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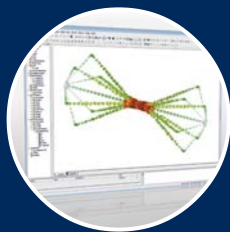

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What's In This Issue

The EMC Journal

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Front Cover

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EMCUK 2008 14/15th October
The Racecourse Newbury
Now in its 5th Year
70% Sold, 9 Months to Go

Over the years EMCUK has developed into being much more than just an Exhibition and Conference. It has become a true visitor, exhibitor experience providing a very friendly networking environment. The industry now looks upon it as the place to meet and the support of the EMCIA, EMCTLA, IET, IEEE UKRI chapter and The EMC Journal ensures an excellent quality event. Plus, of course, the excellent team of Chairman and Speakers that provide the nucleus of the conference.

2007 saw 256 delegated through the conference doors supported by around an additional 600 visitors, we are confident that 2008 will be at least as successful and quite possibly more so, the provisional outline of the programme can be seen below.

A new feature this year to complement the conference programme will be a series of sessions concentrating on "hot topics" and Chaired by Dave Imeson, Secretary of the EMCTLA. Free to visitors.

An extra Training stream will also be added to the conference programme..

The major reason for the success of EMCUK is almost certainly down to the fact that it is fully focussed on just EMC everyone knows what to expect unlike broad based electronics shows which tend to have just a few exhibitors from a cross section of sectors and as such have no focus, which is probably why we have seen their demise over the years. Plus of course the internet has made them somewhat irrelevant.

Conference Programme Outline

Day 1

Session 1 Training
Electronic Fundamentals for Good EMC
Presented by Keith Armstrong and Tim Williams

Session 2
Rail Safety & Assurance
Chairman: Ken Webb, Technical Consultancy Manager, TÜV Product Service

Day 2

Session 3 Training
Testing - titles to be confirmed
Presented by Keith Armstrong and Tim Williams

Session 4
Defence & Avionics
Chairmen:
Professor Nigel Carter, Consultant & Ian MacDiarmid, BAE Systems

Days 1 and 2

Hot Topics to be held in the Marquee.
Chairman: Dave Imeson
Attendance Free

www.emcuk.co.uk

News and Information

TÜV SÜD Rail... twin launch for UK

TÜV SÜD Rail makes twin announcement for the UK, the launch of its Rail Safety Certification and Assurance Services and a Rail Product Certification scheme by combining its extensive track record in certifying safety critical applications with TÜV Product Service's expertise in Electromagnetic Compatibility (EMC).

Says Ken Webb, Technical Consultancy Manager, *"The Rail Product Certification scheme will enable manufacturers to provide a visible and powerful demonstration of their commitment to safety and assurance in the rail industry.*

TUV Product Services have one of the most comprehensive equipped testing facilities in Europe. We are a UKAS (United Kingdom Accreditation Service) accredited test laboratory (No. 0141) for testing both at permanent premises and off-site. We are members of the Link-Up preferred supplier scheme, an ISO9001 registered company, and a DTI appointed EMC Competent/Notified Body."

Ken Webb, Technical Consultancy Manager

These facilities have been designed specifically to meet the demanding requirements of test standards including the EN 50121, EN 50155, EN 61373 series of rail EMC standards together with Railway Industry Association (RIA) and London Underground specifications. This ensures that your modern rail assets are assessed/qualified/certified to the levels required by EU legislation, regulations and industry standards.

In cases where logistics are an issue, equipment is tested 'in-situ' at either the manufacturer's premises or location of final installation. Our engineers are approved for working 'trackside'."

TÜV SÜD Rail, part of the TÜV SÜD group, is a major rail certification body providing safety assurance services (eg. Independent Safety Assessments) throughout the world. The services offered are in the areas of functional safety for Signalling and control technology, rolling stock and infrastructure.

TÜV Product Service, also part of the TÜV SÜD group, based in Fareham, Hampshire has provided consultancy, testing and Notified Body services to the rail industry for more than 40 years, supporting rail manufacturing and operational sectors in the fields of EMC and Environmental simulation.

More information can be obtained by visiting the TUV SUD Rail Stand No.243 at the forthcoming Infrarail Exhibition at NEC 11-13 March 2008. Or contacting Ken Webb by email: kwebb@tuvps.co.uk or tel: +44 (0)1489 558210.

Recommended Events to Visit

Southern Manufacturing & Electronics
6-7 February, FIVE, Farnborough
www.industry.co.uk/southern

Mtec
13-14 February, NEC, Birmingham
www.mtecukshow.com

Infrarail 2008
11-13 March, NEC, Birmingham
www.infrarail.com/register

CEM 2008
8-10 April, Brighton
http://conferences.theiet.org/cem

Electrex & Drives and Controls
22-24 April, NEC, Birmingham
www.electrex08.com

EMC Training Course
23 April, Millennium Stadium, Cardiff
www.blackwood-labs.co.uk/trainingcourses

Nepcon 2008
29 April - 1 May, NEC, Birmingham
www.nepcon.co.uk

CMSE Europe
10-12 June, Marriott Hotel, Portsmouth
www.cmse-eur.com

Farnborough Air Show
14-20 July, Farnborough
www.farnborough.com

IEEE EMC Symposium
18-22 August, Detroit, USA
www.emc2008.org

EMCUK 2008
14-15 October, The Racecourse, Newbury
www.emcuk.co.uk

News and Information

Alan Warner to work with Nutwood UK

Having retired from TECAN at the end of the year Alan is to join the Nutwood team in a freelance capacity. Alan will become involved in many facets of the Nutwood portfolio, including the EMCUK Academy training programme, secretariat duties for EMCIA and some new regional events.

Alan will continue to run the Southern Region Compliance Group (SRCG).

Says Alan E Hutley Managing Director of Nutwood UK "I am absolutely delighted that Alan has joined our team, his considerable Technical and Marketing expertise will provide a wealth of support to Nutwood."

Alan was responsible for the development of the EMC shielding business within Tecan. He has a degree in Electronics & Systems Engineering, is a member of the IEEE and ISMM and brings to his role over 40 years of experience in the electronics industry.

His experience includes the development of airborne and shipborne military equipment and Test Manager for a medium volume sub contract assembly company with several SMT assembly lines, manufacturing tuners and LNBs for satellite television.

TÜV SÜD appointed as Global CATL - CITA Authorised Test Laboratory Battery Certification Program

We are pleased to announce that the TÜV SÜD Group has been appointed as a CTIA (Cellular Telecommunications & Internet Association) Authorised Test Laboratory under the CTIA Battery Certification Program. We are currently one of three organisations in the world to gain this prestigious appointment. This means that we are now authorised to carry out testing and auditing of cellular product systems and their accessories in accordance with CTIA Certification procedures based on the international standard IEEE 1725 (IEEE Standard for Rechargeable Batteries for Cellular Telephones). Leading US network operators such as AT&T and Verizon now require cellular product systems to be registered with the CTIA before they will be permitted to connect to their networks.

The CATL scheme replaces the existing BCRO (Battery Compliance Review Organisation) scheme where cellular product system vendors were simply required to submit a technical file to an appointed BCRO for review. The CATL scheme requires mandatory testing and auditing to be carried out. Our custom test facility at TÜV SÜD PSB Pte Ltd in Singapore is fully equipped to carry out all required testing and is supported by an international team of subject matter experts, auditors and technical certifiers.

We are currently in a transition phase where both BCRO and CATL schemes are operating in parallel; however the CATL scheme will completely replace the BCRO scheme at the end of this transition phase (anticipated to be between 3 & 6 months).

The TÜV SÜD Group has facilities in 600 locations worldwide and employs approximately 11,000 people, predominantly in North America, Europe and Asia.

The Group has been in existence for over 140 years and has an extensive and proven track record in the fields of Product Testing, Consultancy & Certification.

We provide a full range of compliance solutions to the radio and telecoms industry as well as associated industries such as power supply and battery manufacturing to enable fast access to global markets. Services include compliance management, terminal & base station testing, Bluetooth qualification, EMC, Environmental, Safety, Telecoms, RF, SAR, chemical & material testing, regulatory conformance services, management systems certification, product certification and training.

For more details of our test and certification services please visit our web site **www.tuvps.co.uk**, e-mail us on info@tuvps.co.uk or call on 01489 558100 for prompt assistance.

2008: New nanotech guidance

BSI British Standards will publish nine documents for nanotechnology terminology and guidance for UK industry in January 2008, addressing nanotechnology health and safety issues, materials specifications, and labelling of nanotechnology-based products.

Nanotechnology is based on the manipulation of matter at the "nano" scale - with one or more dimensions less than 100 nanometres - and has significant potential in fields as diverse as healthcare, IT and energy generation, and information storage.

Seven new Publicly Available Specifications (PAS) and two Published Documents (PD) will be published, covering everything from carbon nanostructures to the safe handling and disposal of engineered nanoparticles. These documents will underpin the development and commercialization of nanotechnology.

All nine documents will be available as free downloads. Register now for updates at **www.bsigroup.com/oct07nano.**

EMC Training Course Millennium Stadium, Cardiff

Blackwood Compliance Laboratories will be hosting an EMC training course on Wednesday 23rd April 2008 at the Millennium Stadium, Cardiff. Tim Williams and Keith Armstrong will be presenting their highly acclaimed "Electronic Fundamentals for Good EMC" course which was successfully given at the EMCUK 2007 conference at Newbury Racecourse.

This full day course covers mechanical layout, shielding, filtering, cables, PCB layout, tracking and layer stackup, incorporating the very latest techniques for today's EMC design requirements. EMC Test Engineers, Electronic Design Engineers and Compliance Engineers would all benefit from this course.

Availability on this course is limited as it is being held in one of the Stadium's conference suites and not in the main 74,500 capacity Stadium itself. The cost of the course is £135 with concessions for multiple bookings. For more details & to book your place call **01495 229219** or visit **www.blackwood-labs.co.uk/trainingcourses**.

Syfer secures stamp of approval for extended capacitor range

Equipment manufacturers seeking quality-assured surface mount capacitors for high reliability and safety critical applications, now have an extended range to choose from, thanks to leading UK-based manufacturer, Syfer. The company offers the most extensive line-up of devices available with the internationally renowned IECQ-CECC release approval.

Syfer has been working closely with BSI and IECQ to produce urgently needed updates to the CECC 32101-801 qualification. Significant advances in surface mount capacitor technology have rendered the 1988 approval too restrictive, such that popular new devices could not be qualified. Using the IEC 'Fast Track' Rules of Procedure, a new IECQ-CECC Component Specification and Assessment Specification, called QC32100, have been created.

Incorporating the key elements of the existing release approval, the new specification has extended coverage to include smaller chip sizes, voltage ratings of 16, 25, 500 and 1kVdc, and increased capacitance ranges in C0G and X7R dielectrics. The result is that

procurement departments can now source a far wider range of IECQ-CECC approved surface mount capacitors than previously.

"The outdated 1988 standard had become restrictive, covering an increasingly reduced range of the components that are being designed in today," commented Howard Ingleson, Syfer's Managing Director. "Yet demand for quality assured components has never been higher," he added. Syfer has noted that some competitors have ceased offering quality approved

devices because the costs associated with the process audits and component tests were too high to justify over a narrow range.

The extended range of quality assured surface mount capacitors now available from Syfer are expected to appeal particularly to equipment manufacturers in the military, avionics, space and automotive industries.

Syfer is reassuring customers that under the new QC32100 process, there is no change to components previously qualified under the old system, in terms of design, manufacturing, test or inspection processes.

Examples of Syfer parts now, for the first time, offered with IECQ-CECC approval, include the miniature 0603 surface mount capacitors with capacitance ranges from 1.5nF in 16V to 100pF in 250V for C0G dielectrics, and 100nF in 16V to 5.6nF in 250V for X7R. Existing ranges, in 0805 to 2225 footprints, have been extended to cover 16 and 25V dc and 500 and 1kV dc voltage ratings, while maximum capacitance ranges now qualified under IECQ-CECC approval have been extended.

All termination types now offered by Syfer, including tin, tin/lead and Syfer's FlexiCap™, are also IECQ-CECC approved.
www.syfer.com

Appointment of David Gilmour extends Link Microtek's design capabilities

The Engineering Division of Link Microtek, which designs and manufactures a wide range of microwave products, has appointed David Gilmour to the position of microwave design engineer.

As well as generally strengthening the engineering team, Gilmour brings with him particular knowledge and expertise that will extend the division's capabilities into the area of active design – for example, where subsystems require built-in amplifiers, oscillators or mixers.

Gilmour spent the early years of his career with GEC Marconi, initially as a graduate engineer in the Radar Systems Department and subsequently as a development engineer, which involved him in the design of products as diverse as filters, couplers, VHF/UHF PCBs, D/A waveform generation circuitry and low-noise reference sources.

He then moved to Channel Master (formerly Cambridge Industries), where he was responsible for all aspects of the design and testing of a new dual low-noise block for use in home satellite TV systems.

Link Microtek's managing director, Steve Cranstone, was upbeat about the appointment: "David's addition is exciting for the company as it will enable us to tackle more integrated assembly work. We are looking forward to an interesting 2008 in this regard."
www.linkmicrotek.com

Link Microtek launches new website for Engineering Division

Link Microtek has launched a new website dedicated to activities of the company's Engineering Division, which designs and manufactures a comprehensive range of waveguide and coaxial microwave components, assemblies and subsystems.

www.linkmicrotekeng.com

IEEE EMC Soc. UKRI Chapter Events Calendar for 2008

Wednesday 26th March
Location: TBA
Duration: Afternoon meeting, 13:00 - 17:00.
Content: TBA

Wednesday 2nd July
Special Event.
Location: Bletchley Park, National Codes Centre, Milton Keynes.
Meeting Duration: 10:00 - 15:00. After meeting attendees may tour the site.
Content: TBA

Tuesday 14th and Wednesday 15th October
Experiment Demonstration Sessions at EMCUK2008 Newbury Racecourse Conference Centre.
http://www.emcuk.co.uk
Duration: 09:30 to 13:00 both days. Location: prominent side marquee position.
Content: Minimum of four practical experiment and computer solution demonstrations each day, TBA.

Wednesday 3rd December
Annual General Meeting and afternoon technical meeting.
Location: Central London TBA
Duration: Morning AGM 10:30 - 12:00 and afternoon technical meeting 13:30 - 17:00.
Content: TBA.

News and Information

CST Announces Acquisition of Flomerics' EM Business Line

Computer Simulation Technology (CST) announces the acquisition of the Flomerics electromagnetics simulation software business including MicroStripes and FLO/EMC with effect from 1 January 2008.

Through this acquisition, CST will gain complementary EM technology for its customers; of particular interest is the transmission line matrix (TLM) method, as an alternative Time Domain approach. Furthermore, Flomerics' strong position in the emc market and related specialised product features will offer new possibilities to CST's users, also operating in this market.

"Flomerics has decided to focus on maintaining its leadership position in electronics thermal analysis and growing its market share in general-purpose CFD," commented Gary Carter, Chief Executive of Flomerics. "We chose to sell the business to CST to ensure first-class ongoing support and the commitment to providing the best tools in the business for electromagnetics simulation."

All MicroStripes and FLO/EMC customers will continue to receive full technical support from CST GmbH. CST will continue to provide further updates for MicroStripes customers and expects to continue to support and enhance the transfer of geometry from FLOTHERM models to MicroStripes and FLO/EMC. This transaction further increases CST's share in the 3D EM simulation market, and signals the beginning of a strategic relationship between Flomerics and CST GmbH. Customers will benefit from using a combination of world-leading analysis software products from the two companies.

Flomerics and CST will be working together to ensure that Flomerics EM staff will be offered continuous employment by CST GmbH, including those in sales, support, engineering and R&D roles. This also ensures the best possible ongoing support and future migration path for customers.

"The acquisition of the Flomerics EM business line and its TLM technology follows CST's strategy of providing the most complete technological offering for the high frequency EM market," said Dr. Bernhard Wagner, Managing Director, CST. "We will ensure a high level of continuity for all users of the MicroStripes and FLO/EMC products and are looking forward to working closely with all customers."

www.cst.com

TÜV Product Service Shows Commitment to Supply Chains in the 21st Century

TÜV Product Service has recently become a signatory to SC21 (supply chains in the 21st century). SC21 is a programme set up by SBAC (Society of British Aerospace Companies) and is designed to promote and accelerate the competitiveness of the aerospace and defence industry, by raising the performance of its supply chains.

In becoming a signatory, TÜV Product Service has given its commitment to developing supply chains and delivering increased value within the aerospace and defence sector.

This initiative has come at a good time for TÜV Product Service as it enters its third year of integrating LEAN and continuous improvement into our business, which has added significant value to our clients through fast turn round for reports, improved set up and changeover times.

TUV is an ideal partner to contribute effectively to the SC21 Programme as we already have in place many of the practices and performance measured demanded by the SC21 plan. For more information please contact Tel: 01489 558100 or email: info@tuvps.co.uk. **www.tuvps.co.uk**

TTS Group Adopts Ansoft's PCB Design Suite for High-Performance Design

Test Tooling Solutions Group (TTSG), a global manufacturer of ATE test toolings for the semiconductor industry, has adopted Ansoft Corporation's (NASDAQ:ANST) PCB Design Suite, including HFSS™, Nexxim®, Ansoft Designer® and Optimetrics™. TTSG's adoption of the Suite extends the firm's core design competency, strengthens its pool of intellectual property assets and minimizes time-to-market for new products--critical success factors in the fast-moving semiconductor tool market.

TTSG is developing innovative design flows that link process-accurate models of critical, board-level structures with advanced circuit and system simulation. TTSG will use HFSS to model 3D structures such as spring contact probes and then extract frequency-based circuit models for these structures. The extracted sub-circuit models will be inserted into full-channel models, which will then be simulated in the Ansoft Designer/Nexxim circuit simulation environment. Optimetrics will be used to test design changes, visualize trade-offs and identify the optimal design solution prior to fabrication. Distributed Solve will reduce simulation times by running parallel simulations across TTSG's compute farm.

With Ansoft's PCB Design Suite, TTSG designers will be able to accurately predict system-level behaviour prior to device fabrication. With this insight, TTSG Quality engineers are anticipating fewer first-run failures - a step closer to the much-discussed goal of first-pass system success. "Our customers are requesting fast turnaround of highly engineered PCB solutions, and they expect these solutions to work correctly the first time," said S.L. Wee, president and CEO of the Test Tooling Solutions Group. "Our research and testing show that Ansoft offers the best solution to help our customers meet these objectives."

"Ansoft is pleased to announce this partnership with TTSG," said Alex Teo, country manager for Ansoft Singapore. "TTSG's traditional business model has been to build an intellectual property infrastructure around its design and production processes to deliver a value proposition based on quality and timely delivery. Ansoft's PCB Design Suite will support this tradition."

www.tts-grp.com
www.ansoft.com

SMTA supports SMART Group Seminars at Nepcon UK

Nepcon, the complete electronics production line exhibition for the UK and Ireland, is pleased to announce the exclusive participation of SMTA, Surface Mount Technology Association, in the SMART Group seminars at the 40th Anniversary event 29th April - 1st May 2008.

SMTA will bring a wealth of expertise and technical content to Nepcon, as they work with the SMART Group to create topical and relevant presentations tackling today's manufacturing challenges.

The SMTA is an international network of highly respected professionals, who develop skills and solutions in electronics assembly technologies and share practical experience with the industry in areas such as microsystems, emerging technologies and related business operations. "The SMTA has been developing solutions in electronics assembly for over 20 years," said Exhibition Director, Liz Finlay. "We are extremely pleased that they will be a part of the 2008 event and their contribution will be a valuable element of our comprehensive seminar programme."

Call the Nepcon team on +44 (0)20 8910 7979. **www.nepcon.co.uk.**

435 Cellphone interferes with ECG

Trigano et al, in [5] report an electrocardiogram recorded during 1800 MHz cellular phone ringing with high amplitude and high-frequency artefacts that appears 3 seconds before the first ringing tone and that persisted until end of ringing. As consequence of these facts many hospitals have prohibited the use of cellular phones in some areas.

[5] Alexandre Trigano, Olivier Blandeau, Christian Dale, Man-Faï Wong and Joe Wiart "Risk of cellular phone interference with an implantable loop recorder" International Journal of Cardiology, In Press.
(Taken from "Medical Equipment Immunity Assessment by Time Domain Analysis", *Mireya Fernández-Chimeno, Miguel Ángel García-González and Ferran Silva, 2007 IEEE International Symposium on Electromagnetic Compatibility, 8-13 July 2007, Honolulu, Hawaii, ISBN: 1-4244-1350-8, IEEE EMC Society: http://www.ewh.ieee.org/soc/emcs)*

436 Safety while swimming in a sea of electromagnetic energy

In this issue of Mayo Clinic Proceedings, 3 articles bring the issue of exposure to electrical transmissions and patient safety to the forefront. Tri et al1 report on their investigation of possible cell telephone interference with medical equipment in a hospital setting. Gimbel and Cox2 provide a report of 2 patients with implantable cardioverter defibrillators (ICD) who had adverse interactions with electromagnetic scanning devices in their community. Finally, Austin et al3 report on a person whose consumer electronic device interfered with an electrocardiogram (ECG) and led to an initial misdiagnosis of atrial flutter.

The current investigation by Tri et al1 is a follow-up to their previous 2005 in vitro report.4 In their earlier research, the authors discovered that cell phones produced interference in 44% of the tested devices, although the incidence of clinically important interference was only 1.2%. Older analog cell telephones that emit a relatively high-energy signal produced the most interference. Cell telephones had to be placed fairly close to the tested device (ie, <33 in) to produce any interference. Cell telephones were less likely to cause interference in newer medical technology. The authors concluded in 2005 that technologic advances had improved the resistance of medical devices to interference from cell telephones, but that the type and number of electronic designs were anticipated to steadily change, necessitating ongoing testing.

Tri et al heeded their own advice and tested newer technology, using a study design more relevant to daily patient care. Specifically, in the current 2007 report, they investigated cell telephone and wireless handheld device (Blackberry, Research In Motion, Waterloo, Ontario) interference of medical equipment while

Banana Skins

the equipment was being used on hospitalized patients, including those in intensive care units. The tested medical equipment was both diagnostic and therapeutic (e.g. physiologic monitors, infusion pumps, mechanical ventilators). The authors performed 300 tests of cell telephone interference and 40 tests of wireless handheld device interference. They found no interference with any of the tested medical technology. The authors concluded that institutions should consider revising hospital policies that restrict cell telephones.

In contrast, Gimbel and Cox reported on 2 patients having ICD devices that were triggered by electronic article surveillance (EAS) systems (ie, electronic devices placed at store exits to detect stolen merchandise). In both cases, the patient had relatively close contact with an EAS device at a retail store exit. In one case, when the patient collapsed after being shocked, an employee propped the patient against the EAS pedestal, thereby triggering further shocks. In both cases, the patients had ICDs from the same manufacturer. Austin et al reported on a similar but less dramatic electrical interference event. A healthy volunteer had an ECG recorded as part of an extra-hospital drug study. The ECG was read as atrial flutter with an atrial rate of 333/min. It was discovered that the volunteer had a portable compact disk (CD) player (Walkman, Sony Corp, Tokyo, Japan) close to the right-arm lead of the ECG. When the CD player was turned off, the ECG recording returned to normal sinus rhythm (also see Banana Skin number 422 – Editor).
(*Extracts from:* "Safety while Swimming in a Sea of Energy", *Editorial, Mayo Clinic Proceedings, March 2007, Volume 82, Number 3, pages 276-277, www.mayoclinicproceddings.com.)*

437 Financial costs of delayed EMC compliance

A manufacturer of electrical test equipment took an order worth several million dollars for new product to be used worldwide to help service the vehicles manufactured by a major multinational. It failed to meet the EMC standards required for compliance (which had also been made a part of the contract).

Testing and consultancy to discover the causes and find do-able fixes for the EMC problems (several low-cost options not being possible due to the late stage of the project) cost around $20,000; iterating the PCBs to a compliant build standard cost around $60,000; and refurbishing non-compliant units already supplied to the customer cost around a further $70,000.

The delivery of the (eventually) EMC-compliant units was also delayed by five months from the target date, causing equivalent delays in receiving the first payments and incurring greater costs of financing the project (by putting the financial break-even point back around half a year on what was intended to be an 18 month project). Whether any harm has been done to the test equipment manufacturer's reputation with their customer, or with the marketplace as a whole, remains to be seen.
(A contribution in June 1999, the source wishes to remain anonymous.)

438 Pump at ski resort causes interference

In 1996, a ski resort near Silverthorne, Colo, installed a pumping system to lift water up to a river, whose water flows into a lake at the base of the resort and is then used on the mountain for snowmaking. At that time, the pumping system consisted of a 350-hp, 480VAC, 3-phase, SCR, variable-frequency drive (VFD), which was located at the base village. Because the pump and motor were positioned 900 feet below the river and VFD, the resort used 4,1560V as the distribution voltage from the VFD to the motor and pump. The power source for the pumping system was, and still is, a 1000kVA transformer fed by a 25kV, 3-phase overhead power line located five miles from the ski resort. This line also runs beyond the pumping system and serves a local community.

This pumping system worked well for several years with only the 350-hp pump, but as the ski resort expanded its snowmaking system, more water was needed. As a result, a 750-hp VFD, pump, motor and new pipe to the river were installed in 2002. At this point some real operational problems surfaced.

During the 2002-03 ski season, the resort could not run the 750-hp VFD at full capacity by itself, let alone together with the 350-hp VFD running at full capacity. The drives would drop off-line because of their under-voltage protection. Another concern was that homeowners and businesses in the area and nearby community complained of flickering lights.
(*Extracted from:* "Solving a Power System Compatibility Problem", *Vaughn DeCrausaz, EC&M, June 1st 2006, http://ecmweb.com/powerquality/electric_solving_power_system/index.html. The rest of the article describes how the problem was solved with careful measurement and the application of reactive power factor correction to achieve a unity power factor for the VFD systems.)*

439 Electric 'bum' hazards

I've been reading up on various standards relating to test equipment safety and stumbled across BS EN 50110-1 1996 section 3.1.6 Injury (electrical) which cites "electric bum" as a potential hazard! I zoomed in and re-read it several times, it's definitely B U M and not B U R N.

'Electric bum' sounds quite painful, I'm definitely taking all the necessary precautions to avoid that one!
(Sent in by James Toddington of BAE Systems Electronics & Integrated Solutions, Rochester, 9th May 2007.)

440 Switching of power-factor correction capacitor interferes with contactor

A case study illustrates negative impulses of 366V followed by positive impulses of 420V at the terminals of a LV load when a power factor correction capacitor was switched on within an adjacent installation. These transients caused a contactor within a switch panel to fail to latch correctly.
(From subclause 9.2 of IEC/TR 61000-2-14:2006,"Environment – Overvoltages on public electricity distribution networks"*, Clause 9: "Case Studies", www.iec.ch)*

441 Interference from insulation breakdown caused by vibration

This case study shows how high levels of vibration in a three-phase induction motor could cause insulation breakdowns causing momentary earth-faults on one phase. The resulting short voltage peaks on the mains distribution networks caused frequent misoperation of electronic regulators.
(From subclause 9.3 of IEC/TR 61000-2-14:2006,"Environment – Overvoltages on public electricity distribution networks", *Clause 9: "Case Studies", www.iec.ch)*

442 Switching MV power factor correction trips LV circuit breaker

This case study concerns frequent operation on a circuit breaker protecting a PVC moulding plant, causing lost production. It was found that the cause was the switching of a 120kV power factor correction capacitor in the upstream substation.
(*From subclause 9.4 of IEC/TR 61000-2-14:2006,*"Environment – Overvoltages on public electricity distribution networks", *Clause 9: "Case Studies", www.iec.ch)*

443 Wireless interference problems in the home

Take a look at any Sunday newspaper's advertising section for stores that sell electronics, and it is clear that wireless devices are everywhere. Visit these stores and listen to the salespeople selling wireless local-area-networks (WLANs), cordless phones, and all else wireless to often-naïve consumers.

What salespeople fail to tell consumers is that before consumers buy the latest wireless gadget, they should make sure that it will function properly in their home environment. For an unknowing consumer, it can be frustrating to buy a microwave, a 2.4GHz cordless phone, a 2.45GHz video transfer system, and a 2.4GHz WLAN, and then find that only some work error-free once installed in the home.

Manufacturers often take the view that as long as their products are certified, interference it the other guy's problem. What most manufacturers fail to acknowledge is that the consumer ultimately ends up with the problem. Unfortunately, consumers don't necessarily know why it doesn't work, just that it doesn't. These devices often end up as returns or consumer complaints.
(*Extracted from:* "Residential Spectrum Management: The Manufacturer's Role", *David A Case, Compliance Engineering 2005 Annual Reference Guide, pages 106-107, www.ce-mag.com.)*

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 to the Editor together with the source of the information: editor@nutwood.eu.com

Although we have used a rather light hearted cartoon in which 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

Exciting times ahead

In the next few years, we shall see the retirement to the Great Archive in the Sky of several very widely-used standards, and their replacement with completely new ones. This is not evolution, it's revolution, and revolutions often end in tears before bedtime. So it's in the interest of *everyone* in the compliance world to look at what is being proposed and make their views known *before* the standards are published – it's substantially too late then to complain.

The standards in question concern EMC and safety and will replace the current standards indicated:

New standard	concerns	To replace	BSI DPC number
IEC/EN 62368	safety	IEC/EN 60065 IEC/EN 60950-1	07/30091745/DC
CISPR 32/EN 55032	EMC emissions	CISPR 13/EN 55013 CISPR 22/EN55022	06/30148335/DC
CISPR 35/EN 55035	EMC immunity	CISPR 20/EN55020 CISPR24/EN 55024	07/30165158/DC

You can buy the DPCs (Drafts for Public Comment) from BSI Shop, but those for the CISPR standards are not the latest drafts. A second DPC issue will take place for CISPR 32 later in this year, and it is quite likely that the same thing will happen for CISPR 35 as well. However, you can also obtain the latest committee drafts, which are for restricted circulation, through your Trade Association or from a member of the relevant BSI committee, if you promise to submit comments. In case of difficulty, you can contact me through Nutwood.

The reason for all these changes is that it is becoming difficult, if not impossible, to distinguish home entertainment products from ICT products, so different standards should not apply.

The major changes in the EMC standards concern the special methods of measurement developed over many years for CISPR 13 and CISPR 20, by the radio and television industry sector, which were not adopted into CISPR 16. But the number of amendments made to CISPR 22 and CISPR 24 has caused their structures to become less than optimum, so the new standards started from 'blank sheets'.

Furthermore, CISPR 35 takes a 'function-based' approach, because of the diversity of functions that any one product type may include. Unfortunately, this is not as easy as it looks; consider an 'audio' function, for example. Is this the audio function of a personal music player or the audio function of a professional audio workstation? Clearly, there are likely to be differences in the details of the measurement procedures, and differences (probably very large) in the immunity levels *expected by the users*. Those three words are important, because they embody what the EMC Directive expects, in terms of the product operating *satisfactorily* in its intended EMC environment.

In contrast, it might be expected that the emission limits and methods of measurement are well-established, so that the development of CISPR 32 should have been relatively easy and quick. But 'the best laid schemes' often succumb to the all-pervading Law of Murphy; it has taken more than five years so far, and the development is not nearly finished.

Experience with existing EMC standards is that many hidden snags or doubts appear for some considerable time after a new standard comes into effect; witness the continuous on-going work on amendments and interpretations. So the sooner people begin to try to use these new standards in the real world, the better.

The new safety standard is even more of a revolution. The existing standards originated a very long time ago – the origins of IEC 60065 can be traced back, in part, to British Standard BS415:1931, and IEC 60950 to IEC 380 about 40 years ago. There has been criticism that the requirements are arbitrary, or at least that any original rationale has long been lost. So, it was decided to base the new standard on a new principle, the 'hazard-based approach', and to ensure that all rationales for the requirements are preserved. It remains to be seen whether that will happen.

The approach is to first identify all the hazards that a product might present to a user, and to maintenance and repair technicians. Since the standard includes office machines in its scope, those hazards include chemical hazards from liquid and solid consumables.

The second step is to require one or more 'safeguards' between the source of the hazard and any person exposed to it. Just one safeguard may not be sufficiently robust or reliable (similar to the concept of 'basic insulation') alone, so that two (like basic and supplementary insulation) or one of superior performance (like reinforced insulation) may be demanded.

The principle can be seen as entirely logical and should produce requirements that everyone can understand and respect. Unfortunately, the execution has attracted very considerable criticism, on several grounds. Because a new principle is involved, new terminology is required, which caused disquiet among some other IEC committees, now largely resolved. But YOU will need to become familiar with these new terms. Early drafts included rationales within the normative texts, which made the documents (the whole thing was divided into five 'fragments') very long indeed, and the rationales themselves were not received without controversy.

The latest draft (this is a first voting stage draft – a CDV – so that this could very well be the last opportunity for technical criticism) has much less non-normative material, but already there has been considerable technical comment. It also has over 300 pages and uses colour printing, so it will be, if this form is retained, extremely costly.

This project is obviously a very large one, and a team of about 70 people has been involved. It has to be said that, for many, this was a first, or an early, experience of standards writing, especially in an IEC, as opposed to national, context. As a result, there are unexpected features in the text, (such as cartoons, which seem quite incongruous in such a serious document!).

It really is essential that BSI receives as much informed comment on these very important standards as soon as possible, and from as much of the UK compliance community as possible. Please DON'T imagine that others will take care of your interests; they will be too busy looking after their own!

If you have difficulty in obtaining the drafts, or you are not sure how to submit comments (they must be on the latest version of IEC FormComments, which includes a column for line numbers), please contact me by e-mail through Nutwood.

J. M. Woodgate B.Sc.(Eng.), C.Eng. MIET MIEEE FAES FInstSCE
Email:desk@nutwood.eu.com
Web: www.jmwa.demon.co.uk

CEM 2008

CEM 2008 is organised by the Institution of Engineering and Technology Electromagnetics Professional Network, Antennas and Propagation Professional Networks, EMC Professional Network and in association with the International Compumag Society.

This conference will focus on current research into the various computational techniques now available for solving problems in electromagnetics, aspects and applications of numerical modelling based on these techniques.

The conference will provide delegates with a forum to present, discuss and network. Sessions will include oral papers to provide an introduction to the topics presented followed by interactive posters with plenty of opportunity for informal discussions.

Scope

- Methods and Techniques of Computational Electromagnetics
- Numerical Methods
- Applications of CEM (where the novelty should reside in the CEM technique and not the application)
- CEM in Education
- Code Validation

Fees

Registration fees include attendance at all sessions for the duration of the conference, a copy of the proceedings, morning & afternoon refreshments & lunch each day, evening reception, **Monday, 7 April 2008** & conference dinner on **Wednesday, 9 April 2008**.

Registration Fees

Member:	£395.00 (+ £69.13 VAT= £464.13)
Non Member:	£540.00 (+ £94.50 VAT= £634.50)
Author:	£310.00 (+ £54.25 VAT= £364.25)

For further information see Ad on IBC or contact:
Tel: + 44 (0) 1438 765648 or E-mail: eventsa2@theiet.org
http://conferences.theiet.org/cem

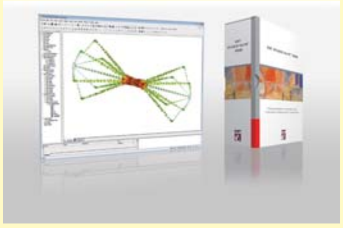
PRODUCT GALLERY

CST STUDIO SUITE™ 2008 Now Shipping

CST - Computer Simulation Technology has announced its new product release CST STUDIO SUITE™ version 2008 is now shipping. CST STUDIO SUITE™ offers RF & microwave, SI and EMC engineers considerable product to market advantages such as shorter development cycles, virtual prototyping before physical trials, and optimization instead of experimentation. Version 2008 promises users significant enhancements, particularly in the critical areas of workflow integration and performance.

Major improvements include:

- New interfaces to streamline the design workflow;
- Performance optimization - through hardware acceleration, improved parallelization of transient and frequency domain solvers, and ongoing code optimization projects with Intel;
- Transient far-fields - especially important for engineers working on UWB antennas;
- Integral Equation Solver for electrically large structures - of particular interest to engineers working on RCS or antenna placement;
- Numerous time saving additions and features.



"CST STUDIO SUITE™ 2008 continues CST's tradition of innovation in electromagnetics. Our R&D team has been working with fellow technology leaders to develop new workflow integration tech-niques and optimise simulation performance," said Martin Timm, Marketing Director, CST. "We are confident that Microwave, RF, SI and EMC engineers will not only appreciate the numerous enhancements in this new release, but also the easy access to an increasing number of best-in-class tools."

Workflow Integration

CST has invested heavily in new workflow integration technologies. Two new interfaces are being introduced to streamline design workflow, particularly for engineers involved in Signal Integrity. The first of these is a new native interface to Mentor Graphics Expedition™, which uses COM/ DCOM to exchange data of entire layouts, areas or nets. The second, an ODB++ interface, enables the access to layouts from a large variety of tools such as Mentor Graphics Board Station®, and Zuken CR5000. To round the interoperability improvements off, users of CST MICROWAVE STUDIO® (CST MWS) can now utilize current distributions from Sigrity® or SimLab as field sources, and export HSPICE models.

Performance Optimization

Performance optimization has been a key concern for this release. User will benefit from the improved parallelization of transient and frequency domain solvers, and ongoing code optimization projects with Intel ensure that the latest and upcoming generation of processors and technologies are exploited to the full. Furthermore, dedicated hardware acceleration boards are now available for the transient solver. The direct frequency domain solver on tetrahedral grids has also been focused on, and has experienced vast improvements in memory usage and speed.

Usability

Time saving additions and features will be particularly welcomed and include: project management facilities, structural parts' availability via copy/paste or sub-model imports, and automatic software updates.

Integral Equation Solver

Engineers working on RCS or antenna placement may want to try CST MWS' Integral Equation Solver for electrically large structures. New functionality enables the excitation of fields through waveguide ports or via preloaded farfields, e.g. from transient simulations. Models can now also include lossy metals (skin effect) or impedance sheets.

CST DESIGN STUDIO™

Using CST DESIGN STUDIO™ 2008 (CST DS), layouts can be created from schematic blocks, for use directly in CST MWS. With Signal Integrity engineers in mind, IBIS and Berkeley spice models can now be included in CST DS simulations.

Charged Particle Dynamics

Last but not least, another premiere for those involved in the design of electron guns, travelling wave tubes etc. A new particle-in-cell (PIC) solver is available with CST PARTICLE STUDIO™ 2008 (CST PS). This is capable of the fully consistent simulation of charged particle dynamics in the presence of external and space charge fields.

Availability

CST STUDIO SUITE 2008 is now available. Please cont™ act CST or your local distributor for more information and to test the software.

Tel: +49 6151 7303-0
info@cst.com
www.cst.com

Lightweight, Cost-effective EMI Shielding Plastic for Fuel-conscious Aerospace Applications

Chomerics has developed a lightweight, electrically conductive plastic for EMI shielding of high temperature avionics. PREMIER™ PEI-140 maintains high temperature tolerance, chemical resistance and UL 94V-0 flammability rating for a cost-effective electronics shielding solution up to 85dB in aerospace applications. PEI-140 complies with avionics smoke density requirements in the event of an on-board fire.

PolyEtherImide (PEI) was chosen for the base resin of avionics grade PREMIER for its outstanding elevated thermal resistance, exceptionally high-strength mechanical properties, flame resistance and extremely low smoke generation. PEI-140 is an amorphous thermoplastic re-inforced with matrix of proprietary conductive fillers to provide EMI shielding. PEI-140 is engineered to optimize stable electrical, mechanical and physical performance for EMI shielding in continuous use at temperatures up to 340°F (170°C). PEI-140 is also appropriate for high performance applications in other industries such as defence, medical electronics and transportation, where properties of light weight, strength, flame resistance and EMI shielding add value.

PREMIER PEI-140 provides the only commercially available thermoplastic system with a homogenous dispersion of the fibre throughout the moulded part, regardless of part geometry.

This proven filler morphology,

formulated for consistent shielding up to 85dB over a wide range of frequencies, combined with proprietary dispersion agent, provides excellent conductivity and consistent shielding throughout the part. PEI-140 complies with RoHs, WEEE, EPA, EU and TCO specifications for ecological compatibility, and contains no halogenated compounds. Used material may be recycled using standard industry practices.

According to Chomerics global product line manager John Perkins, "PREMIER™ PEI-140 is designed to meet the requirements demanded by the avionics industry. By using PEI-140, avionics systems suppliers can offer their customers weight reductions to help drive fuel efficiency and closer tolerance mechanical parts to facilitate tighter fit, improved sealing and excellent EMI shielding performance.

Tel: +44 90)1628 404000
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www.chomerics.com

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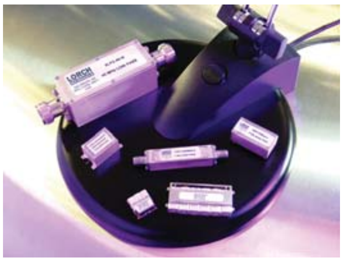
Low Cost, No Compromise Ceramic Filters



Just available in the UK, exclusively from **Aspen Electronics**, is a comprehensive range of highly cost-effective ceramic filters designed for use in telecommunications and test equipment applications. The devices are manufactured by Lorch Commercial & Wireless (LCW), a division of the US-based, Lorch Microwave, a renowned vendor of high quality RF and Microwave products for 40 years.

"This LCW range of ceramic filters is highly cost-effective in production volumes, but makes no compromise in terms of build quality and specification," confirmed Howard Venning, Managing Director of Aspen Electronics. "Specialising in supplying the needs of the industrial and commercial marketplace, LCW offers a fast turnaround on prototypes, and rapid follow through on high volume production deliveries," he added.

The LCW ceramic filters are available to cover the frequency band from 40MHz to 5GHz, making them particularly suitable for high volume applications such as cellular infrastructure equipment and wireless LANs. They will also appeal to manufacturers of wireless base stations and high speed telecoms systems, and will be useful in test equipment and systems components such as synthesisers.

There are two principal design styles, array and monoblock. Both designs offer very small sized cavity filters that can be surface mounted. The filters are fitted with High Q ceramic resonators ranging in size from 3mm to 6mm square. Various size combinations are offered featuring from 2 to 6 poles. Typical VSWR is 1 to 5:1, while power handling is quoted at 1W. Operating temperature range is an extended -40 to 85°C.

The devices are designed for PCB mounting, being considerably smaller than conventional cavity designs. Yet the filters offer similar insertion loss and rejection characteristics as traditional components.

Pricing is highly competitive, ranging from £10 to £80, depending on the specification and volume ordered. Sample filters can be available within two weeks at Aspen, and volume orders are on 4 to 8 week delivery. Manufactured in the US and the Far East, the filters are fully RoHS compliant.

Tel: +44 (0)20 8868 1311
sales@aspen-electronics.com
www.aspen-electronics.com

New Wallplug Filter for PLC applications

Spanish company **Premo** EMC Filters has announced its wallplug filter for high frequency PLC applications (30 MHz).

The device presents a compact and light design and incorporates a single phase filter specially designed to minimize the differential noise effect that domestic appliances may inject into the mains disturbing them either as voice and video, and information communication (triple play).

The Wallplug PLC Filter is specially designed for IPTV's distribution domestic systems (like the Spanish Imagenio of Telefonica or France's Maligne TV Telecom) across DSL's adapter to PLC.

It supports up to 10 Amp and work voltages up to 250 Vac. It has internal fuse protection.

Premo designs and manufactures accessories and components for PLC applications in Access and In-Home scenarios. Its wide range of products for this technology includes both accessories and components, providing customers most components needed for deployments over this technology.

Tel: +34 951 231 320
www.grupopremo.com

New 3D Interactive Design Tool

Laird Technologies, a global leader of critical components and systems for advanced electronics and wireless products, announced the launch of its new Virtual Design Tool for Fabric-over-Foam EMI shielding gasket products. The new web-based tool offers customers an interactive online catalogue that allows users to easily configure, view and seamlessly download 2D drawings and 3D models directly into their designs in all conventional CAD formats.

Laird Technologies' Virtual Design Tool is ideal for design engineers as users can configure Fabric-over-Foam EMI shielding gaskets using the tool's drop-down menus and then immediately download a CAD file. The tool ties directly into the company's EMI Essentials catalogue, so users have access to many of the standard Fabric-over-Foam EMI shielding gaskets listed. The tool also allows customers the capability to request a quote for any Fabric-over-Foam EMI shielding gasket that is configured and downloaded.

"One of the great things about this web-based tool is that it eliminates the time-consuming process of searching through a paper catalogue for the correct part number and then modelling the identified part from scratch," said Sean Honer, Fabric-over-Foam product manager. "The tool streamlines a process that used to take one to two hours down to a few minutes, allowing the design engineer and customer to complete their designs faster."

Customers worldwide have access to the online tool and can configure the parts in either metric or English measurements. The tool is available now by accessing:- www.lairdtech.com.

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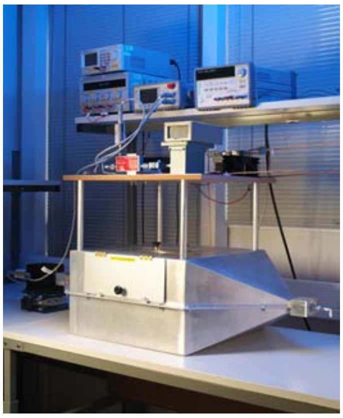
New TEM cells are ideal for calibrating field strength meters



The Engineering Division of **Link Microtek** has expanded its line-up of TEM cells with a range of models specifically designed for the testing or calibration of field strength meters, monitors or probes.

Suitable for incorporating within an ATE system, the TEM cells feature an equipment support tray positioned at the correct height for measurement, a side access screened door to enable equipment to be placed inside the unit, and top and side ports to allow access for cables.

The TEM cells can be specified with overall lengths from 600mm to 2400mm, and they are available with maximum frequencies from 100MHz to 500MHz. The dimensions of the main section and tapered ends are selected to provide a 50-ohm characteristic impedance along the whole length of the cell, thereby creating a uniform electromagnetic field of known pattern and intensity.

Equipped with female N-type connectors as standard, the TEM cells are manufactured from aluminium, with an optional alochrome and epoxy paint finish.

In addition to its range of standard TEM cells, Link's Engineering Division offers a custom design and manufacturing service to enable it to accommodate customers' special requirements.

For further information, visit the Engineering Division website at www.linkmicrotekeng.com.

Tel: +44 (0)1256 355771
sales@linkmicrotek.com
www.linkmicrotekeng.com

Robust subracks can handle extreme shock and vibration

Now available from **Schroff** is a range of 19in. subracks that can withstand the most rigorous and demanding environmental conditions, particularly where equipment is subjected to extreme levels of shock and vibration.

Featuring a robust aluminium construction, the europacPRO subracks are designed to provide high mechanical stability to protect electronic systems in mobile applications, e.g. when mounted in trains.

To verify their durability and stability under shock and vibration, the subracks have been thoroughly tested by an independent test house in accordance with a number of industry standards, including IEC 61587-1, EN 50155, SNCF standards NF-F 67-012/60-002 and Deutsche Bundesbahn standard BN 411002.

These RoHS-compliant subracks are available unshielded or with EMC cover plates and contact strips to provide typical shielding levels of 40dB at 1GHz and 30dB at 2GHz.

The subracks are 84HP wide and can be specified with heights of 3U or 6U and depths of 235 or 320mm.

A comprehensive range of accessories is also available, including card guides, front panels and plug-in units.

Tel: +44 (0)1442 218726
schroff-sales@schroff.co.uk
www.schroff.co.uk

Special Jigs delivered in 7 days

Richard Marshall Limited has recently shipped a set of custom-made test jigs to a well-known EMC test house ***just seven days after receiving the order.***

The jigs were for testing the common-mode immunity of balanced signal ports of professional audio equipment according to EN55103-1. They comprised a Test Interface as defined by figure B1 of the Standard together with the necessary close-tolerance calibration jig.

The principal obstacle to speedy delivery of these items was the procurement of components. A 480pF variable capacitor is not a common item these days!

Richard Marshall is currently involved in the development of other test jigs for future updates to Standards.

Enquiries for specials are always welcome.

Tel: +44 (0)1582 460815
richard.marshall@iee.org
www.design-emc.co.uk

350-Watt, 10Hz - 1MHz Magnetic Immunity Amplifier

AR RF/Microwave Instrumentation has unveiled a new magnetic immunity amplifier for susceptibility testing. Model 350AH1 (350 watts, 10 Hz – 1 MHz) is powered by a high efficiency switching supply with auto-ranging AC input circuitry that automatically accepts voltages from 90 to 260 VAC in the 47 – 63 Hz frequency range.

The new amplifier, which has a very low output impedance, will be used primarily for susceptibility testing for magnetic and audio frequency tests in MIL-STD-461D/E, D0160D/E, and a variety of automotive test standards. It can also be used as an AC voltage source, for watt-meter calibration, and as a driver for higher-power amplifiers.

Tel: +1 215-723-8181
www.ar-worldwide.com

QinetiQ carries out Civil and Military EMC Testing at its Chertsey Facility

A midlife update that includes new electronic systems, transmission and engine for a major foam vehicle from the Specialist Utility Vehicles IPT part of the Directorate General Land Equipment has meant that its Electromagnetic Compatibility also needed retesting to the appropriate defence standard (Defence Standard 59-41). This work has just been completed by QinetiQ's Electromagnetic and Environmental Services (EMES) Group in its whole vehicle chamber at Chertsey in Surrey.

"Chertsey is just one of our Electromagnetic Compatibility (EMC) facilities that's becoming increasingly busy in meeting the ever growing civil and military requirement," explained Peter Tanner, MD for QinetiQ's System Evaluation Services. "As part of the overall update to the fire engine it had to be tested and re-qualified to the Defence Standard to ensure it continues to meet operational electromagnetic environment and emission requirements both in UK and for overseas applications."

System susceptibility to external RF and RF emissions testing is critical for all vehicles and sub-systems to ensure they perform as expected at all times and don't themselves cause problems to other users. QinetiQ has been involved in developing procedures to determine the coupling between the external environment and the internal RF stresses on equipment for many years and its test facilities are widely used by both military and civilian customers alike.

QinetiQ's semi-anechoic screened EMC facility at Chertsey is UKAS accredited and equipped with a number of high power amplifiers and sensitive emissions measuring equipment. It measures 16m x 16m x 8m with 5m x 5m double access doors and has both extensive exhaust and heat extraction capabilities. Another unique feature of this facility is its 60 tonne floor loading capacity which means even the heaviest of the MODs current main Challenger II battle tanks can, and have, been accommodated.

A comprehensive range of internal and external UKAS accredited test facilities are available from QinetiQ capable of testing large systems and complete platforms/vehicles as well as small individual components or sub-systems. The facilities include: ten screened EMC test chambers, three of which are advanced capability reverberation chambers; two hybrid lined anechoic chambers; four screened instrumentation/control rooms; two mobile EMC test laboratories that can be taken to a customers' site to carry out the required tests; in addition to the whole vehicle semi-anechoic Chamber at Chertsey. An outdoor Radio Frequency Environment Generator (REG) is also available to test high power radiated susceptibility over a wide 5 MHz to 35 GHz frequency range and can accommodate most things including large civil and transport aircraft.

In addition to the EMC facilities QinetiQ also operates a diverse variety of test and evaluation facilities across various UK sites that deliver strategic capabilities of national importance and cost effectively deliver through life analysis of systems – from concept to disposal – to increase reliability and fitness for purpose. These include: environmental test facilities for whole vehicles/aircraft as well as equipment; various real-time simulators covering all types of vehicle; test and vibration rigs; land, sea and air test and evaluation ranges; a suite of human physiology testing facilities and specialist materials and physical testing capabilities. **www.QinetiQ.com**

Interference emission from TV receivers in theory and practice

By Richard Marshall, Richard Marshall Limited

Abstract

The paper will describe a field study of interference suffered by short-wave listeners from TV receivers. This lead to laboratory measurements and some theoretical modelling of the emission from such products, their aerials, and their mains supplies.

Since the new Multimedia Standard provides an opportunity to review the emission requirements for TV and similar products the work has been undertaken with the co-operation of members of CISPR/I/WG2.

This work is aimed at understanding the cause and route of such interference and has implications for emissions from other cable-dominated situations - including Power-line telecommunications.

1. Introduction

Members of the (Amateur) Radio Society of Great Britain experience significant problems of interference ***from*** TV receivers. These are usually solved by replacing the offending TV - which is then out of reach of technical study. Alternatively the inter-personal relationship between Culprit and Victim becomes too strained to allow technical investigation.

However, in one case last year the TV and Short-wave equipment were in the same ownership – and the TV was just too old to return to the shop.

The problem was a complete wipe-out of short wave reception from 3 to 30MHz when the TV was operating; interference being strongest in the 7MHz band. The installation layout was as shown in ***Figure 1***. The amateur equipment is some 13 met

res from the TV – further than the conceptual "protection

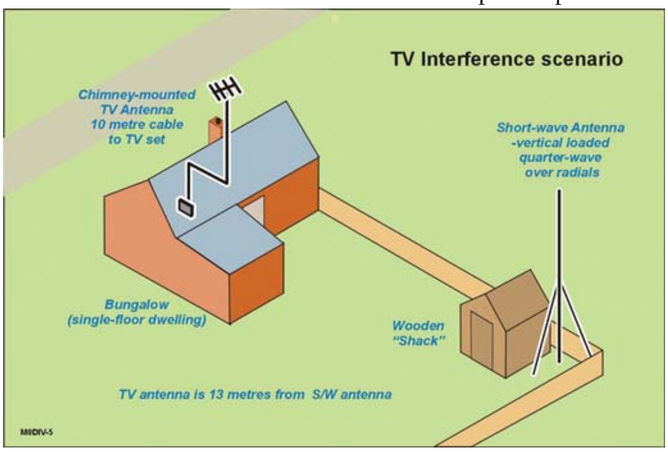


Figure 1 TV Interference scenario

The author had a hunch that the maximum of interference at 7MHz would have some connection with the 10 metre length of the TV antenna cable, since the TV antenna and its coaxial cable might be acting in common-mode as an quarter wave antenna, end-fed above ground, in the mode shown here in ***Figure 2***. A vertical antenna driven relative to a low-impedance ground is a classic design, shown here on the left as a medium – wave transmitting aerial. The current and voltage distribution at resonance is as shown in the middle drawing. The feed is impedance next to the ground plane is about 35 ohms.

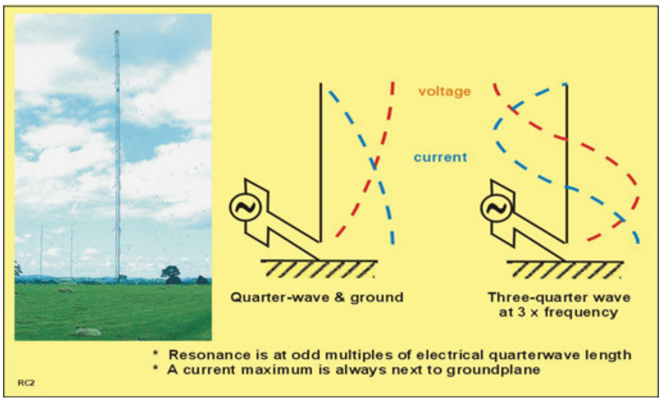


Figure 2 Aerials with one free end

Note the right-hand drawing which shows the resonance at three times the frequency. Later we will find both resonances in a common mode emission current plot for a TV antenna.

2. Measurement method

The work that we could do on-site at our member's bungalow could only use his amateur receiver and simple low cost additional items. Since 7 MHz was to him the worst frequency, and since we wanted quality of data, not quantity, we concentrated on measurements at 7MHz. Our first results are shown in ***Figure 3***.

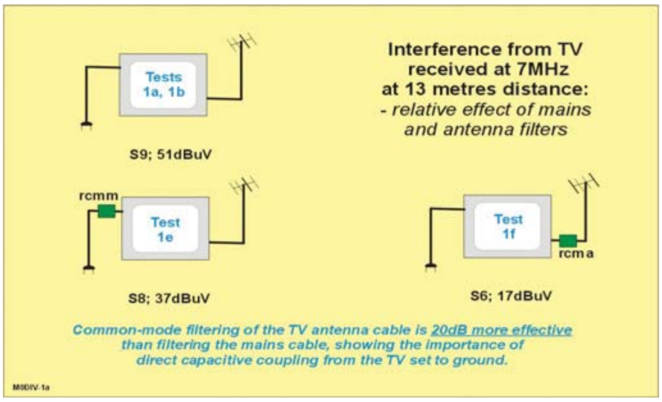


Figure 3 Experiments with just one common-mode filter

The antenna filter "rcma" was a low-capacitance winding on a ferrite toroid. It had an impedance of 3,000 ohms at 7 MHz and behaved as a lossy inductor with a phase angle of 22 degrees. The mains filter rcmm comprised a similar toroid in series with a differential-mode filter, and so had a slightly higher impedance.

The dBuV figures here are translated from the receiver "S" meter readings using published calibration data for that make of receiver: subsequent comparison with a Rhode & Schwarz measuring receiver suggests that they are correct to within 3dB.

We did of course try the filters together, and found the further improvement set out in ***Figure 4***. However, substitution of the antenna filter HPFS whose c/m impedance was a higher value – but capacitive - showed **worse** performance. This really interesting result confirmed that the antenna cable ***was*** operating near resonance, as was expected from the postulated quarter-wave vertical antenna operation mode, and that the reactance of the filter contributed to the tuning – for better or for worse in the inductive/capacitive cases.

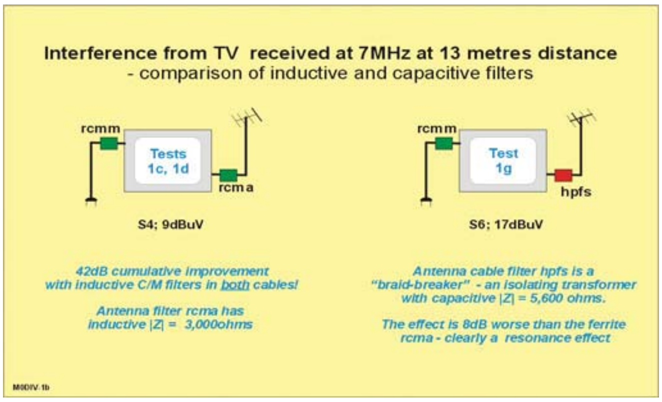


Figure 4 Experiments with two filters

We also made a number of tests to confirm that the coupling route from culprit to victim was not conduction via the mains wiring.

The fact that a filter in series with the antenna has a 20dB greater effect than a similar filter in the mains lead was very clear evidence that the interference current in the antenna cable is greater than that in the mains cable – which invalidates the assumptions underlying the CISPR13 measuring method. This was reported to the TV's makers and to the CIS/I/WG2 Multimedia Emission Standard committee, which resulted in the professional measurements that will now be summarised.

3. TV manufacturer's Investigation

Later, with professional assistance and equipment (R&S receiver and FCC coupling transformer), the in-situ plots of peak common-mode (c/m) current against frequency shown in ***Figure 5*** were made for both the antenna cable and the mains cable.

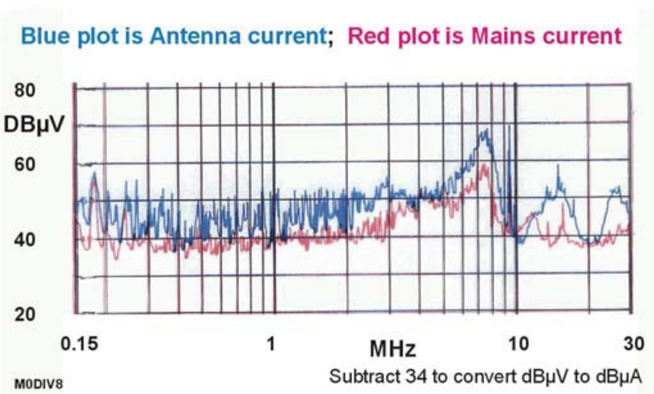


Figure 5 The conducted emission spectra measured at Hayle

First – and most important – note that the antenna current is typically 8dB ***higher*** than the mains current. This confirmed directly what we had already concluded from the results of inserting filter chokes. We return to this topic in sections 4 and 5.

Note also the strong resonance at 7.5MHz, which is still enhancing emission at 7MHz – confirming the initial quarter-wave antenna theory. Furthermore, the three-quarter wave resonance is evident at around 25MHz as would be expected from ***Figure 2***.

The narrow spikes are currents induced from broadcast transmitters – note particularly the concentration in the medium-wave band 0.5 to 1.5 MHz and in the 31metre band short-wave broadcast band at 9MHz.

We found that the 7.5MHz resonance moved to 6 MHz when the ground connection to the TV was supplemented. This confirmed that the resonant frequencies were dependent on the antenna system as well as on the TV itself.

Note the the peak antenna current of 34dBµA at 7.5MHz. Assuming that the TV antenna is acting as a quarter-wave monopole over ground, with 37.5 ohms input impedance and 0dB gain (the theoretical gain is 2dB) it may be calculated from this that the power input to this antenna from the TV is 93 Nanowatts, and hence the field at the "protection distance" of 10 metres is 44.5 dBµV/m.

This is ***above*** the 40 dBµV/m CCIR service area field strength for broadcast transmitters. Since reception of such transmitters requires a signal/noise ratio of 30 to 40dB, the common-mode current launched onto the antenna by the TV is some 35 to 45 dB too high for reception to be of the quality intended.

4. Laboratory Tests

The TV was then moved to an EMC test- house, and subjected to a series of tests starting with the CISPR13 conducted emission test. This requires no test directly on the antenna port, but seeks to infer the antenna current from measurements on the mains lead made with a LISN. These are carried out with the antenna port first isolated and then grounded. The plot when grounded is shown in ***Figure 6***. The equivalent plot with the antenna floating was almost identical at high frequencies and a few dB lower below 10MHz and so is not reproduced here.

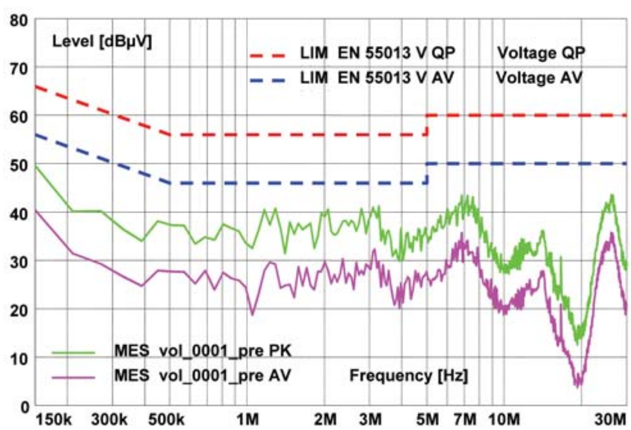


Figure 6 The mains cable noise measured with a Line Impedance Stabilization Network

It may be seen that the TV receiver meets the CISPR13 requirements comfortably – even though it had produced serious interference. One calls to mind here the broad obligation in the EC EMC Directive to "not cause undue interference".

Note the peaks at 7MHz, 14MHz and 28 MHz which were close in frequency to those observed in the on-site test. There does seem to be an unfortunate co-incidence of the TV's inherent 7MHz emission peak with the common-mode resonance of the user's TV antenna installation. The next tests were to compare the common-mode rf currents in the mains and antenna cables under laboratory conditions. To do this a current transformer was first applied to the mains cable, with the antenna cable grounded. This translated the curve of the previous plot to the changed measuring method, and yielded the plot in ***Figure 7***. Note that the general shape is as before: The maximum current peaks are at about 20dBµA.

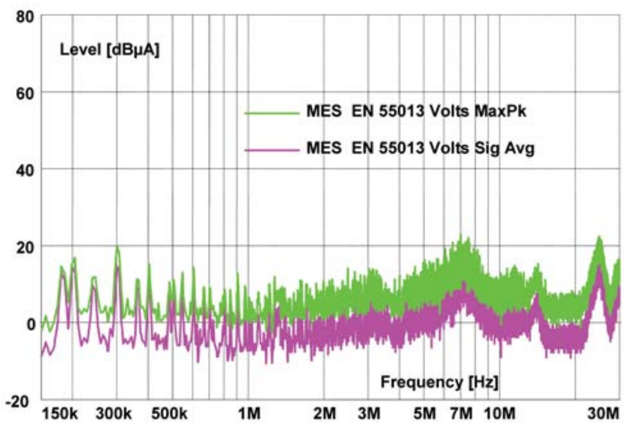


Figure 7 The mains cable noise measured with a current clamp transformer

We compared this with the antenna cable current as shown in ***Figure 8***.

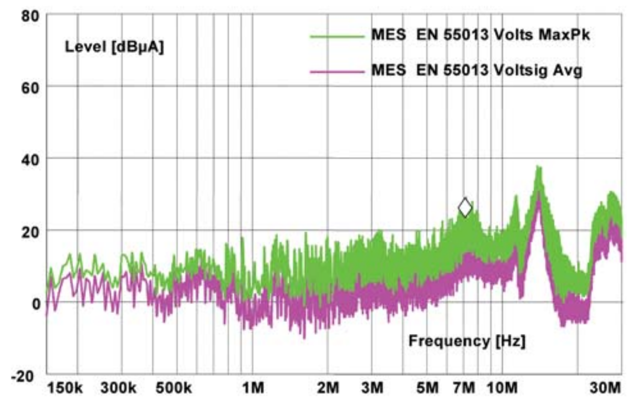


Figure 8 The antenna cable noise measured with a current clamp

From 500KHz to 30MHz this current is *larger* than the mains noise current plotted previously. The increase is about +5db from 500KHz to 5MHz, rising to +10dB at 10MHz and peaking to +20 dB at 14MHz.

This comparison is the third piece of evidence that brings into question the assumption of equal mains and antenna currents that underlies CISPR13. It does justify the concern of those working on the new multimedia standard.

The peaks at 7, 21, and 28 MHz are reminiscent of those observed in the measurements at Hayle, but the magnitudes are rather different. In the laboratory the 7MHz peak is smaller – presumably because the circuit impedance is higher. The 14MHz peak is much larger – at this frequency the TV antenna at Hayle would have been half-wave resonant and exhibited a very high impedance which would reduce the current flow. So we may note that the interference current experienced in practice will vary widely with installation conditions.

It is of great interest to know if the subject TV set would have passed or failed the emission limit that is applied to telecommunications cables in office equipment**.** ***Figure 9*** shows that it would pass – but only just. This issue was of some concern to TV manufacturers, since a natural form of construction is to mount all the external connectors onto a metal plate and there is no natural place to mount a common-mode choke such as was used in the tests on the TV users premises that were described earlier. Accordingly the team found another TV - a larger and more up-to-date 32" LCD model. It was tested to the telecommunications cable limit. ***Figure 10*** shows that it passed with a comfortable margin.

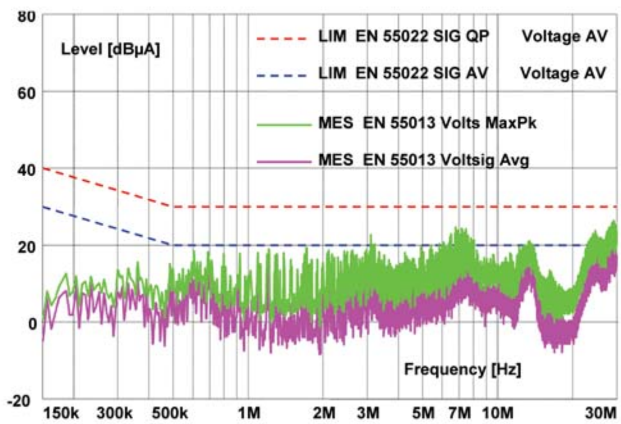


Figure 9 The antenna cable of a 28" CRT TV tested as a data cable

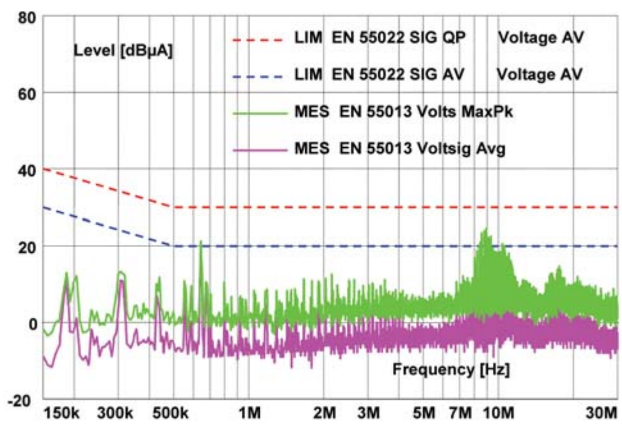


Figure 10 The antenna cable of a 32" LCD TV tested as a data cable

The author would not recommend common-mode chokes as cures for problems of this sort in mass-production items, even though they are often the only option for an external fix. Today's TVs and future Multimedia equipment have increasing numbers of ports interfacing to telecommunications and audio cables all of which require similar treatment, and which cannot economically use common-mode chokes. The theoretical considerations that follow suggest that minimal additional shielding of EUT components carrying high rf voltages will provide a much cheaper improvement for all ports.

5. Theoretical Analysis of conducted emission from a generic product

For the EMC analysis of products with cables it is accepted for international standards that conducted emission and immunity is the prime concern at *low* radio frequencies, and radiated effects predominate at *high* frequencies. The cross-over point is conceptually based on EUT size, and is generally set at 30MHz. This choice of frequency is almost certainly too high for a large-screen TV whose screen diagonal may be more than a tenth of a wavelength at 30MHz.

Cable emission is the result of common-mode current flow and so it is necessary to understand the sources and relative magnitudes of this c-m current flow in the various cables connected to multimedia equipment. Consider the common-mode equivalent circuit of an EUT shown in ***Figure 11.*** The EUT is symbolised as a TV receiver but the analysis would equally applicable to other products. For simplicity we consider a receiver with a mains supply cable and an antenna cable but no additional cables such as SCART. Additional cables are an important complication that is considered in a later section.

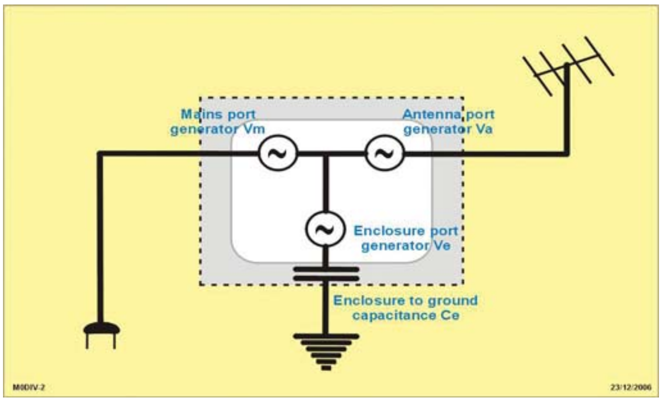
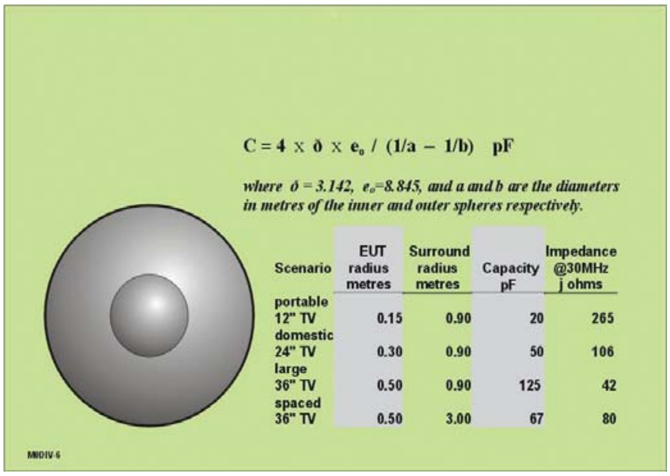


Figure 11 A basic multimedia equivalent circuit.

The EUT is visualised as having three ports as shown here. Each has the possibility in principle of having an associated emission source.

The method of measurement in CISPR13 is based on the assumption that the enclosure port capacitance Ce is sufficiently small to render the current to ground negligible, so that the c/m current in the mains lead is identical to that in the antenna cable. The measurements reported earlier have shown that this is clearly not correct in the case of a 28" CRT-type TV receiver. Therefore we next scope the value of Ce.

In ***Figure 12*** we use the formula for the capacitance between two concentric spheres which may be derived from Gauss's Law. From the Table it may then be seen that the capacitance is approximately proportional to the EUT size, and not too sensitive to the proximity of its surroundings. Whilst the earthed surroundings of a real EUT do not form a concentric sphere this approximation leads to a relatively small error as may be seen from a comparison between the last two lines of the chart



$$C = 4 \times \eth \times e_0 \,/\, (1/a - 1/b) \quad \text{pF}$$

where $\eth = 3.142$, $e_0 = 8.845$, and a and b are the diameters in metres of the inner and outer spheres respectively.

Scenario	EUT radius metres	Surround radius metres	Capacity pF	Impedance @30MHz j ohms
portable 12" TV	0.15	0.90	20	265
domestic 24" TV	0.30	0.90	50	106
large 36" TV	0.50	0.90	125	42
spaced 36" TV	0.50	3.00	67	80

Figure 12 An estimation of enclosure port capacitance

The reactive impedance figures in the right-hand column, by comparison with the typical c-m cable impedance of 150 ohms [as standardised, for example, in IEC61000-4-6], show that the enclosure port exhibits an impedance to ground *which should not be neglected in any of the tabled scenarios*. Of course, since the enclosure port is capacitive, its impedance is inversely proportional to frequency and so in most cases below 1MHz it will be too large to provide an important route for interference current.

For an independent corroboration of these impedance estimates, see ***Figure 13***. This $\mathbf{S_{11}}$ graph is of the impedance to nearby objects of the antenna port in common-mode of the author's 28" CRT type TV with all cables disconnected.

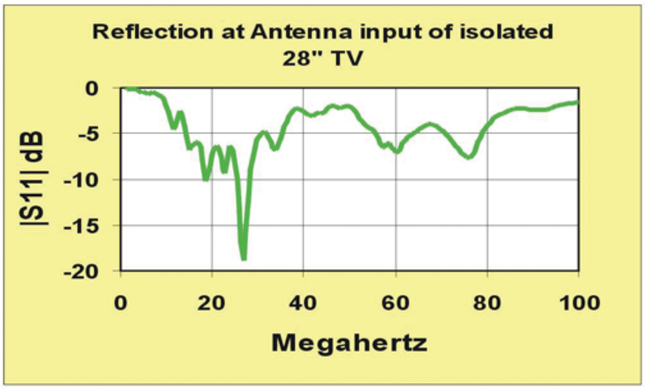


Figure 13 Reflection at the Antenna port of an isolated 28" CRT TV

It confirms again that the Ce impedance is of the order of 50 ohms above 3MHz. The near-perfect 50 ohm match at 26.8 MHz is due to resonance of the TV enclosure capacitance with the inductance of the ground connection of the Vector Network Analyser. The enclosure port certainly has a more serious effect for larger EUTs such as large-screen TVs that have become more commonplace in the last 15 years.

6. Sources of emission driving TV ports

It is now necessary to consider if it is possible for the three common-mode voltage generators ***Va***, ***Vm***, and ***Ve*** to exist in practical TV and other multimedia equipment. We have considered the EUT as a "star" circuit" though it should be remembered that some internal sources may be acting in the "delta" configuration. Mathematical transformation between "delta"and "star" would be possible if necessary.

A first argument might be that since CISPR32 is to be "technology neutral", then the standard must provide for the situation where all three might exist in future products using as-yet-unused design techniques.

However, all three will result from circuit features within today's electronics, coupled in some cases with poor electrostatic shielding and poor arrangement of the EUT's internal ground connections.

Specific causes are as follows;

- The EUT voltage ***Va*** that drives the antenna in common mode might result from coupling to the intermediate frequency (IF) or local oscillator frequency (LO) circuitry due to finite impedance of equipment conductors between the tuner and the remainder of the receiver.

- ***Vm*** will result from differential-mode to common-mode conversion within the main and standby switched-mode power supplies.

- ***Ve*** will result from the operation of CRT, LED, and plasma display screens as well as from any of the conductors internal to the EUT that carry high-potential high-frequency voltages such as switched mode power supplies, line scan circuits and video drive circuits.

Note that since the EUT must be regarded as a "black box", we cannot use any calculations that involve the addition or subtraction of these three voltage sources because we do not know if they are;

- Manifestations of a single interference source coupled through various shared impedances within the EUT, in which case vector addition of ***Va, Vm*** and/or ***Ve*** might be appropriate, *or*
- Independent, as listed in the three starred items, in which case addition of total interference power within the measurement bandwidth might be sensible.

Further note that, in the presence of a relatively low-impedance enclosure port, only an attenuated portion of ***Va*** can ever be presented at the mains port, and so the measurement of common-mode current on the mains lead *only* as presently proposed for CISPR32 cannot assess the interference generation characteristic of the TV receiver.

7. Other Cable Ports

In the previous sections this paper has concentrated on the TV receiver with minimal interconnections because it is easy to measure and to model. However, the need for new "Multimedia" standards follows from the integration of computing and TV technologies that have resulted in products, each with many different sorts of cabled connections – both analogue and digital – and these must also be considered.

Accordingly, current transformer tests were also made on the "Cornish domestic installation" described above with the SCART cable restored to its normal interconnection to a VCR to explore the effect of adding a third cable. No additional filters of any sort were present during this test.

The dBμA figures in ***Figure 14*** were obtained with a carefully-calibrated 1:5 current transformer used with the same FT100 receiver as before. Readings were taken from the receiver "S" meter and converted into dBμV and thence to dBμA. Accuracy should be similar to the +/- 3dB already proven for the antenna current. The fluctuations noted are variations with TV picture content.

MHz	Antenna Cable	Mains cable	SCART cable
1.8	-3 to +10	< -10	10
3.5	22	10	10
7.0	37	22	37
10.0	2 to 10	10	10
14.0	10 to 22	-6	10
18.0	-9	< -10	10
21.0	-3 to +10	< -10	22
24.0	37	22	22
28.0	37	10	10
50.0	< -10	< -10	< -10

Figure 14 Common-mode current flow on a SCART cable

The *enclosure port* is of course also carrying interference current – but we cannot measure this directly.

These current measurements do show that;

a) The antenna cable current shows strong maxima at 7MHz and 24 to 28MHz. These maxima appear to correspond to the c-m low-impedance resonance of the TV antenna cable in its quarter-wave and three-quarter wave modes as discussed above. Once again we are reminded that for a comparison of real-life emission with standard test parameters the possibility of low-impedance resonance of EUT cabling must be considered.

b) In almost every case the interference current on the mains cable is *less* than that on either the antenna cable or the SCART cable. *We may conclude that the EMC filtering within the EUT is effective for the mains lead – but not for other ports because of the effect of the enclosure port.*

c) The current flowing between the TV and the VCR is relatively large. If we take an installation-sized view, this suggests that if a TV set is used with a VCR, then it would be a waste of time putting a common-mode choke at the TV antenna port, since interference current would simply flow from the TV via the SCART cable to the VCR and thence onto the actual antenna cable. This teaches that it is equally important to limit the emission from the TV's SCART port, since this becomes an antenna port upon connection to the VCR . *This reinforces the case for minimising TV emission at all ports as set out earlier.*

8. Installation Cabling

The user's installation discussed at the beginning of this paper was connected to a "Protected Multiple Earth" TN-C-S mains distribution system. The TV was directly in front of a central heating radiator, and it was found that cross-connecting the copper heating pipe to the local green-yellow earth wire considerably affected the interference current flow in the antenna cable increasing it at some frequencies and decreasing it at others. We concluded that the dominant resonance was of the antenna and mains cables in combination. This taught that a mains "ground" connection is a very uncertain thing at radio frequencies.

This effect, and the strong common-mode resonance of the TV antenna that we observed, have implications for the possible resonance of mains cable systems should PLT (PLC, BPL) be contemplated.

9. General Conclusions

The author's general conclusions are Broad Conclusions are that;

- Domestic TV aerials in common-mode may be particularly efficient emitters at their resonant frequencies

- CISPR13 does not adequately address the emission from the antenna port of physically large TVs

- Wideband interference emitters "seek out" the frequencies of structural cable/antenna resonances at which they are well-matched. For interference to occur, a culprit, a Victim, and a path must all exist at the same time and at the same frequency. However, for wide-band emitters the chance of a valid interference frequency is much increased, as in the case of this TV problem.

This is a relevant consideration for wideband telecommunications services too.

10. The Multimedia Emission Standard

The CISPR Multimedia committee had been acquainted with the earlier work described in this paper by the contribution CIS/I/WG2 (Morsman-Marshall) 07-01. Several members of that committee attended the laboratory tests that we have described and after discussion agreed to amend the next CD. So, hopefully, the need for measurements at the Antenna port is now understood.

This draft CISPR/I/224/CD was circulated to National Committees in the second quarter of 2007 with a new test in Annexe B Table B7 that introduces limits for antenna port emission. This is a really positive step.

The common-mode impedance of 150 ohms, and the proposed voltage or current limits, are consistent with those standardised for measurements on telecommunications cables - but as we have shown in this paper 150 ohms is much higher than will be observed in practice at resonant frequencies.

These test requirements must be tightened if customer complaints are to be avoided. In the present paper we have identified the following additional evidence for this:-

- Zero or negative signal-noise ratio for broadcast reception at the 10 metre protection distance

- The evidence of TV antenna resonance and the known theoretical feed impedance of a monopole above ground that results in the current flow in use being much higher than that during test.

11. Summary

In this paper we have introduced the general problem of emission from the antenna cable of TV receivers, and explained how we seized an opportunity to explore this problem, using very limited test equipment.

Our findings came at just the right time to attract the attention of the Standards Committee working on the Multimedia Emission Standard, and as a result of their interest our early results and theoretical analysis have been confirmed, and taken into account for the next draft of the Standard.
We have also discussed the wider implications for cable-borne emission, and set out the case for tighter limits for the common-mode interference introduced into antenna cables.

12. Acknowledgements

This work has been successful thanks to an extreme degree of co-operation between many people. In particular, the author would like to thank;
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Design Techniques for EMC
Part 6 - ESD, electromechanical devices, power factor correction, voltage fluctuations, supply dips and dropouts

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

This is the **sixth** and final article in this series on basic good-practice electromagnetic compatibility (EMC) techniques in electronic design, published during 2006-8. It is intended for designers of electronic modules, products and equipment, but to avoid having to write modules/products/equipment throughout – everything that is sold as the result of a design process will be called a 'product' here.

This series is an update of the series first published in the UK EMC Journal in 1999 [1], and includes basic good EMC practices relevant for electronic, printed-circuit-board (PCB) and mechanical designers in all applications areas (household, commercial, entertainment, industrial, medical and healthcare, automotive, railway, marine, aerospace, military, etc.). Safety risks caused by electromagnetic interference (EMI) are not covered here; see [2] for more on this issue.

These articles deal with the practical issues of what EMC techniques should generally be used and how they should generally be applied. Why they are needed or why they work is not covered (or, at least, not covered in any theoretical depth) – but they are well understood academically and well proven over decades of practice. A good understanding of the basics of EMC is a great benefit in helping to prevent under- or over-engineering, but goes beyond the scope of these articles.

The techniques covered in these six articles will be:

1) Circuit design (digital, analogue, switch-mode, communications), and choosing components
2) Cables and connectors
3) Filtering and suppressing transients
4) Shielding (screening)
5) PCB layout (including transmission lines)
6) **ESD, electromechanical devices, power factor correction, voltage fluctuations, immunity to power quality issues**

Many textbooks and articles have been written about all of the above topics, so this magazine article format can do no more than introduce the various issues and point to the most important of the basic good-practice EMC design techniques. References are provided for further study and more in-depth EMC design techniques.

Table of contents for this article

6. Part 6 – ESD, electromechanical devices, power factor correction, voltage fluctuations, immunity to power quality issues

6.1 Electrostatic Discharge (ESD)

6.1.1 ESD threats

Normal commercial and industrial ESD tests employ the IEC/EN 61000-4-2 basic test method that attempts to simulate 'personnel discharges' from people's fingers. We have all experienced such discharges when the humidity of the air is low, when touching a metal object such as a door handle. Ordinary people do not generally notice ESD events from their fingers that are less than about ±3kV, and ESD events that make people hop about and complain loudly are generally in excess of ±15kV.

Figure 6A gives some examples of the electrostatic voltages that can be generated on a human body just by moving around in a typical building and doing ordinary things, for various values of the relative humidity of the air, from [3]. The mechanism by which this and most other terrestrial electrostatic charges are generated is called tribocharging, but this is not the article to discuss that phenomenon.

The IEC/EN 61000-4-2 test method uses an ESD 'gun' that discharges a 150pF capacitor through a 330Ω resistor to create ESD events up to ±8kV at up to ±30A, with risetimes between 0.7 and 1ns. The high dV/dt and dI/dt of these ESD events ensure that they have significant EM energy at frequencies beyond 1GHz. The test method is described in [4] (page 184), Chapter 43 of [5], Part 3 of [6] (which also describes some low-cost alternatives), and in the guide to EN 61000-4-2 in [7].

Generation method	Typical electrostatic voltage generated (in kV)	
	10-20% Relative Humidity (RH)	65-90% Relative Humidity (RH)
Walking across carpet	35	1.5
Walking on vinyl floor	12	0.25
Worker moving at non-metal bench	6	0.1
Opening a vinyl envelope	7	0.6
Picking up a polyurethane bag	20	1.2
Sitting on a polyurethane foam padded chair	18	1.5

Figure 6A Examples of personnel electrostatic charging

Figure 6B sketches the basic circuit elements of an IEC/EN 61000-4-2 ESD gun, which can be fitted with two types of discharge tip: a round one that simulates a human finger and is used for creating discharges in the air, and a pointed tip used for discharging by direct contact with conductive surfaces or objects.

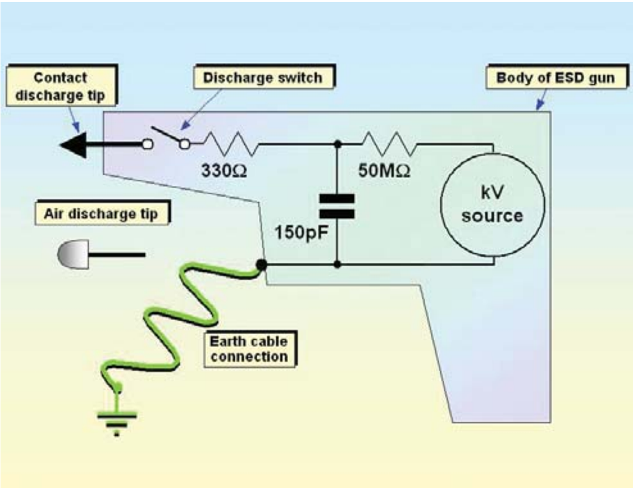

Figure 6B Overview of an IEC/EN 61000-4-2 'ESD Gun'

Figure 6C shows an example of a commercially available ESD gun, that has plug-in modules for various discharge waveshapes, including that specified in IEC/EN 61000-4-2 (see Figure 6F).

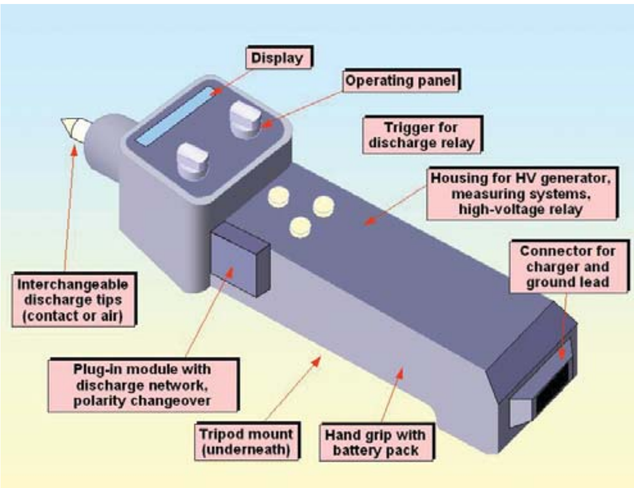

Figure 6C Example of a KeyTek MiniZap®

Figure 6D shows that testing to IEC/EN 61000-4-2 simulates three different kinds of 'personnel ESD' events, and can also cause 'secondary arcing' to occur – effectively ESD events within the product's structure. The 'near-fields' from an ESD test can be kV/m at 1m from a discharge, and kA/m within 100mm of a discharge – these are very intense fields indeed.

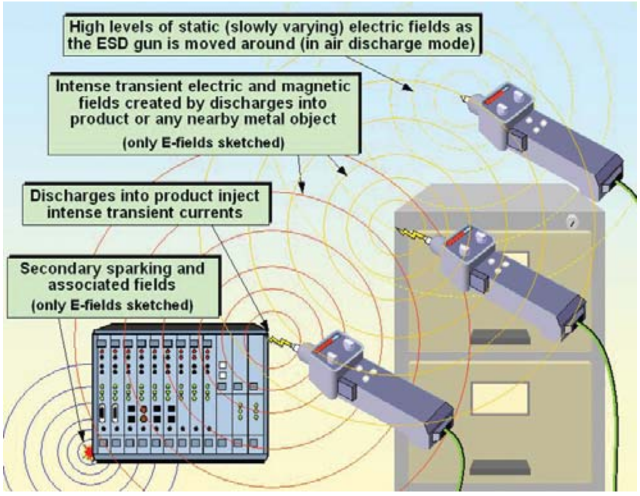

Figure 6D Various EM phenomena associated with ESD testing

The automotive industry uses the ESD test method ISO 10605 instead of IEC/EN 61000-4-2, and tests up to ±25kV with products powered, and when unpowered to simulate handling during shipping and installation [8].

These ESD tests inject sufficient voltage and current into products to permanently damage ICs and transistors, and even some passive components, see Figure 6E. And the intense electric (E) and magnetic (H) fields they create can couple transient noises into nearby circuits and disrupt signals, causing errors and often creating big problems for software.

Type of Device (typical 2002 technology)	Typical level at which damage occurs (kV)
MR heads, RF FETs	0.01 - 0.1
Power MOSFET transistors	0.1 - 0.3
VLSI (e.g. microprocessors, FPGAs, memory)	1 - 3
Film resistor	1 - 5
HC and similar CMOS glue logic	1.5 - 5
Small-signal bipolar transistor	2 - 8
Power bipolar transistor	7 - 25

Figure 6E Examples of ESD damage levels for devices

The damage levels in Figure 6E are based on tests in 2002 on unassembled devices (so ignores any protection provided by their circuits and enclosures) using the semiconductor manufacturing industry's 'human body model' – which discharges a 100pF capacitor through a 1.5kΩ resistor, generating a peak current of ±2A with a risetime of between 5 and 20ns. Modern (2007) microprocessors, memory devices and glue logic use insulating layers that are a great deal smaller than their 2002 ancestors, and probably have damage levels around 100V – reducing all the time as silicon feature size continues to reduces according to Moore's law [26].

Figure 6F shows the waveform of the discharge current that is specified when calibrating an ESD gun to IEC/EN 61000-4-2, and it also shows the sort of waveform that can obtain in real life due to radio-frequency (RF) resonances in the product being tested. Resonances can extend the ns transient of an ESD spark into a complex electromagnetic event that lasts for tens of µs.

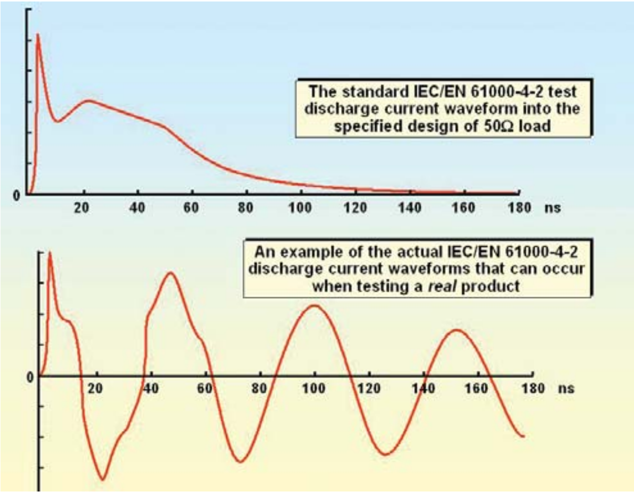

Figure 6F Examples of ESD waveforms

There are concerns [9] that the IEC/EN 61000-4-2 tests do not simulate real-life personnel ESD events well-enough to prove that products incorporating modern microprocessors and memory chips will be reliable in real life. [9] also claims that the standard does not specify the design of the ESD gun well enough to prevent significant differences when testing a given real product with different manufacturers' guns. This is also discussed in the guide to EN 61000-4-2 in [7].

But in real-life applications, ESD events can originate from a wide variety of sources other than people's fingers, as sketched in Figure 6G. These sources can have much higher values of capacitance than 150pF, and/or much higher voltages (up to ±40kV has been seen) or risetimes as low as 10ps.

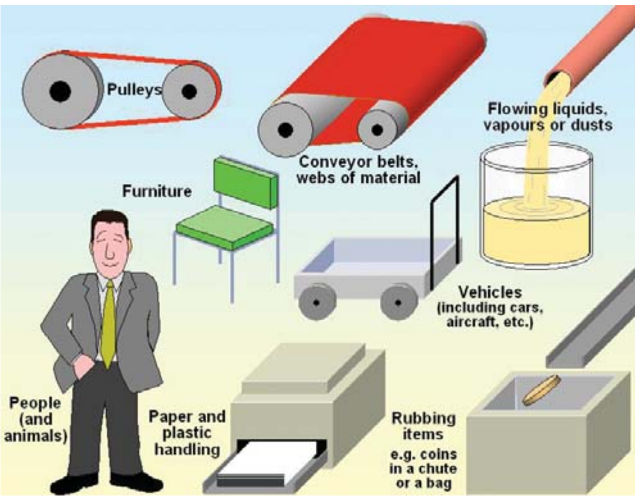

Figure 6G Examples of some ESD sources

It may seem odd that, as indicated in Figure 6G, fluid flow can cause ESD – but many serious incidents and accidents in the petroleum and other industries have occurred due to this very problem (see No. 458 in [12]), and it is also implicated in the crash of TWA 800 from an explosion caused by sparking in one of its fuel tanks. Spacecraft can suffer from very high levels of ESD due to charging of insulated parts by the solar wind, and by charged particles from outer space. And aircraft (fixed and rotary wing) can become charged up to very high levels due their passage through the air, especially during certain weather conditions (see No's 22, 23, 294, 295 and 431 in [12]). Motor vehicles can also become highly charged (see No. 366 in [12]).

Products that pass ESD tests in a laboratory can fail in the field due to more aggressive ESD events in their operational environments. Very high voltages and very low risetimes do not generally go together. High-voltage events tend to have a risetime of 1ns or longer, whereas low-voltage events (such as caused by jingling coins in a plastic bag, see [10]) can have risetimes as low as 10ps – with a spectrum of energy that extends well beyond 10GHz. The measurement of ESD risetimes is limited by the availability of suitable instrumentation, and it seems that as oscilloscopes get faster, we discover that real-life ESD events can be faster than we previously thought.

For more background on ESD and the forms it can take visit [10] and [11]. 21 examples of real-life ESD problems are described in [12]. An interesting example is the ESD caused by the rotors of AC motors running in nylon or other insulating bearings. Few designers would expect the little motor embedded within their product to be an ESD source, but the E- and H-fields created when its rotor discharges across its bearing to its frame can easily upset microprocessors and cause software to malfunction or crash.

6.1.2 Prevent ESD by preventing electrostatic charge from building up

This is generally a system or installation design technique, but it is used in all semiconductor manufacturing areas, and widely used in electronic assembly areas, so products intended for use in such environments can benefit and may not need to pass any ESD tests.

There are two basic methods: one is to make sure that all the materials used are dissipative (i.e. have a resistance between 10^6 and 10^9 Ω/square), and are connected to the ground reference, so that electrostatic charges decay quicker than they are generated and high voltages cannot build up. Some materials are made dissipative by coating them with appropriate materials (e.g. antistatic spray for carpets and furnishings). But many coatings only function as intended in atmospheres with a certain minimum relative humidity – so humidity control becomes a necessary feature of the heating, ventilating and air-conditioning system of the area.

The other method is to make the air itself conductive by using high-voltage needles to create alternating batches of negative and positive ions in a fan-blown air-stream. Ionised air is conductive, and alternating negative and positive ionisation results in air that is neutrally charged on average and so does not cause electrostatic charges to accumulate. Blowing the ionised, conductive air around the area to be protected causes any static charges on products, furniture or people to dissipate. In fact, a neutrally ionised air stream is the one sure way to remove charge from the surface of an insulator without having to wipe all over it with a grounded conductive brush or cloth.

The above techniques can also be used *within* products, to improve their reliability by discharging rotating belts, pulleys, motors with nylon bearings and the like so that they don't give rise to internal sparks that could upset their electronics. Dissipative materials can be used, such as conductive rubber (instead of insulating rubber) for drive belts, conductive plastics for wheels and pulleys, etc.

Insulating parts that move, including consumables such as the paper in a photocopier or printer, can also be discharged with grounded conductive brushes, often made of stainless steel or carbon fibre for longevity. Also, neutrally ionised air streams can be blown inside equipment to prevent the build-up of static charges.

6.1.3 Prevent the discharge from happening with insulation

When a product has to cope with external ESD from people or other sources, a very powerful design technique is insulation. We use plastic enclosures, membrane keyboards, plastic knobs, switch caps and control shafts, etc. to prevent the injection of the intense discharge currents into the product – in effect we simply do not permit the charged person or object to discharge into our product.

Figure 6D shows that this technique still leaves the product exposed to the slowly varying electrostatic fields and the intense E and H-fields from nearby discharges. Slowly varying fields are generally only of concern for very high impedance circuits (typically >1MΩ), and both these and the intense fields can be dealt with by techniques described in 6.1.8: for example a product might use all the techniques described in the earlier parts of this series [13] [14] [15] [16] and [17] – and then have insulation applied all over as well, to prevent direct ESD.

Typical plastics have a breakdown voltage through their thickness of about 40kV/mm, which can be a problem for membrane type control panels in extreme ESD environments if we want to use 'clicky' tactile buttons. To get a good button-clicking experience we need to a top plastic layer of about 0.5mm that will insulate up to about 20kV, if we have to use thicker layers it will ruin the feel of the button.

Membrane panels can employ a metal shielding layer immediately below their top layer of insulation, as described in 4.3.13 in [16]. This should intercept any discharges that manage to penetrate the top insulating layer, but to be effective it must be connected to the product's RF Reference, which in a shielded enclosure will be the enclosure shield itself [16], and in an unshielded enclosure will be the PCB's 0V plane [17] [18].

4.3.13 in [6] says that the shield layer should RF-bond to the metal enclosure all around its perimeter. This not the normal method used by membrane panels manufacturers, who generally use a 'shield grounding' trace in the flexi-ribbon cable that connects the panel's switch traces to the PCB. This is effectively a 'pigtail', like the bad-practice method of terminating cable shields discussed in 2.6.6 of [14], and it allows stray RF coupling into the membrane panel's conductors. If we do not use a metal shield within our insulating enclosure, for example as discussed in 4.7.7 of [16], we might need to filter the membrane panel's interconnections as described in [15] or ESD-suppress them as described 6.1.5 below.

Capacitive sensing techniques will work through almost any practical thickness of plastic, glass or ceramics and so can be made to withstand any ESD voltages, but they provide no tactile feedback at all. Using a remote control, such as a wireless remote, allows us to locate the human interface in a more benign ESD environment.

Air and vacuum are the biggest problems when using insulation to prevent actual discharges from occurring to the product. Enclosures must have seams and joints to make it possible to assemble them, and these create gaps in the insulation, and the gaps contain air. Air has a breakdown voltage of only about 1kV/mm, less if humidity is high. In space the gaps are filled with vacuum, which also has a breakdown voltage of about 1kV/mm but does not suffer from variations due to weather.

The resulting problem is shown in Figure 6H – we need very large air gaps between conductors and places that could be touched by people or other ESD sources, to be sure they don't break down and allow a discharge into the product.

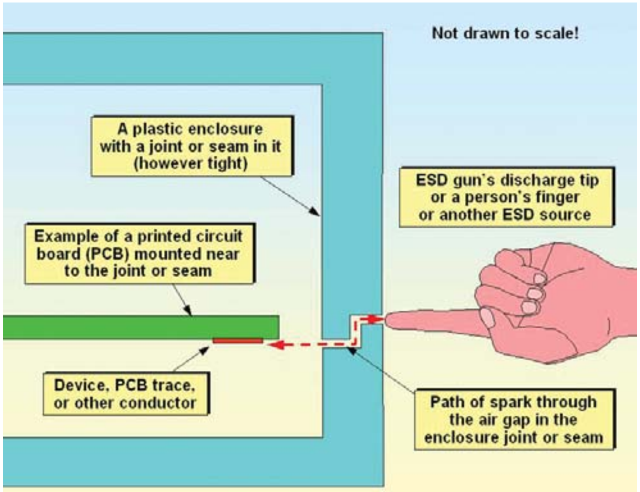

Figure 6H ESD penetrating a seam in a plastic enclosure

To withstand ±8kV we need *at least* an 8mm air-gap, and *at least* 25mm for ±25kV, taking into account the reduced breakdown voltage with increased humidity (unless the product is intended to work in a vacuum instead). Another issue is that all practical insulating surfaces are coated with dirt, damp, greasy fingerprints, possibly even mould, so discharges will find the surface of an insulator to be an easier path than even the air. It is not uncommon during ESD testing to see a spark from an 8kV discharge wriggle around on a painted metal surface for several tens of millimetres, tracking through the dirt and other contamination before finding a microscopic pinhole that allows it to reach the metal surface underneath.

So the best approach to insulating surfaces is to assume they are conductors and not take them into account at all in the total length of the air gap. Figure 6J shows how the air gap in Figure 6H can be increased, and also introduces the 'guard ring' PCB technique and the possible need to use shielding for very sensitive devices or traces.

People have been using perimeter guard rings on PCBs for decades, but because of the prevalence of the 'single-point grounding' myth, they thought it best to use a long trace around the PCB perimeter, connected to the 'chassis ground' – or whatever – at one point. As [14] shows, all they were really doing was creating resonant structures that were very effective antennas at certain frequencies. These take the broadband energy in the ESD discharge and re-radiate it as a very intense field at their resonant frequency, possibly replacing one type of ESD failure with another.

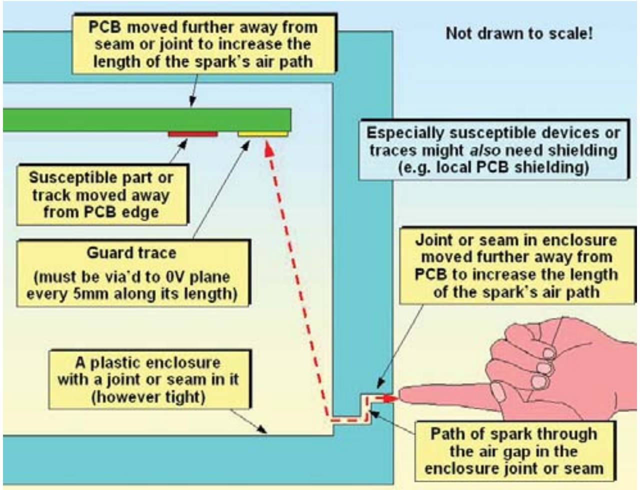

Figure 6J Solutions to the problem of ESD penetrating seams in plastic enclosures

Another possibility is that because the inductance of such a guard ring was so high, when it received a discharge its voltage could rise so high that it then caused a secondary discharge to the devices and traces it was supposed to be protecting.

The *only way* to implement an effective guard trace for ESD (or for any RF purpose above a few MHz) is to start with an RF Reference plane layer that maintains a very low impedance up to the highest frequency of concern for ESD (in excess of 1GHz) – and then connect the guard trace to the plane with via holes whose spacing is much smaller than the wavelength of the highest frequency. The effect of the dielectric constant of the PCB on the wavelength must be taken into account [17] [18].

The previous part of this series [17] only describes basic EMC techniques for PCBs, so for the details of implementing perimeter (or other) guard traces that are effective for RF and/or ESD, see [18].

An alternative approach to the problem of joints and seams in insulating enclosures is simply to fill them up with insulator, such as a (gas-tight) rubber gasket, silicone or epoxy sealant. The sealant approach is very acceptable for joints and seams that should never need to be opened during the life of the product (e.g. around the edges of a display), and the rubber gasket approach can be practical where access is required.

Beware of the temptation to try to make a totally sealed product. It is more difficult than it seems, and there have been many attempts that ended up with excessive amounts of condensation sloshing around inside, causing rapid corrosion.

Controls and displays are weak points in any ESD scheme, because they must somehow connect between the protected circuitry and the world inhabited by charged-up people and other ESD threats. Plus, of course, the charged-up people keep insisting on pointing at things on displays and touching the controls. (Cable and antenna connections are also weak points, and these are discussed in 6.1.5.)

LED and filament lamp indicators can use surface-mounted devices with plastic light guides to communicate their light to the human interface, as shown in Figure 6K. The light guides can be cheaply made from injection mouldings that snap into the enclosure and align with the LEDs or lamps on the PCB. This method is very low-cost, but it is important that any seams or joints between the light guides and the enclosure's insulating surface are friction-welded, glued or sealed so that sparks cannot track along contamination on the light guide's surface and get into the PCB.

Another technique is to present the LEDs or lamps at apertures in the enclosure, but cover them with a glued-on plastic overlay, generally the one carrying the control panel markings, that has transparent areas over the displays.

A problem with glued plastic layers, that also afflicts membrane panels, is the uniformity of the glue layer. Any missing glue, or imperfect bonding with the insulating enclosure surface, will create an air-gap that will allow sparks to slip under the overlay or between the laminated layers in the membrane panel and inject discharge currents into indicator devices, or into printed traces in membrane panels.

Where glue uniformity and quality cannot be guaranteed, make sure the edges of the plastic layer extend a very long way beyond the vulnerable components or traces. For 8kV ESD, 20mm would not be excessive. Or else seal them with silicone or other insulation as shown in Figure 6K.

For rotary shafts for switches, potentiometers and encoders, toggle switches, and similar manual controls, plastic knobs, shafts and toggles are recommended. For many years now, equipment has been so miniaturised that their control knobs are so small that discharges from operator's fingers can easily track across their surfaces and into any metal shafts they are mounted on – thereby penetrating the insulating enclosure and damaging some vital device or scrambling its software. So plastic shafts should be used, as shown in Figure 6K.

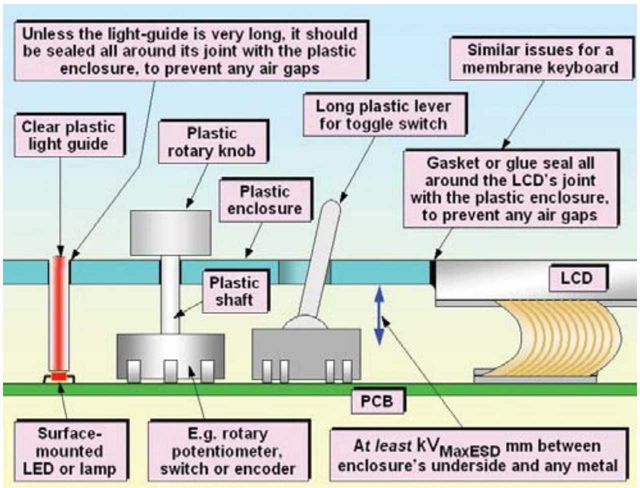

Figure 6K Indicators, displays and controls penetrating plastic enclosures

Figure 6K also shows that the assembly of LCD panels and graphics displays should avoid exposing their edges to ESD events. This is where a good mounting bezel with a rubber gasket, or a silicone or other type of sealant (that could also be used to hold the display in place, simplifying assembly) can be very useful. The fixed windscreens in almost all models of motorcars introduced since 1990 are an example of appropriate assembly techniques. Older vehicles used to have all sorts of bezel contraptions to hold them in place, and it was not unusual for them to leak (allow water to penetrate the enclosure) – but these days they simply glue them in, and incidences of water penetration are rare.

6.1.4 Control the discharge with shielding

Shielding is an alternative ESD suppression method to insulation (see 6.1.3). It allows the discharge to occur to the product, but then seeks to control it so that it doesn't upset any of the product's electronics. Shielding techniques were discussed in Part 4 of this series [16], and at first sight it might seem that all we need to do is design our shielding to be effective enough at a high-enough frequency.

For normal ESD testing, with risetimes close of 0.7ns or longer, we can assume the highest frequency of concern ($1/\pi t_r$) is about 500MHz, but real ESD events are much faster than this, at 0.3ns or less [9] and so we should assume 1GHz or more instead.

But the very high intensities associated with ESD events (tens of amps with sub-ns risetime, E-fields of kV/m, H-fields of kA/m) significantly increase the demands on our shielding, In fact, designing shielding for ESD is rather like designing it for military or aerospace purposes, where we can be dealing with kV/m E-fields at 1GHz or more from nearby radars, so in this section we need to discuss how to apply the techniques described in [16] to the ESD situation.

Clearly, with such high levels of E and H near-fields, the shielding effectiveness (SE) required at the highest frequency of concern will be higher than what is usually required to cope with the normal domestic, commercial and industrial environments (typically tested at 3V/m or 10V/m, although achieving immunity to the close proximity of cellphones, walkie-talkies or GPRS-enabled computing devices can require testing at 60V/m or more).

Because of the very high levels of ESD current flowing around the outer skin of a shielded enclosure, any gaps or apertures that make these surface currents divert from their natural paths become very intense sources of secondary E and H-fields. So it is very important to locate sensitive devices, PCB traces and conductors *very far away* from even tiny gaps or joints in the shield. Figure 4R in [16] shows the general principle, but much more than its 40dB of SE might be required.

The voltages developed across a gap or aperture in a shield, due to their diversion of the flow of the ESD currents, can be so high that they break down the air (or vacuum, in the case of spacecraft) at that point and spark across the gap. This is known as *secondary arcing* and, as might be expected, where it occurs it can cause very great problems. It can even occur *inside* products whose external shielding provisions are not as good as they should be, generally playing havoc with their electronics.

Secondary arcs are often small faint blue things that are hard to see even when right in front of your eyes, but more often than not they are hidden within a metal seam, or inside or on the bottom surface of the product being tested and so even less visible, as sketched in Figure 6L. When secondary arcing is suspected, for example when the ESD gun is applied to the top of the product, but the microprocessor that resets (and its reset lines) are located near the bottom, a powerful diagnostic technique is to do ESD testing in the dark.

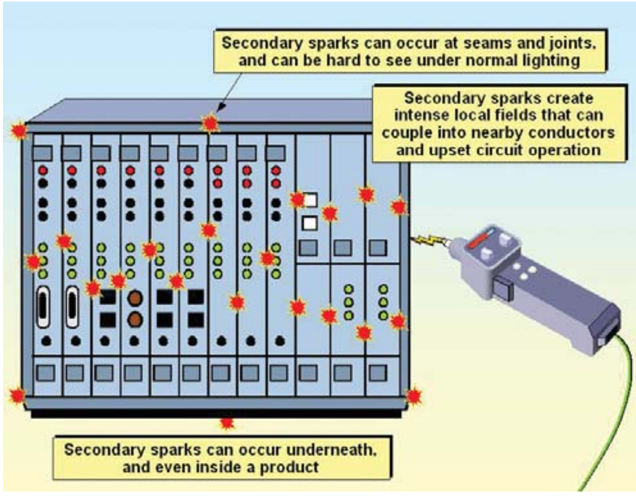

Figure 6L Sketch of some secondary arcing possibilities

It is of course inadvisable to do ESD testing in <u>total</u> darkness, because we need to see what we are doing well enough to:

a) Apply the ESD gun to the correct point on the product, and in the specified manner

b) Not accidentally discharge the gun to ourselves (painful, but not damaging to people. Where one's health depends on implanted or portable electronic medical devices such as pacemakers or defibrillators, you should not be anywhere near an ESD test anyway.)

So close the blinds and/or turn the lights down quite a lot, and wait a few minutes for your eyes to get accustomed to the gloom. People can see quite well by moonlight, which has one-millionth the luminous intensity of sunlight, so given time our eyes adapt to gloom very well.

The tester has to watch where the ESD gun is applied and has a limited ability to monitor other areas of the product, so spotting any secondary arcing can be made much easier if someone else looks closely at different parts of the product during the tests. It can also help to reorient the product, for example lying it on its side to see its underside. Detecting internal secondaries can require more radical techniques.

Indicators, controls and displays are weak points for ESD when relying on shielding, just as they are for the insulation techniques discussed in 6.1.3. The insulation-based techniques sketched in Figure 6K (plastic light guides, knobs, shafts and toggles, etc.) are effective with metal enclosures too, but the apertures they create in the shield might cause problems for nearby sensitive devices when discharges occur to the metal surface, or when shielding for frequencies above 300MHz. Figure 6M shows some alternative techniques that prevent the creation of apertures in the shield.

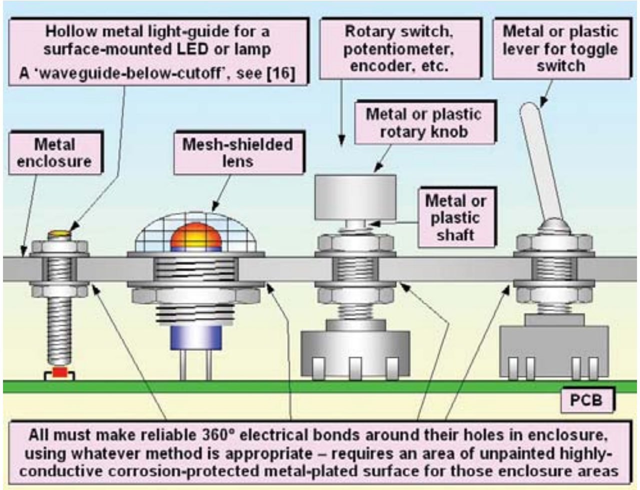

Figure 6M Indicators, displays and controls penetrating shielded enclosures

Figure 6M does not show how to deal with panel-type displays or membrane keyboards. Displays need to be treated using one of the techniques described in [16] (e.g. Figure 4AH). Membrane keyboards should RF-bond their metal backing plates, and/or any internal shielding layers to the shield all around their perimeter, using conductive gaskets, see 4.3.13 in [16]. Care should be taken to prevent discharges into their edges or backs.

It is often assumed that a Faraday Cage (i.e. an effective shielded enclosure) always prevents any external voltages from creating voltage differences within it. Whilst this is true for established DC voltages (as Michael Faraday found, when sitting inside his eponymous cage holding a gold-leaf electroscope) – and also true for continuous RF for enclosures with no apertures made of a metal with at least 10 skin-depths at the frequency concerned. But it is not true for transient voltage fluctuations such as ESD.

When a discharge is applied to a shielded enclosure, at first the transferred charge spreads all over the outer skin of the metal shield, and in the short-term whilst current is still flowing, it is confined to the outer surfaces by skin effect. Once the currents have equalised the voltage all over the outer skin of the shield (which they do at the speed of light, so it would only take about 1ns for a small enclosure) they stop flowing, and the charge then becomes static – an electrostatic voltage on the outside of the metal enclosure.

Over the next few ns the charge diffuses through the thickness of the metal shield material until it appears on its inner surface. The rate of diffusion depends on the relative permeability of the metal – the higher it is, the smaller the skin depth and the slower the rate of diffusion.

Inside any metal enclosure there are hundreds or thousands of stray capacitances between the shield material and each device (in fact, each pin of each device), PCB traces and other conductors – and they are all different. When the charge appears on the inner surfaces of the shield, it charges up these stray capacitances, and during this process they carry charging currents (sometimes called displacement currents). These transient charging currents will of course be injected into the devices, PCB traces and other conductors that they are 'strays' to. Figure 6N shows the general idea, but really needs an animated sequence to better show the sequence of events.

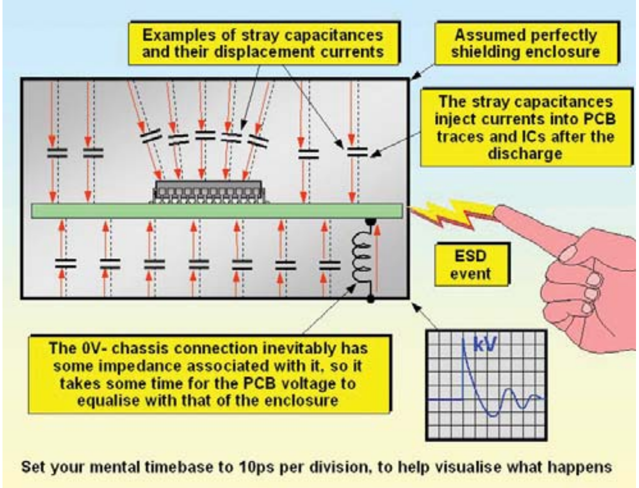

Figure 6N Effects of a discharge to a shielded enclosure

Eventually the 0V-chassis connection (if there is one) will carry currents that equalise the static voltages throughout the interior of the product. If there is no intentional connection, equalisation will happen more slowly due to ionisation of the air in the product. The transient currents in the stray capacitances are different for each device pin, PCB trace or other conductor, and so they cause transient voltage differences between different parts of the circuits. These transient differential-mode voltages can upset the operation of circuits, and reset or crashed microprocessors are a common consequence.

Note that a wired connection between the enclosure shield and a safety earth or other external 'ground' has no effect over the process described above. The length (and hence inductance) of the earthing/grounding wire or strap is simply too great for it to carry the charge away from the outer surface of the shield before it has time to diffuse inside. However, direct metal-to-metal bonding at multiple points around the perimeter of a metal enclosure, to a large metal surface (e.g. the metal hull of a ship or metal fuselage of an aircraft) should allow the surface charge to 'drain away' fast enough to have *some* effect.

One solution to this ESD problem is to create a high-quality 0V plane on the PCB, as described briefly in [17] and in detail in Chapter 4 of [18]. Then 'RF bond' this plane to the shield with multiple low-impedance (at 1GHz) bonds – described briefly in [17] and in detail in Chapter 3 of [18].

Another solution is to use filtering and shielding techniques on the PCB, at least over the most sensitive components. These techniques are described briefly in section 5.3 of [17] and in detail in Chapter 2 of [18], from which Figure 6P is taken, and PCB shielding-cans can be quite low-cost. It may be necessary to apply the 0V planes and RF bonding at the same time as the PCB-level filtering and shielding.

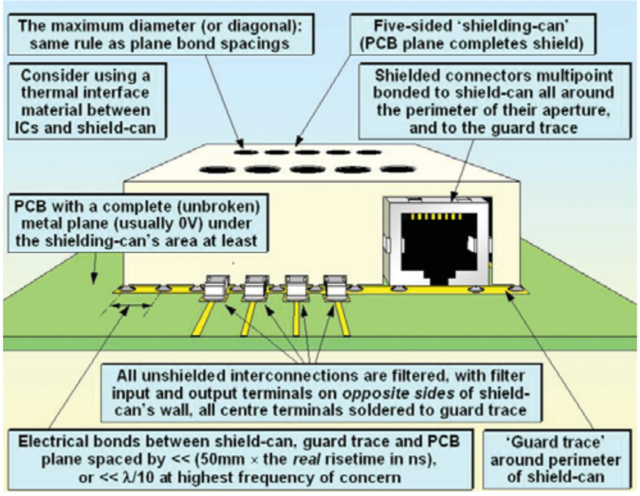

Figure 6P Overview of PCB-level filtering and shielding techniques

6.1.5 Protecting signal, data, control or power conductors

Discharges into semiconductors can be fatal for them, so if it is not possible to protect conductors with the methods described in 6.1.2 - 6.1.4 above, and if we really have no choice but to expose conductors to ESD discharges, for example the antennas on portable radio receivers, we need to apply appropriate suppression or filtering techniques to them.

This is especially a problem for the pins of connectors, which are exposed to ESD discharges from:

- Personnel discharges (e.g. people fingers)
- Plugging in other equipment (equipment with two-core mains leads are not earthed, so could be charged up to kV)
- Charged-up cables (dragging a cable over the floor can cause all of its conductors to take on an electrostatic charge at several kV)
- Discharges from a variety of other sources

A solution for passing tests to IEC/EN 61000-4-2, which attempts to simulate personnel ESD, is to use small metal-shrouded connectors with their shroud directly connected to the product's RF Reference (its shielding, or PCB 0V plane if unshielded). Appropriate connectors include D-types, USB, Firewire, RJ45, etc. If the 8mm diameter 'air discharge' tip was used for such tests it would most likely discharge to the metal shroud, sparing the connector pins. But in any case there is a clause in IEC/EN 61000-4-2 that mandates using the pointed 'contact discharge' tip, and only applying it to the metal shrouds of such connectors.

Although this is an appropriate technique for personnel discharge, it doesn't deal with the remaining three bullet points above. It allows a product to pass the ESD tests as part of declaring compliance with the EMC Directive, but it doesn't necessarily mean that the product is protected against all the ESD events it will experience in real life.

(Some manufacturers place all their connectors on the rear of their product, so they can state that they are not "accessible to persons during normal use" to take advantage of a clause in IEC/EN 61000-4-2 that removes the requirement to do *any ESD tests at all* on those connectors. I'm sure I don't need to say why I don't recommend that approach!)

For signal conductors that could be exposed to any types of ESD discharges, current-limiting, transient suppression, or filtering techniques will almost always be needed to protect their circuits from upset and damage to their devices. Some DC power conductors may also need similar protection, although if they are well decoupled (see [17] and Chapter 5 of [18]) this should be sufficient.

As far as I am aware, almost all ICs are fitted with ESD protection diodes that shunt overvoltages and undervoltages to their DC power rails, and those that are not have bold warnings of this fact on their data sheets. But because of the commercial pressures to make devices cheaper, hence use smaller silicon die, these diodes have never been very large or powerful and they are becoming progressively smaller and less powerful. We can help these diodes do their job by putting impedances in series with the conductors that are suffering from the ESD event (e.g. connector pins), as shown in Figure 6Q.

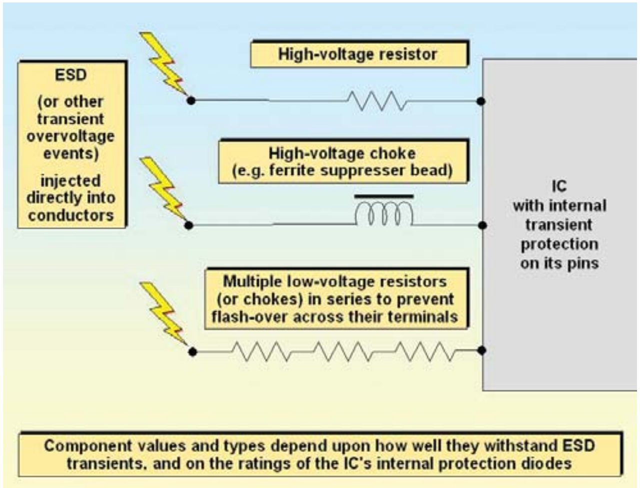

Figure 6Q Adding impedance in signal lines to limit discharge current

As Figure 6Q shows, the resistors or soft-ferrite chokes used must be rated to withstand the full ESD voltage. If ordinary 0805 or similar types are used, *at least* ten (possibly twenty) will be required in series, otherwise their terminals will spark-over – defeating their purpose of limiting discharge currents. When many resistors are used in series, they must not be placed close to each other on the PCB, otherwise the ESD might flash-over between different resistors or track across the inevitable surface contamination on the PCB.

The values of the resistors or chokes are chosen to limit the worst-case discharge current to one that the IC's own protection diodes can handle, the data for which should be provided on the data sheet. All such designs should be proven by assiduous testing, not just a few discharges. And some ESD testing should also be done in the near-dark, to reveal any 'sneak' discharges on the PCB. Where contamination by dust or condensation is likely, test in the dark with foreseeable contamination simulated.

Unfortunately, the values of impedance required may be so high that high-data-rate signals suffer from degraded signal quality (e.g. collapsed eye-pattern). Also, many types of individual semiconductors are unprotected against overvoltages and some are especially susceptible, so just adding series impedance isn't going to work for them.

Filtering or suppression techniques must provide at least 40dB of attenuation (e.g. reduce 8kV to 80V) and possibly as much as 70dB (e.g. from 24kV to 8V) for transients with risetimes of 0.7ns (ideally 0.2ns) – equivalent to a frequency of 460MHz (ideally 1.6GHz). They will not be able to achieve this very high performance without an RF Reference that provides a very low impedance up to the highest frequency of concern. Suitable RF References will either be a metal plane in the PCB (see [17] and Chapter 4 of [18]) or the wall of a shielded enclosure that has a good SE at the highest frequency of concern (see [16]). Figure 6R shows two general techniques: a TVS device, and transient-rated diodes.

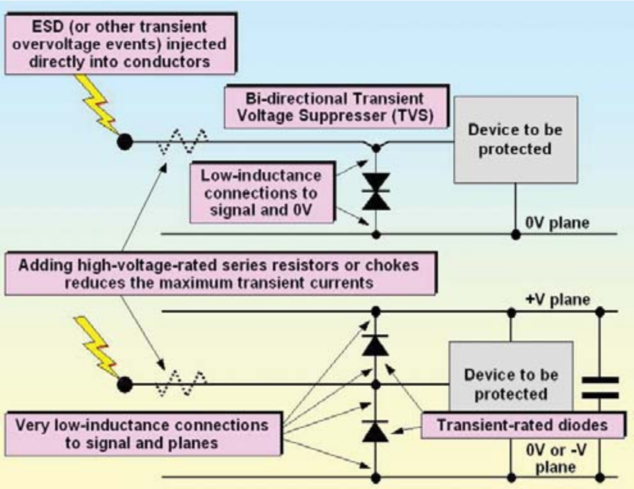

Figure 6R Adding transient voltage protection

The basic principles of transient overvoltage protection were covered in the final sections of [15], for low-frequency surges. TVS devices are generally avalanche diodes, which seem to be increasingly referred to as SADs (silicon avalanche diodes) – the fastest-operating type of transient protection device. Surface-mounted metal-oxide-varistors (MOVs, sometimes called VDRs) should be fast enough to suppress ESD with 0.7ns risetimes, but might not be quick enough where risetimes of 0.5ns or less could occur.

Transient-rated diodes usually come in pairs in SOT-23 packages or similar, and are specified exclusively for transient suppression applications, not for use as ordinary diodes. Sometimes the level of ESD exposure makes it necessary to use high-voltage-rated impedances in series with TVSs or transient diodes, in which case all the high-voltage issues discussed earlier apply to the resistors or chokes.

Many TVS devices have too large a self-capacitance for high-frequency or high-data-rate signals, although low-capacitance versions, some as low as 1pF, are becoming increasingly available – spurred by the rapid increase in high-speed interconnections such as USB2 and Firewire. Transient diodes are reverse-biased in normal operation and so have a low capacitance, which makes them suitable for high-speed signals, as long as the discharge currents are not too high. When using transient diodes, the DC power rail they connect to should be a plane with very low impedance at the highest frequency of concern, just like the RF Reference plane.

A problem with reverse-biased transient diodes is that their leakage currents double with every 10°C rise in temperature, making them difficult to use in high-temperature applications, or on sensitive high-impedance DC-coupled circuits. Many other exotic solutions are possible, for example using an isolated-gate FET (IGFET) arranged so that an incoming overvoltage turns it on and temporarily shorts the trace to the RF Reference.

The placement of the components on a PCB, and the routing of their traces, is vital if the required transient attenuation is to be achieved, and Figure 6S sketches the details, for a TVS. The same layout rules apply to transient-rated diodes as well.

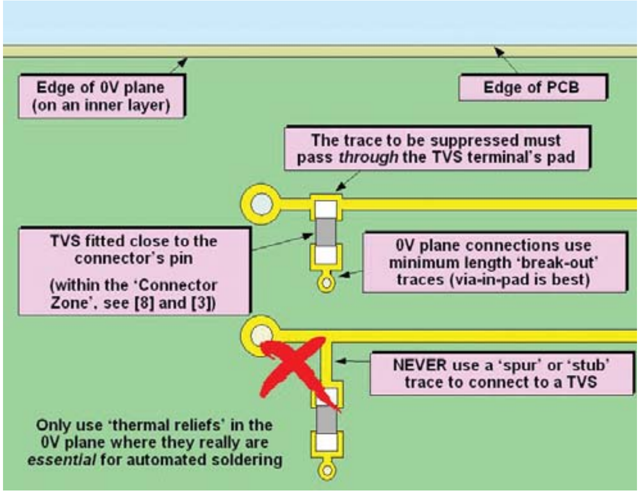

Figure 6 SPCB layout issues for transient voltage protection

An IEC/EN 61000-4-2 ESD test at 8kV can generate a dI/dt in excess of 43A/ns. A 1mm wide trace just 1mm long, routed over an RF Reference plane layer, will have a self-inductance somewhere between 0.3 and 0.6nH (depending on its height above the plane) [18]. At 43A/ns the peak voltage drop along the 1mm trace will therefore be between 13 and 26V. So the short trace shown connecting the TVS to the via hole in Figure 6Q could limit the efficacy of the transient suppression.

The via hole to the reference plane shown on Figure 6S also has self-inductance. On a two-layer 1.6mm thick board the length of the via hole carrying TVS current will be 1.6mm, giving it a self-inductance of 1.6nH. 43A/ns in such a via hole would drop 70V peak. The TVS device itself will also have internal series resistance and self-inductance, which will also add more peak volts.

The faster risetimes or higher voltages possible with some types of real-world ESD events could double or even triple the above estimates. Clearly it is possible for the PCB layout itself to degrade the performance of the TVS or transient diodes by so much that even if they had zero clamping voltage (which of course they do not) the ICs would still be exposed to quite high peak voltages, just from the self inductances of very short traces, via holes and the transient suppression devices themselves.

However, as long as these voltages are not *too* high, the internal transient protection devices in the ICs themselves should cope with them.

The very best suppression devices are three-terminal types, like the three terminal filter components discussed in [15]. To get the best performance from them, they should be used with at least two parallel vias to their Reference plane, arranged symmetrically around the device and very close to it. Also, the PCB dielectric between the Reference plane layer and the layer on which the suppression device is mounted should be as thin as is practical, say 0.15mm or less. Such precautions are not yet generally necessary, but perhaps they will become more common in future as devices explore silicon processes at 45nm and smaller.

[15] covered the basic principles of filtering, and the above descriptions of the issues associated with ESD suppression using a TVS also apply to the high-voltage-rated series resistors (or chokes) and shunt capacitors when using filtering instead. Where the signals are very slow, some manufacturers just use a large capacitor on its own, with no series impedance, to act as a capacitive voltage divider with the capacitance of the ESD gun, by charge redistribution.

For example, if the ESD gun had a 150pF capacitor charged to 15kV, using a 150pF shunt capacitor to protect an IC's pin would result in 7.5kV at the IC's pin, 1.5nF would give about 1.5kV, 15nF would give 150V and 150nF would give 15V. These are idealised calculations – as shown above the self inductances of even short PCB traces and via holes could easily add tens of peak volts to these values, and there is also the issue of the behaviour of the capacitor with such transient charging currents.

Ceramic capacitors are the only suitable types, with COG or NPO being the best. A typical surface-mounted capacitor might have an internal series resistance of 10mΩ and a series inductance of 1nH, generating an additional peak voltage of 43V with a current risetime of 43A/ns.

The voltage ratings for any series resistors or chokes are the peak ESD voltage itself. Because kV can leap large distances through air or vacuum, their location on the PCB and proximity of them and their traces to other devices and their traces is very important. The voltage rating for the capacitors in any voltage dividers or filters is set by charge redistribution. The value of capacitor or 'clamping voltage' of a TVS should, of course, be less than the level that damages the IC it protects, taking into account the additional transient voltages caused by the self-inductances of shunt components, traces and via holes, and itself. The TVS's capacitance is set by the circuit impedance and data rate; and its peak current rating by the magnitude of ESD event (taking into account any current limiting by high-voltage-rated series resistors or chokes).

6.1.6 'Earth lift' problems for interconnected items of equipment

The above discussions have only considered the ESD protection of a single product, on its own, but when two or more products are interconnected (e.g. by power, signal, control or data cables), 'earth lift' adds a new type of ESD problem.

As Figure 6T shows, when an ESD event injects current into a chassis or enclosure (either directly or via a shunt suppresser like a TVS, transient diode or capacitor), the chassis (etc.) suffers an 'earth lift' transient as the discharge current flows in the very high inductance of the earth-bonding network.

As mentioned before, self-inductance of ordinary conductors is so high that earthing using wires or even braid straps has little/no effect on the peak transient voltage attained by the chassis of the product suffering the discharge. In fact, the peak voltage attained will be almost the same as it would be for an unearthed product, for example one that was battery powered, or 'double-insulated' from the mains power and so powered by a two-core mains lead with no safety earthing conductor.

The peak transient voltage of a product can be determined by charge redistribution between the ESD source's capacitance and the space-charge capacitance of the product. We can calculate the capacitance of the product very approximately as:

$$C = 4 \cdot \pi \cdot 8.85\left(\frac{1}{a} - \frac{1}{b}\right) \quad pF$$

where:

a = the radius of the sphere representing the product, and…
b = the distance of the product from the nearest floor or wall or ceiling that is either made of masonry or has substantial metal in it (e.g. a suspended ceiling)

For the value of 'a' I suggest using half of the average of the two longest product dimensions, e.g. width and length, solely on the basis that it feels about right. Obviously, we do not expect to get a very accurate assessment using the above formula, and this carries across into the accuracy we can expect of the peak transient voltage we would calculate by charge redistribution. Accurate calculations of peak transient voltage can be achieved using modern computer simulation techniques, which can also determine the capacitance of the ESD source.

The earth-lift voltage is common to all of the conductors in an interconnecting cable, so it is a common-mode (CM) ESD transient, which just means that it can damage a number of input and output devices simultaneously.

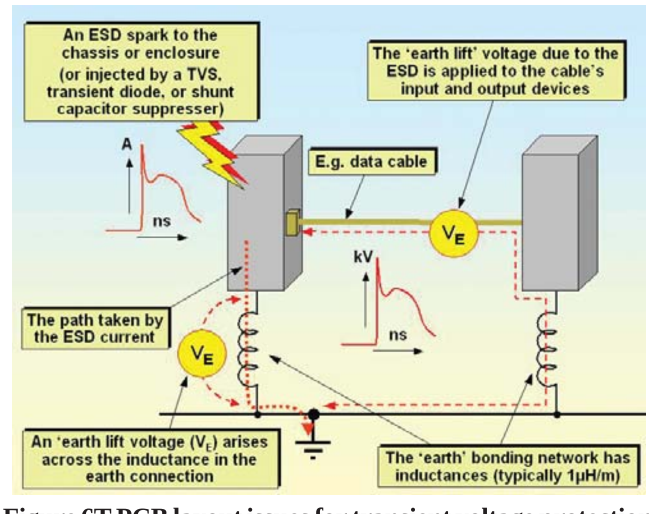

Figure 6T PCB layout issues for transient voltage protection

For protection, either prevent the ESD from happening in the first place using the techniques described in 6.1.2 or 6.1.3, or reduce the impedance of the products' local earthing network to negligible amounts by direct metal-to-metal bonding each of the interconnected products to the same sheet of metal, at multiple points around their perimeters. Such brute-force 'earth bonding' can be quite straightforward in a ship, aircraft, offshore oil platform or other structure made solely from large metal sheets.

Also, using well-shielded cables and connectors to interconnect the products, each cable shield 360° bonded to the frame/ chassis/shield etc. of the product at *both* ends as described in [14], will reduce the earth-lift voltage; although I am not sure whether this method on its own always guarantees freedom from earth-lift problems.

If all of the above methods are impractical, or inadequate, we are left with applying circuit techniques to the input and output devices: either galvanic isolation or suppression with TVSs, transient diodes, filters or just capacitors, as discussed in 6.1.5. Since earth-lift is a CM phenomenon, a CM choke may be just as effective, if not more so, than individual chokes in series with each of the conductors in the interconnecting cables. PCB-mounting CM choke components are available, but are probably not rated to withstand ESD voltages.

Figure 6U shows a few of the very wide variety of cable-mounted CM chokes that are available for round and flat cables. Whilst these do not generally offer as high values of impedance as the board-mounted types, they have very good high-voltage performance, limited only by the insulation of the cable they are used on.

Figure 6U Examples of cable-mounted CM chokes

Galvanic isolation is by far the most robust technique, and can use transformers (e.g. pulse transformers in Ethernet, microphone transformers in professional audio), optical isolators, fibre-optics, wireless, infra-red, free-space modulated lasers, and other techniques. But the vast majority of transformers and optical isolators are not rated for kV isolation and will spark-over when subjected to ESD test voltages.

Transformers can be designed and made with appropriate ratings, usually to special order. 10kV-rated optoisolators have been available from some suppliers for many years, essentially just an emitter and receiver spaced 20-30mm apart by a light guide. It is difficult to obtain such devices that will also handle high-rate digital data, for which fibre-optics and free-space lasers will generally be required. Fibre-optics are generally preferred for EMC reasons anyway, see [14].

6.1.7 Protecting data and signals from errors

Transient suppression devices such as TVSs, transient diodes and shunt capacitors only prevent actual damage to devices, they don't prevent signal corruption. But after a typical ESD test, if the operating state of the product has altered, or any data has been lost, the result is a failure. So it is not sufficient to simply prevent device damage, we have to maintain signal integrity too.

Hardware and/or software design is generally needed to discriminate between ESD events and valid signals. Keyboard strokes, button presses and slow signals, control or data are all easy to distinguish from ESD events using simple techniques, because the ESD events are so brief.

For example, a very quick 'jab' at a momentary contact switch might last as little as 25ms, which is at least 10,000 times longer than almost any ESD event, including the decay of any product resonances it excites. So a simple resistor-capacitor low-pass filter, or a couple of lines of keyboard polling software that checks whether the data is still valid after a few ms, is often perfectly adequate.

But high-speed data uses signals with risetimes and/or durations that might not be so very different from ESD events, making simple discrimination schemes unreliable. High-speed analogue signals should use high-quality shielding (see [14]) and digital data can too. Alternatively, convert all signals into digital data and employ error-detecting or error-correcting protocols.

Any digital engineer can design error detecting/correcting communications protocols, but the temptation to do so should be *resisted at all costs*! It is not at all easy to get a robust product unless you are an expert *in this type of design*. As Figure 6F shows, even a single very short ESD event can cause surprising EM phenomena whose amplitudes, frequencies and durations are hard to predict, and some ESD events are neither single nor short.

But ESD is not the only type of transient that a data communication link needs to be protected from. Fast transient bursts have hardly been mentioned in this series, because they are generally dealt with quite adequately by techniques already described (making allowances for their frequency range and amplitude), but our error detecting or correcting protocol needs to cope with these long bursts of noise too. In real life, fast transient bursts can last for several hundred ms, sometimes for several seconds, especially in high-power industries or near high-voltage distribution switchyards.

We can easily purchase ICs and/or software that have enjoyed the benefit of experts with aggregate experiences of hundreds of man-years *solely* in protecting data in communications links. So we should always buy these, as they will be much more cost-effective than anything we might think we can do ourselves, no matter how clever we are.

Ethernet and CAN bus are but two examples of robust datacommunications, but they are not perfect – in extreme EM environments the data rate of Ethernet can drop to zero, and so can the CAN bus, due to a small oversight in the CAN bus standard [19]. More sophisticated protocols exist, one highly respected example being that used by the real-time MIL-STD-1553 bus, of which commercialised versions are now available.

6.1.8 Use all the other EM design techniques too...

The EM engineering techniques described in the earlier parts of this series [13] [14] [15] [16] [17], as well as those in [18], control E, H and EM-fields and so can be used to improve immunity to E- and H-fields from ESD events. Sometimes the techniques were described with examples of reducing emissions, and sometimes of improving immunity, but any technique that attenuates fields and/or conducted noise is equally effective for either purpose.

The fields from ESD events within a few metres can be very strong, making it necessary to take more care over the EM design, going into finer detail (e.g. using $\lambda/100$ gaps in seams instead of $\lambda/10$). Other sources of advice on good ESD design include [4] and [5].

6.1.9 Software techniques

Software is easily corrupted by transient voltages due to ESD, leading to a variety of possible errors, malfunctions and crashes. Where the hardware techniques in this series do not provide sufficient immunity to transient or short-term events such as ESD, or are too impractical or too costly, appropriate software programming techniques can be a huge help – and of course they generally add no cost in manufacture.

This series has described hardware techniques only, because this is where my experience and skills lie. I dare not write about software, because my ignorance in that area would soon be revealed, so instead I refer the reader to people who *do* understand software techniques for EMC, especially [20] [21] [22] [23] [24] [25], section 12.2.5 of [4], and Chapter 37 of [5].

Of course, software techniques cannot work if the devices the software runs on are damaged from ESD or other EM disturbances (e.g. surges). However, the use of multiple redundant processor 'channels' with voting and other operations on their independent outputs can be used to detect faulty digital processors, whether the errors are transient or permanent due to damage.

But it important to note that redundant hardware channels are often all exposed to the same EM disturbance in (almost) the same way at (almost) the same time, for example an E or H-field from a nearby ESD or lightning ground stroke, or an overvoltage surge on their common mains power supply.

So if all of the channels use the same technology and construction, they can all fail in the same way at the same time. This is a bad thing and is known as a 'common-cause' failure. It is best dealt with by using:

- Diversity of design (e.g. different types of microprocessor, different software languages, different PCB layouts, different designs of power converters, etc.), plus…
- Diversity of location and cable routing (e.g. not placing all the channels in the same cabinet, not routing all the cable sin the same trunking, etc.), plus…
- Diversity of power supply (e.g. more than one independent mains supply, battery backup, etc.).

For very high-reliability systems, such as those that control weapons, financial institutions, national security and safety-critical applications such as fly-by-wire passenger aircraft, a great deal of care needs to be taken with ensuring diversity of design. It can even require the different software programmes for the diverse channels to be written to different requirement specifications produced by different teams of people who have never shared the same university courses or employers.

6.2 to 6.6 will appear in Issue 75

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