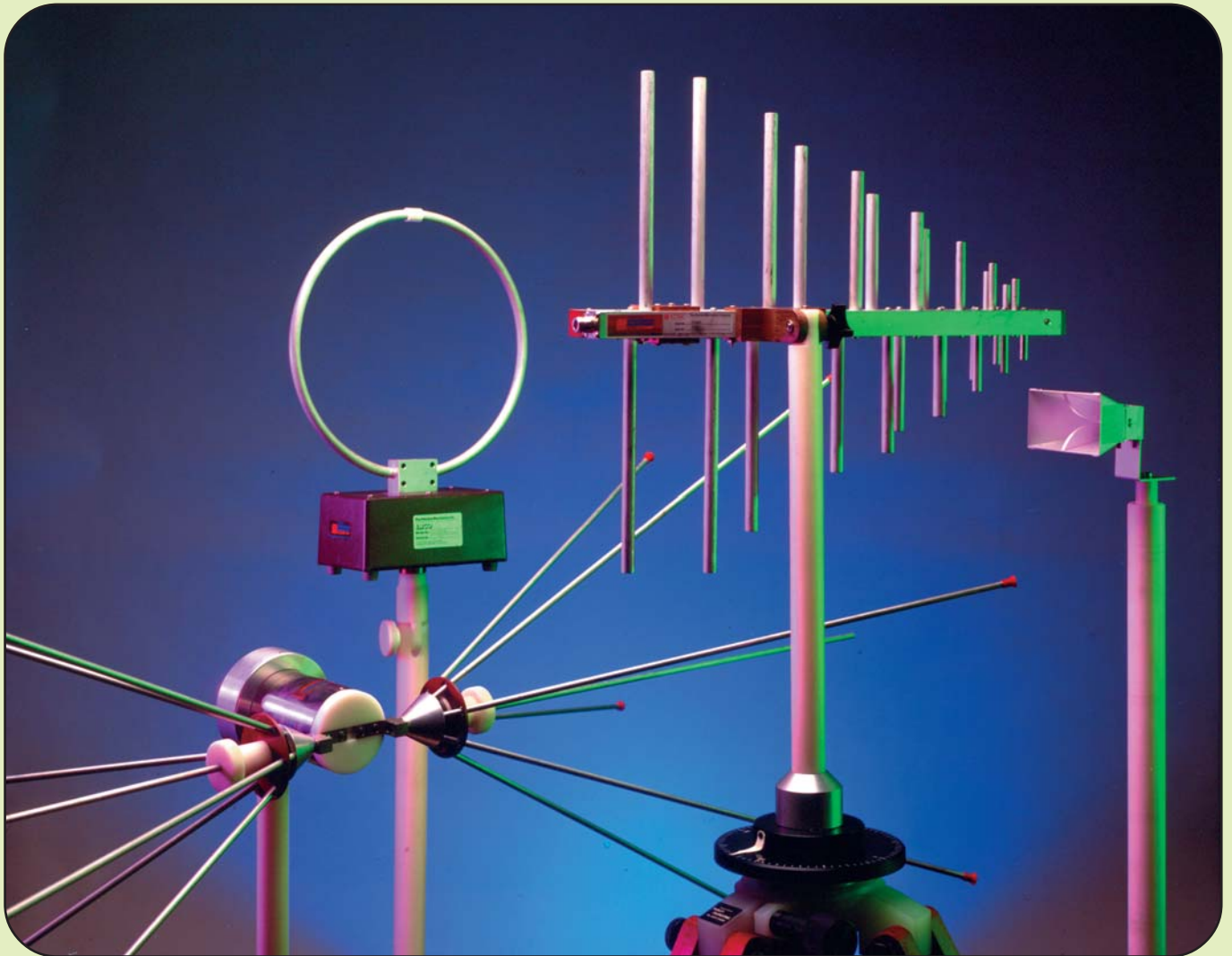
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