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Electromagnetic Compatibility Industry Association

10th Anniversary Year

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Significant revenue increase keeps Rohde & Schwarz on track for growth

The Munich-based electronics group Rohde & Schwarz can look back on an extremely successful 2010/2011 fiscal year (July to June), a year that yielded the company's best ever results in terms of revenue, investments and number of employees.

Rohde & Schwarz ended the past fiscal year (July 2010 through June 2011) with a revenue of EUR 1.58 billion. This represents a 25 percent increase over last year's level of EUR 1.26 billion (July 2009 through June 2010). The size of workforce reached an all-time high of 8,400 employees by the end of the fiscal year. Worldwide investments also reached their highest levels ever, especially investments in new production facilities (EUR 130 million) and in research and development (EUR 228 million).

After two years marked by the effects of the global economic crisis, Manfred Fleischmann, President and CEO of Rohde & Schwarz, has every reason to be pleased. "We are back on track for growth, and have actually exceeded our sales targets by a wide margin. We plan to continue steering this course in the future."

The company's four pillars – test and measurement, broadcasting, secure communications, radiomonitoring and radiolocation – provide Rohde & Schwarz with a broad foundation. The strongest growth driver in the past fiscal year was mobile radio T&M. The Rohde & Schwarz order books are full thanks to the continuing boom in smartphones and tablet PCs, and the kickoff of LTE. "The sudden surge in demand created a special challenge for our production plants," said Fleischmann. "We responded by increasing the production capacity of our Memmingen and Teisnach plants in Germany and of our Vimperk plant in the Czech Republic."

Rohde & Schwarz profited from positive developments in the wireless communications market, particularly in the USA and China. These two countries were among the top contributors to total group revenue. Major growth was achieved in the wide-base market, especially in Europe. The new oscilloscopes launched in mid-2010 were well received by the market. Rohde & Schwarz also expanded its global market share in aerospace and defense.

The company's broadcasting business also improved in 2010/2011 compared with the previous fiscal year. Rohde & Schwarz maintained its position as the global market leader for digital terrestrial TV transmitters. The successful takeover of Hanover-based DVS Digital Video Systems AG, a leading manufacturer of hardware and software for professional film and video post production, was another contributing growth factor. One objective of this new partnership is the transfer of technology between studio and broadcasting solutions.

Results in the secure communications and the radiomonitoring and radiolocation business fields were more moderate due to a number of factors, including the consolidation of public spending in 2010/2011. Nevertheless, both fields made positive headway in the past fiscal year. In 2011, Rohde & Schwarz expanded its product portfolio for air traffic control (ATC) by adding voice communications systems based on a product from Topex, a Romanian company in which it acquired an interest in 2010. As a result, Rohde & Schwarz can now offer complete IP-based, single-source system solutions, from the air traffic controller's microphone to the radio system antenna. The radiomonitoring and radiolocation business gained new expertise in the analysis of IP data packets by acquiring Leipzig-based ipoque GmbH in 2011.

In the past fiscal year, the family-owned company continued to forge ahead with its global strategy by expanding activities in the USA and Asia. Rohde & Schwarz plans to improve its portfolio for the regional growth markets in these countries and is therefore focusing on the rapid expansion of its market position in the USA and its R&D center in Singapore. In addition, production plants set up in Singapore at the beginning of 2011 and in Malaysia in July 2011 bring production geographically close to the company's R&D activities at its Asian headquarters.

Taking a look at fiscal year 2011/2012, Fleischmann is convinced that Rohde & Schwarz is well positioned to face new challenges and withstand any possible setbacks. He expects revenue in the new fiscal year to be comparable to the 2010/2011 level. Over the coming years, the company plans to expand mainly through organic growth and by launching more new products. "We will continue to expand our position as a technological leader in the future to ensure that we can offer our customers the solutions they need to achieve success," stated Fleischmann.

www.rohde-schwarz.com

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News and Information

Rohde & Schwarz adds HAMEG products to its European sales network

Customers can now obtain the entire HAMEG Instruments T&M portfolio via the European Rohde & Schwarz sales network. Andre Vander Stichelen, Director of Sales and Business Development Test & Measurement at Rohde & Schwarz, elaborates: “We now offer what many of our European customers have requested, the ability to purchase HAMEG products directly from Rohde & Schwarz.”

HAMEG Instruments was fully taken over by electronics specialist Rohde & Schwarz in 2005. The subsidiary’s T&M instruments supplement the Rohde & Schwarz portfolio in the lower price segment. HAMEG Instruments is an established supplier of general purpose instruments, especially oscilloscopes. In 2010, Rohde & Schwarz itself successfully broke into the high end of this market with the launch of its own families of oscilloscopes. “By integrating the product portfolio of HAMEG Instruments into the sales structure of the parent company, Rohde & Schwarz has succeeded in providing its customers with T&M instruments in all price classes from a single source,” emphasizes Vander Stichelen. **www.rohde-schwarz.com**

EMCIA 10th Anniversary

The EMCIA was formed on 20th March 2002 for the benefit of companies involved in Supplying, Designing, Testing and Manufacturing EMC products. Networking lunches are held 3 times a year. The Christmas lunch has established itself as a very enjoyable networking event. Members have access to a “Members only” section of the web site which contains many interesting documentation on relevant Standards and various documents issued by BIS.

The inaugural President was Chris Marshman. Over the past ten years other presidents have been Vic Clements and Keith Armstrong, the current President is Paul Duxbury. Presidents serve for a term of two years and at the AGM on 16th May a New President will be elected.

The EMCIA is led by an Executive team appointed from its members. Decisions that do not affect the constitution are made at this level; thereby ensuring actions can be introduced in an efficient manner. For a list of Executive Committee Members go to the About page tab on the menu: www.emcia.org

The Association provides an excellent vehicle for promoting your company’s products and services via the web site. Your literature and Application notes can be listed Free of charge to all members.

Secretariat is Nutwood UK Limited Publishers of the EMC Journal. If you would like to attend the next meeting as a guest, with a view to becoming a member please contact Pam Hutley, emcia@emcia.org.

Next Meeting: AGM held on 16th May at Broadway House, Tothill Street, London SW1H 9NQ

www.emcia.org

AR RF/Microwave Instrumentation names New Regional Sales Manager for Pacific Rim

AR RF/Microwave Instrumentation has announced the appointment of Mike Alferman to the position of Regional Sales Manager for the Pacific Rim. Alferman joins Alan Melnyk in servicing AR clients in this region. Mr. Alferman will provide service to India, Singapore, the Pacific Rim Countries, South America, and South Africa. This appointment will bring AR additional focus in this very important region.

Mike became a Ham Radio operator more than 40 years ago; and he was able to turn his interest in electronics and RF into a successful career. He’s held key positions in RF Applications Engineering, Product Marketing and Business Development throughout his career at EPCOS/Siemens, Andersen Laboratories, IWPC, Eastman Kodak, and Loral. His experience includes working on the development of integrated RF modules that enabled the size reduction and functionality in the cell phones and laptops that are in widespread use today.

News and Information

University of Oxford Technology Programme 2012

These courses for professionals are taught by leading industry and academic specialists.

Small class sizes allow for maximum opportunity to enhance learning and discuss individual questions with the course tutors.

Short intensive courses delivering practical knowledge that can be used immediately in the workplace.

All classes held in a relaxed and informal setting.

Open to all - no formal entry requirements.

Electronics/RF/Microwave/Antennas

- Successful RF PCB Design (9 February)
- Practical Antenna Design (11 - 12 June)
- Overview of Electronics (26 - 27 June)
- Overview of Digital Electronics (28 - 29 June)
- Practical RF/Microwave Design (2 - 6 July)
- Digital Signal Processing: theory and application (3 - 5 July)
- Digital Signal Processing Implementation: algorithms to optimization (6 July)
- Microwave Radio for Next Generation Networks (4 - 6 July)

Signal Integrity/High-Speed Digital Design/EMC

Howard Johnson, author of High-Speed Digital Design - A Handbook of Black Magic is back at Oxford University in June 2012 with his two world-renowned courses. These two courses are not available to the public anywhere else in Europe.

- High Frequency Measurements: probes and equipment used in Signal Integrity and EMC work (19 - 20 June)
- EMC and ESD Lab Techniques for Designers: troubleshooting to proactively avoid field or compliance problems (21 June)
- Advanced Troubleshooting Techniques for Circuits and Systems (22 June)
- High-Speed Digital Design (26 - 27 June)
- Printed Circuit Board Design for Real-World EMI Control (26 - 27 June)
- High-Speed Noise and Grounding (28 - 29 June)
- Advanced EMC: Fullwave Modelling for EMC and Signal Integrity (28 - 29 June)
- Power Distribution Design (2 - 3 July)

Telecoms and Mobile Technologies

Harri Holma and Antti Toskala (Nokia, Finland) authors of the current definitive works, LTE for UMTS - OFDMA and SC-FDMA Based Radio Access, HSDPA/HSUPA for UMTS and WCDMA for UMTS are back with a new series of LTE-related courses.

- LTE and HSPA Evolution: System Design and Operation (2 - 6 July)
- LTE and HSPA Evolution Standards and System Performance (3 - 4 July)
- LTE and HSPA RF Design and Performance (5 July)
- LTE and HSPA Protocols (6 July)
- Beyond 3G – Bringing Networks, Terminals and the Web Together (17 - 18 October)
- Designing Multiplatform Apps: TV Web Mobile and Automotive Platforms (18 October)
- Forum Oxford Mobile Applications Conference 2012 (19 October)
- WCDMA and HSPA Networks and Terminals (date to be confirmed)
- IMS / SIP (date to be confirmed)

Systems Engineering

This course is based on 20 years experience in systems engineering and draws in current state-of-the-art knowledge in the field - this course has quickly become known throughout industry for the quality and depth of its content and teaching.

- Systems Engineering Fast-Track (25 - 26 February and 10 - 11 March, a four-day course held over two weekends)

Management Skills for Engineers, Scientists & Staff in Hi-Tech Companies

These four intensive one-day courses are all aimed at engineers and scientists. Due to their popularity, these are offered three times each year in April, July and November.

- Applying Knowledge Management: Principles and Practices (17 April)
- Successful Change Management for Engineers & Scientists (18 April)
- Essentials of Project Management for Engineers & Scientists (19 April)
- Advanced Project Management for Engineers & Scientists (20 April)

For further information or to register visit our website: www.conted.ox.ac.uk/technology or contact us on +44 (0)1865 286958 or email electronics@conted.ox.ac.uk

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York EMC Services part of 2.5M Euro Railway EMC Research project – TREND

York EMC Services is pleased to announce that the 2.5M Euro TREND project has received EU approval. TREND (Test of Rolling Stock Electromagnetic Compatibility for Cross-Domain Interoperability) is part of the EU FP7 framework (Project reference: FP7- TRANSPORT-285259) and is intended to address the variability of electromagnetic compatibility (EMC) measurements of rolling stock, with the intention of informing current Railway EMC Standards and improving the interoperability of trains across Europe.

Chris Marshman (3rd from left, front), Managing Director of York EMC Services accompanied by Rob Armstrong (3rd from left, back), newly transferred from the Department of Electronics (University of York), attended the project 'kick-off' meeting in San Sebastian, Spain on the 23rd and 24th of November 2011. Chris remarked: "We are delighted to be involved in TREND, which will keep us at the forefront of Railway EMC measurements and testing".

TREND project consortium

Chris Marshman (3rd from left, front), Managing Director of York EMC Services accompanied by Rob Armstrong (3rd from left, back) newly transferred from the Department of Electronics (University of York) with other project partners at the 'kick-off' meeting in San Sebastian.

York's contribution to the project will bring all of the experience obtained both from the Department of Electronics and York EMC Services to the fore in a European setting. We have the unique experience of being involved in all stages of the EMC assurance process in the Railway industry from initial EMC management plans all the way through to on-site testing. York EMC services will be leading both the first research based work package and the crucial work package involving the design and verification of a new testing procedure. The TREND project will run for 36 months and has brought in 440k Euros. York should also look forward to hosting a scientific meeting in the city as part of the TREND project.

For York EMC Services this work will build on earlier research carried out for independent regulator Ofcom, which culminated in receiving a National Measurements Award 'honourable mention', the IET Award for Advancement in Railway Safety and an IEEE EMC Symposium Award for best paper.

Banana Skins...

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

676 EU Spectrum Policy Does Not Answer Interference Questions

Latest negotiations that pave the way for a coherent set of rules on new spectrum use are poised to help the EU achieve the much talked about Digital Agenda. The Commission has made a clear call to Member States to put in place procedures to promote coexistence between new and existing services. But the latest text of the new Radio Spectrum Policy Programme (RSPP) falls short of capitalizing upon efficient use of spectrum if new services interfere with existing services.

The latest developments give hope that the European Commission wishes to promote competition, investment and the efficient use of spectrum. However, back in 2009, Cable Europe issued a call to the Commission and EU member states to take interference to a range of existing services into account. In the current absence of an answer of how to respond to potential interference, future spectrum challenges for consumers will need to be examined more closely.

Cable Europe published a News Release in Brussels on 15 November 2011, entitled "Getting European Spectrum Policy Right Through Coexistence — EU deal leaves key questions on coexistence between new & existing services unanswered; Who's responsible if new services create interference?"

In this document they said: "However, back in 2009, Cable Europe issued a call to the Commission and EU member states to take interference to a range of existing services into account. In the current absence of an answer of how to respond to potential interference, future spectrum challenges for consumers will need to be examined more closely."

"The interference issue is not new. It was signaled to the European Commission and national administrations as soon as it was identified," says Cable Europe Labs Managing Director, Peter Percosan. "Spectrum in Europe is something that almost every single EU citizen relies upon daily in some form. Given its importance, it is disappointing to see that interference has not been given adequate attention on the technical level. Technical bodies, such as CEPT, have an important role to play in ensuring coexistence. However, CEPT has not agreed to look into interference with consumer equipment as we anticipate new spectrum needs for new technologies such as cognitive radio. We all know that there will be a growing cocktail of devices and getting those to work together is critical for Europe and its Digital Agenda."

(Taken from www.interferencetechnology.com/ standards-update/article/ eu-spectrum-policy-does-not-answer-interference-questions.html 11/17/11 11:10 AM and www.cableeurope.eu/ uploads/MediaRoom/documents/ 111115_gs_News%20Release_EU%20 Spectrum%20developments%20FINAL.pdf.)

677 Electromagnetic Interference Enables/Disables GM Airbags; GM Forgets to Inform Customers

What happens when you put your iPad on the front passenger seat of a 2012 Buick Enclave?

That depends on which General Motors (GM) source you consult. In May, the automaker sent out a Technical Service Bulletin warning that when "certain electronic devices" such as computers, MP3 players and cell phones are placed in the front passenger seat of a wide range of recent models, the front passenger airbag indicator may illuminate, enabling the airbag, and activating the seatbelt reminder light and warning chime – due to electromagnetic interference (EMI). Even though that iPad only weighs 1.5 pounds, the seat sensor suddenly thinks that this designated seating position is occupied. More recently, an OnStar operator told a GM owner that if a passenger is seated in the right front seat with an electronic device in his or her lap, EMI may disable the airbag. In other words, if the sensor correctly perceives that an occupant is in the seat, then interference from the iPad tells the sensor to turn the airbag off. In complaints reported to SRS GM owners said electronic devices held by a front seat passenger turned off the passenger airbag.

"We called OnStar and spoke to a tech," said one owner. "He confirmed that this can be caused by cell phones and cell towers." If one consults the owner's manual of a 2012 Buick Enclave (which is among the models covered in the May 25 TSB), it warns: "The front passenger safety belt reminder light and chime may turn on if an object is put on the seat such as a briefcase, handbag, grocery bag, laptop, or other electronic device. To turn off the reminder light and/or chime, remove the object from the seat or buckle the safety belt." Is this a warning about lightweight objects triggering a seatbelt sensor? Does the seat sensor confuse an iPhone with an occupant too small for safe protection from the airbag? Or, more likely, is this an obfuscated EMI warning? The owner's manual is silent on this caution.

The May 25 TSB covers 12 models over the 2009-2012 model years. It warns "some electronic devices placed on the front passenger seat may interfere with the electric field generated by the PPS system, causing it to enable (turn ON) the passenger airbag and turn on the safety belt reminder light and chime" – even though the seat is not occupied.

The electronic device does not necessarily need to be turned on to cause this condition." It also cautions techs: "Never rest the diagnostic scan tool or components on the passenger front seat or touch the passenger front seat while the diagnostic scan tool is in contact with your body. This may cause the SIR lamp to illuminate while holding the diagnostic scan tool because your body can transfer the electronic 'noise' to the sensor mat in the passenger front seat." (This may explain what happens when a right front seat passenger uses a cell phone.)

The fix was to simply clear the codes – which could relate to a variety of error messages involving the seat sensor or the ECU – and send the customer on his way.

If the GM owner lives in the Texas Panhandle, however, the problem is worse, and requires a more intensive fix. On May 25, 2011, the automaker issued a second and unusual warning for techs in Texas. This TSB warned that the airbag warning light could behave erratically in the presence of EMI. "This condition may be caused by possible electro-magnetic interference in the Amarillo, Texas area from external sources such as aviation airspace traffic radar, creating erratic sensor information to the SDM," the bulletin said.

This TSB covered 18 models in the 2010 and 2011 model years. In this case, the techs were required to amend the sensor by adding ferrite clamp beads (Laird Part No. HFA100049-0A2) on either side of the inflatable restraint sensor wire harness.

There are several international voluntary standards and vehicle manufacturers have set their own criteria governing EMI, but no Federal Motor Vehicle Safety Standard. But as the world goes ever more wireless, are automakers and NHTSA keeping up?

According to EMI Expert Keith Armstrong, "some vehicle manufacturers' standard tests only apply to the normal operating functions of the components and subsystems. For example, an airbag should not operate, a speedometer should show the correct speed within specified tolerances, etc., but they lack requirements to test the correct operation of safety systems, by stimulating them with a signal that should make them operate, and check that they always do operate as designed whilst exposed to EM disturbances."

As the transformation of an automobile continues from a collection of mechanical parts to a computer on wheels with communication interfaces to non-vehicle wireless devices from the driver and passengers inside, or from sources outside the vehicle, today's vehicles are expected to function correctly in a very noisy electrical environment.
(Taken from: The Safety Record, Volume 8, Issue 3, November 2011, published by Safety Research and Strategies, Inc., www.safetyresearch.net.)

678 Early mobile phone interfered with aircraft navigation
Vic Eliason, while reminiscing on the daily "VCY Today" on an American radio station VCY America, told of the early days. What has grown into VCY America began about 50 years ago with borrowed equipment - they did not even own a microphone stand.

Vic remembers their first cell-phone. It weighed about 9 lbs, and had a 5 watt transmitter. This made it useful for outside broadcasts. But they soon learned not to use it in an aircraft. It interfered with the navigation equipment, and every time they pressed the "TALK" button, the aeroplane would veer off course as the pilot adjusted to what the navigation instruments showed.
(Kindly sent in by Robert Higginson, a regular contributor to Banana Skins, who produced the above summary from memory immediately following the broadcast VCY Today on VCY America when presenter Vic Eliason reminisced about the early days of that station which began 50 years ago.)

679 RF susceptibility of Phantom II Aileron-Rudder Interconnect (ARI)
Like many UMR graduates, Doug went to St. Louis to work for McDonnell Aircraft, eventually McDonnell-Douglas, and now Boeing. Mr. Mac probably rolled over in his grave after the Boeing takeover/merger (many say that MacAir took over Boeing, but that is out of scope for this profile).

One of his most enduring of the MacAir educational experiences dealt with the RF susceptibility of position-transducer-fed flight control avionics. The Phantom II (F/RF-4) aircraft was in production during that era and included an Aileron-Rudder Interconnect (ARI) circuit.

Signals from position transducers on each aileron were added, amplified, and used to control a hydraulic valve to add a small amount of rudder when turning. The Wright Brothers had a mechanical method to do the same to connect their wing warp and rudder on the original Wright Flyer. The hip cradle controlled it – they literally flew by the seat of their pants.

Emissions from on-board communications transmitters would couple into the wiring between the aileron position transducers and the ARI amplifier at the vertical stabilizer base. It even happened once during an important sales flight when the Shah of Iran came to St. Louis to purchase some F-4s. He was flying the back seat of an RF-4 and noted controls for the high-frequency (HF) radio. The Shah received permission from the pilot to operate aeronautical mobile on the HF ham bands using his ham radio license. It was embarrassing when his ham transmission caused the rudder to move.

Doug was taught that there is no such thing as an uncommanded flight control surface movement. Increased wire shielding and ARI amplifier filtering fixed the problem. Doug participated in the ARI and nine additional air safety investigations during his five years at MacAir.
(One of several anecdotes of aircraft EMI mentioned in "EMC Personality Profile — Introducing Douglas J. Hughes" by Bill Duff, Associate Editor, IEEE EMC Society Newsletter, Fall 2004, www.ieee.org/organizations/pubs/newsletters/emcs/fall04/personality.html. Doug is still involved in EMI investigations, as an independent, and his email is w3ho@aol.com.)

680 Reason why pilots ban use of personal electronics below 10,000 feet
In USA Today's "Ask the Captain" column, a reader challenged in-flight electronics rules, questioning whether electronics with low EMF emissions, such as electronic book readers, cell phones and computers, interfere with in flight instrumentation. The reader points out that American flights with GoGo inflight wireless access points are enabled throughout the flight. From takeoff to landing these wireless access points are continuously operating and emitting their wireless signals.

The concern of the FAA is that an electronic emitter could cause unintended consequences to navigation receivers or other aircraft systems, said John Cox, a retired airline captain with U.S. Airways who runs his own aviation safety consulting company. Ongoing changes in electronics make it very difficult to test all the devices to ensure their safety, and during some phases of flight, the navigation system is more sensitive than others, Cox said. "An example is during an approach for landing using the Instrument Landing System (ILS). The display uses microvolts to displace a needle showing the extended centerline of the runway. As the airplane flies the ILS course, the needle becomes more sensitive (think of it as a cone with the top of the cone at the runway)."

The FAA has developed criteria for electronic devices proving their safety, but it is much more difficult for the FAA to evaluate the effects of the use of untested electronics. Hence, the ban on all electronic devices below 10,000 feet. *(From "Retired Captain Answers Challenge to In-Flight Electronics Rules" at www.interferencetechnology.com/lead-news/article/retired-captain-answers-challenge-to-in-flight-electronics-rules.html, 10/05/11 03:25 PM, which references the original USA Today story at: http://travel.usatoday.com/experts/cox/story/2011-10-03/Ask-the-Captain-A-reader-challenges-in-flight-electronics-rules/50634340/1?csp=Dailybriefing.)*

681 Inflight Wi-Fi hits more turbulence

Inflight Wi-Fi and cellphone services - which transmit low power microwave radio signals within an aircraft's fuselage – have already been criticised by security engineers for providing a ready means for terrorists to remotely detonate explosives. Now the technology has been found to be interfering with flight critical electronics too.

This latest finding was made by Boeing while testing inflight Wi-Fi equipment for use on its next generation 737 twin-engined aircraft. The Seattle-based plane maker found that a certain type of new, brighter cockpit display made by Honeywell of Torrance, California, could go blank when an inflight wireless system, made by Aircell of Itasca, Illinois, was used nearby.

"Blanking of the display units was reported during electromagnetic interference certification testing of wireless broadband systems (Wi-Fi) on various 737NG airplanes," Boeing said in a statement issued today.

The firm adds it has not delivered any aircraft using the technology and will not activate any passenger Wi-Fi systems in future planes across its whole range of aircraft until Honeywell has made its new displays Wi-Fi proof.

In 2000, the British Civil Aviation Authority borrowed a couple of airliners - a Boeing 737 from British Airways and a 747 from Virgin Atlantic - and generated simulated GSM cellphone signals in them. As New Scientist reported, they found that avionics equipment in the cockpit were susceptible to high levels of interference - the first "scientific proof" there was an issue, said the CAA.

Commercial pressures to allow lucrative wireless services on board, however, led to the development of electromagnetic shielding standards for avionics equipment, designed to ensure that emerging portable electronic devices like smartphones and laptops using 3G and Wi-Fi connectivity did not cause problems.

It was while testing to the US Federal Aviation Administration's relevant standard that Boeing found the Aircell system interfering with the new "phase three" Honeywell multifunction cockpit displays, which are brighter then their predecessors.

The interference happened at Wi-Fi signal levels that are higher than is normally emitted by phones and laptops, Boeing says, but it is quite possible for consumer equipment not to perform to specification and kick out too much power - so no chances could be taken.

"We have identified a fix and are working to ensure that temporary blanking does not occur when displays are exposed to elevated levels of electrical energy," a Honeywell spokesman told New Scientist.

The FAA is on the case. "We are aware of some issues involving interference between Honeywell flight displays and in-flight Wi-Fi that surfaced during certification testing," says Les Dorr, FAA spokesman. "We are currently working with both manufacturers to examine the technical data and test results. After a thorough review, we will consider if further safety action is necessary."
(From "Inflight Wi-Fi hits more turbulence" by Paul Marks, New Scientist, 20:39 10 March 2011. www.newscientist.com/blogs/onepercent/2011/03/inflight-wi-fi-hits-more-turbu.html.)

682 My neighbour's telly has broken my car!

An £80 TV transmitter box is being blamed for 140 cases of car key fobs failing over the past year.

Ofcom says that the 'TV senders', which plug into a satellite receiver and send the signal wirelessly to other TVs in the house, can jam the key fobs of an entire street's worth of cars.

It happened recently on Dimond Road in Southampton, when residents were baffled one Saturday morning to find that their cars wouldn't unlock.

The amount of fobs that had simultaneously failed suggested that battery failure on each was too coincidental.

Ofcom was called out to investigate, and found that one house had a TV sender. A spokesman said that a "leakage" from the device, transmitting at the same frequency as the key fobs, was to blame. It asked the resident to switch the faulty box off, which worked – all the fobs began to work again instantly.

According to Ofcom, it has to send teams of people door-knocking when a case is reported on a street, to see how many people have been affected and work out who has the offending box.

So the moral is: if your neighbor insists on watching Sky in his bedroom without paying for Multiroom, the least you can do is buy an old car...
(Kindly sent in by Sandy Armstrong, from AOL's autoblog, by Mark Nichol, Nov 4, 2011.
This report closes the case reported below – dated 12 October 2011.)

Electronic car key fobs have mysteriously stopped working along part of a Southampton street, according to residents. On Saturday, people living on Dimond Road in the Bitterne Park area found their fobs would not open their cars.

Madeleine Wentworth said: "It's really annoying, I don't like not knowing what's causing it."

It is thought the problem is being caused by interference with the radio frequencies used by the fobs. Brian Deadman described it as "baffling" and said his key fob worked perfectly well away from Dimond Road.

Neighbours have speculated about the interference being caused by a mobile phone mast or the nearby Southampton

International Airport. An airport spokesperson said it had not changed any of its frequencies.

Ofcom said residents could contact them and log a complaint which they would investigate to pinpoint the cause of the interference.

A spokesman said it was likely to be due to a signal from a malfunctioning electronic device "leaking" on to the spectrum of the key fobs.

AA technical specialist Steve Evans said the motoring organisation received about 40 call-outs over key fobs not working each month in the south – usually caused by flat fob or car batteries, or radio interference.

Mr Evans said: "If it is a problem with radio interference, try getting closer to the car and then try walking around the car - the receivers are placed in different places on different cars."
(Taken from: "Electronic car key fobs fail on Southampton street" BBC News, Hampshire & Isle of Wight, 12 October 2011, 13:42 ET, www.bbc.co.uk/news/uk-england-hampshire-15278838. This was very kindly sent in on 13 October 2011 by Tim Williams of ELMAC Services, www.elmac.co.uk; Claire Ashman, EMC test lab assessor for the United Kingdom Assessment Service (UKAS), and Les McCormack of Atkins. Les also provided some solutions he was involved in some time ago, at: http://yorkemc.co.uk/research/low-power-radio/LPD_Guide.pdf, and http://yorkemc.co.uk/research/low-power-radio/LPR.pdf.)

683 Domestic products interfere massively with AM and FM reception

"The article shows a very nice antenna. I've built several less sophisticated than that design already and they don't get the job done. What I really want to do is put an FM antenna on the roof complete with amplifiers and rotor.

The current system with any antenna in the room has to fight off local interference, especially from the new electric blanket.

It seems like FCC class B requirements are no longer being enforced, especially on cheap import products. The control on the electric blanket is the second new product we have gotten that massively interferes with all the radio broadcast bands, both FM and AM reception."
(Kindly supplied by Steve Webb of SELEX Galileo, on 18 October 2011, the second reply, from Ed Weldon: http://cr4.globalspec.com/thread/72947/FM-Radio-External-Antenna-Connector?frmtrk=cr4digest.)

684 M2M GSM module interferes with its own and a neighbouring machine

At the moment, our lab is facing the problem of an M2M (machine-to-machine) GSM module perturbing the machine itself !!! (The reason is bad termination of a shielded cable ... once more.) Also, it is perturbing a sensor on a nearby machine.
(Taken from private correspondence with Keith Armstrong, 20 September 2011. The author wishes to remain anonymous. M2M, like RFID, is a rapidly growing "business opportunity", and M2M suppliers estimate its global market size for GSM transmitters to be double that for cellphones, visit: en.wikipedia.org/wiki/M2M.)

The Editor writes: This Banana Skin highlights a very important issue for the RF immunity of safety-related electronic systems, until now designed to meet quite low RF field strengths, e.g. 3V/m or 10V/m, on the basis that operators will not use their cellphones or walkie-talkies nearby. This is called creating an "RF Exclusion Zone", and I doubt that they have ever worked very well unless actively and continuously enforced – see Banana Skin number 684 (below) and 651 (July 2011).

But with RFID readers soon being used almost everywhere for operational reasons, and M2M transmitters invisibly embedded into items of equipment, as well as wireless transmitters hidden in items that one doesn't think of as a cellphone or walkie-talkie (e.g. laptops, e-book readers) – the days of the RF Exclusion Zone are clearly numbered.

Philip Keebler of the prestigious EPRI thinks so, anyway, and he has written two articles in In Compliance magazine about what should replace it: "Eliminating the Need for Exclusion Zones in Nuclear Power Plants, Part 1", June 2011: www.incompliancemag.com/index.php?option=com_content&view=article&id=699:eliminatingthe-need-for-exclusion-zones-in-nuclear-power-plants&catid=26:design&Itemid=130, and "Part 2": 10 July 2011, www.incompliancemag.com/index.php?option=com_content&view=article&id=737:eliminating-the-need-for-exclusion-zones-in-nuclear-power-plants-part-2&catid=26:design&Itemid=130.

685 Russian Satellite Crash May Have Been Caused By EMI

A Russian Geo-IK-2 satellite launch failed "because of possible external electromagnetic interference from a sea-, land- or air-based source."

The satellite was launched by a rocket converted from a SS-19 intercontinental ballistic missile that apparently did its job sufficiently well, but an additional Briz-KM booster malfunctioned.

Finally, the Geo-IK-2 was boosted to an abnormal 370 to 1,020 km elliptical orbit. The satellite's solar batteries unfolded and contact was established, but it could not function properly.

A "reliable space industry source" told Interfax news agency that the Briz-KM booster failed during the Geo-IK-2 launch "because of possible external electromagnetic interference from a sea-, land- or air-based source" while the platform was on the other side of the globe out of sight of the Russian control center (Interfax, February 14). Of course, only the grand old enemy – the US – could have sabotaged the Geo-IK-2 launch by a presumed death-beam – to undermine Russia's possible GLONASS (GPS) independence.
(From http://www.interferencetechnology.com/lead-news/article/russian-satellite-crash-may-have-been-caused-by-emi.html, 03/09/11 02:16 PM and also from : http://politicom.moldova.org/news/russias-glonass-positioning-system-cannot-work-properly-217776-eng.html.)

Banana Skins

Banana Skins are kindly compiled for us by Keith Armstrong.

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

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

John Woodgate's Column

At last! Or is it?

CISPR32, the new emission standard for multimedia equipment (ITE and consumer entertainment) has passed its second vote. However, several countries are very unhappy with it and have submitted many comments. Some negotiation will no doubt take place, but the IEC rules are very strict about changes to an FDIS text.

The sources of comments are such that it is unlikely that the standard will be widely accepted in the Americas and there will no doubt be persistent demands for Common Modifications in the derived EN 55032 that will surely follow. It would be wise for CISPR/I to start immediate work on a revision, as TC108 did with the unsatisfactory First Edition of IEC 62368-1.

It is quite surprising that the multimedia emission standard has proved so difficult to progress: Emission is a much simpler subject than immunity, since, in principle, emission requirements should be product-neutral and technology-neutral, whereas an immunity level, and even how best to determine it, may be dependent on the precise characteristics of each individual technique or application.

Greek EMI

The Greek authorities have reported EMI problems due to HF band emissions from trams and trolleybuses, mostly in the induction field due to the relation between the wavelength and the measurement distance. The applicable standard is EN 50121-2 *Railway applications. Electromagnetic compatibility. Emissions of the whole railway system to the outside world*, but it is argued that its limits are too lax. The Technical Specification CLC/TS 50217 *Guide for in situ measurements - In situ measurement of disturbance emission* has limits which are considered acceptable.

Two Gigs

The European Commission has submitted a questionnaire for public consultation in order to collect the views of stakeholders on the options for the possible introduction of harmonisation conditions for the terrestrial 2 GHz band, specifically the frequency ranges 1900-1980 MHz, 2010-2025 MHz and 2110-2170 MHz. The closing date was 18 January but there is no indication at present of the timing of any follow-up.

Mind your A's and B's

CISPR has at last attempted to establish definitions of Class A and Class B environments. The proposals a re very similar to some I made about four years ago:

Class B environment is defined as follows:

Residential (domestic) environment is an environment where:

- Class B equipment and broadcast receivers are directly connected to a residential low voltage power supply network;
- where the use of broadcast receivers may be expected at a distance 10 m from the EUT in the frequency range up to 1 GHz;
- the use of radio receiving equipment operating in the frequency range above 1 GHz may be expected down to a distance of 3 m from the EUT;

The Class B environment also includes commercial/public and light industrial environments where equipment is connected to the low voltage power supply network to which residential establishments are connected.

and

Class A environment is defined as follows:

Industrial environment is an environment:

- which does not include a residential low voltage power supply network;
- where the use of broadcast receivers may be expected at a distance greater than 30 m from the EUT in the frequency range up to 1 GHz;
- where the use of radio receiving equipment operating in the frequency range above 1 GHz may be expected at a distance greater than 10 m from the EUT;

The Class A environment also includes commercial/public and light industrial environments where equipment is connected to the low voltage power supply network to which no residential establishments are connected.

Note In France, there are LV networks that feed commercial/ public and light industrial environments only. In other countries, they are rare.

We shall see in due course whether these can be accepted by National Committees.

Less uncertainty?

It has been said that repeatability of emission test in the VHF range can be compromised by different common-mode impedance of cables. Most of the emissions from normal-sized EUTs comes from common-mode voltages on the attached cables, as the EUT itself is to small to be an efficient radiator, even at VHF. The use of a common-mode absorber (CMAD) is really inappropriate, because that tends to minimises emissions compared with the real-life situation, by presenting a high common-mode impedance to the emission source in the EUT. Another possibility is to use the relatively new Coupling and Decoupling Network for Emission (CDNE), and this might well be suitable for some signal cables. However, for mains cables, the common-mode impedances presented by the common Artificial Mains Networks (AMN) for the frequency range 9 kHz to 30 MHz, are much lower than those of the CDNE, so it is proposed to introduce a 'VHF-LISN' (Line Impedance Stabilizing Network) which has the same or similar impedances in the VHF band as the AMNs do in their bands.

The proposed network consists of capacitors, resistors and ferrites only, so if the device is accepted into standards, it may well be possible to build one suitable for pre-compliance testing rather than buying a fully-certified one at significant cost.

Antenna and site calibrations

CISPR/A is having a 'wonderful' time updating CISPR 16-1-5 and -6. Numerous CDs have not received very good receptions, but there is some confidence that the end is in sight with the latest pair. One novelty is the introduction of sweep-frequency measurements to detect reflections from resonant structures. The amendments that result from this work will be large documents (one CD is over 40 pages) , so consolidated issues of the standards, embodying the amendments, will probably be the only usable form of document.

Low-frequency conducted emissions - is the test gear correct?

Or, in short, 'Is your kit fit?'

IEC SC77A has effectively standardized the performance of two specialist test boxes, one for measuring harmonics and other quasi-continuous low-frequency conducted current emissions and the other for measuring flicker and other repetitive or discontinuous voltage changes. Both incorporate precision analogue circuits, which need high dynamic ranges (milliamps to several tens of amps, for example), and fairly complex digital processing. Such arrangements are very prone to unpredicted and highly unwanted effects, that may be well hidden until some particular circumstance makes them evident. The measuring systems also include high-performance power supplies, and even the connecting cables have to be carefully chosen so as not to introduce errors.

It is therefore necessary to have instrumentation that can determine whether the boxes always behave, with a high degree of certainty, as intended, and give results that can be relied on. This can be achieved with top-class general-purpose instruments, but this method is very costly and time-consuming. A much better solution is to use the system to test itself, using test software that simulates real load characteristics that could cause incorrect performance.

Unfortunately, the draft documents have run into problems because they use terms like 'calibration' which have strict definitions that are not widely respected, so that the actual meaning in a given sentence is not clear and is very likely to mislead those who respect the strict definitions. This is an example of 'Tower of Babel' effect - language sometimes fails to give us the precision communication we require, and not only when we stub a toe!

It is perfectly possible to solve this problem, at least In English, where we have at least three ways of saying anything, derived from Anglo-Saxon, Latin or Norman French. You can see what I mean by looking at the above sub-heading and the next sentence. We 'just' write the documents without using the 'sensitive' words. It can be done, but we shall have to see whether our international colleagues will agree.

On the product safety front, we have had two tragic accidents to consider. In one case, a boy swallowed the cap of a USB memory stick, and in another, a boy swallowed a small battery, probably a 'coin cell'. Curiously, no action has been taken in the first case, where a standard could eliminate the hazard by requiring that such devices have no loose parts. For example, BSI itself has a promotional memory stick that has a U-shaped cover hinged at the end remote from the USB connector, and these are freely available in other guises. In the second case, it is proposed to introduce tests in IEC 62368-1 to ensure that such a battery cannot escape from its enclosure by accident or through damage to the enclosure, or be easily extracted from the enclosure by a child. However, this is not sufficient; the most likely hazard is probably due to someone leaving a discarded battery lying around where a child can find it, and that can only be weakly dealt with in a standard, by putting a warning in one of those bits of paper that you throw out, no, *recycle* with the product packaging - it's often called 'Instruction Book', and may be written, these days, in several unknown languages that bear a superficial resemblance to English, French, Estonian...

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Know Your Standards

Diversion

I planned to follow the treatment of CISPR 16/EN 55016 with a similar piece on the IEC/EN 61000-4- series of Basic EMC standards, but the Kindly Editor has agreed that it would be timely to deal with the planned changes to the CE Marking, EMC and Low Voltage Directives prompted by the implementation of the New Legislative Framework, even though EU Directives are not standards and that distinction is important.

Note - Some 'Old style' Directives include technical requirements just like those in a standard, but they are still produced by the Commission and not by CEN, CENELEC or ETSI.

There is opportunity here to introduce pages of legalistic prose, but I hope the diversion will be more diverting than that.

New Legislative Framework

We have to start right here, otherwise none of it will make sense. The NLF is said to be about 'improving the free market', and one of its specific objectives is to remove different interpretations of Directives in the Member States. But a second specific objective is to remove different **implementations** of Directives in the Member States, and effectively that addresses the subject of **market surveillance**. It is well-known that some Member States have invested very heavily in this activity, while others, including UK, have not. There is still a difference among the 'have nots'; some, including UK, have procedures that are likely to catch high-volume non-conforming products, while not bothering too much about low-volume stuff, while others simply don't bother at all. Once products come within the EU borders via a 'not bothered' country, they can legally be marketed anywhere until they are proven non-conforming, which can be a very costly and slow process. This has prompted some countries to devise ingenious methods of preventing their marketing. Other Member States don't like this, because such measures could be applied selectively to products originating outside a *state* border, not the EU border; in other words, scuppering the Free Market. Small and medium sized enterprises (SMEs) should no longer be discouraged from export business. A Member State that refuses a product access to its market has to give detailed reasons, making life easier for companies. Market surveillance systems for industrial products will be strengthened, thus improving the credibility of CE marking.

The NLF is implemented with three documents:

> Regulation (EC) No 764/2008 of the European Parliament and of the Council of 9 July 2008 laying down procedures relating to the application of certain national technical rules to products lawfully marketed in another Member State and repealing Decision No 3052/95/EC

> Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93

> Decision No 768/2008/EC of the European Parliament and of the Council of 9 July 2008 on a common framework for the marketing of products, and repealing Council Decision 93/465/EEC

Regulations are immediately binding on all Member States: they are not debated in Parliaments. Brussels hath spoken! The Decision does not have quite the same legal force, but it includes mandatory provisions related to CE marking and has a great deal to say about conformity assessment. It also includes an explicit format for a Declaration of Conformity:

EC DECLARATION OF CONFORMITY

1. No … (unique identification of the product):
2. Name and address of the manufacturer or his authorised representative:
3. This declaration of conformity is issued under the sole responsibility of the manufacturer (or installer):
4. Object of the declaration (identification of product allowing traceability. It may include a photograph, where appropriate):
5. The object of the declaration described above is in conformity with the relevant Community harmonisation legislation: . . . .
6. References to the relevant harmonised standards used or references to the specifications in relation to which conformity is declared:
7. Where applicable, the notified body ... (name, number) … performed … (description of intervention) … and issued the certificate: …
8. Additional information:

Signed for and on behalf of: ……………………………
(place and date of issue):
(name, function) (signature):

One wonders what the interpretation of 'installer' is in item 3. Is it the fellow who installed my bathroom heater? (;-)

The aim is to strengthen the application and enforcement of internal market legislation and Improve market surveillance rules. There is also seen to be a need to eliminate non-performing conformity-assessment bodies (test houses). T**he meaning of CE marking** needs to be more clearly established and its legal position strengthened, as a trade mark. A common legal framework is said to be needed in the form of **measures for use in future legislation**. One welcome measure is to establish uniform definitions of some terms which are used with different meanings in current EU documents.

Regulation 765 and Decision 768 are separated for legal reasons, and form a basis for future legislation. There is far more in these documents than I can even summarize in one article. You really DO need to download them and read them. Like the ISO/IEC Directives, they are the rules of the game, and if you want to win often, you need to know the rules. It is important to read not only the body text but also the preamble, introduced by the keyword ‘Whereas’. This text often clarifies the purpose and real meaning of the provisions, in particular what they DO NOT mean. For example, ‘Whereas 28’ of Regulation 764 says:

> It is important for the internal market in goods that the accessibility of national technical rules be ensured, so that enterprises, and in particular SMEs, can gather reliable and precise information concerning the law in force.

There is one country in particular that has traditionally established product acceptability rules that no-one in that country is allowed to mention to outsiders. One wonders if the practice will now cease; that is certainly the intention of the Regulation.

Regulation 765 deals with the accreditation of conformity assessment bodies, the market surveillance of products to ensure that those products fulfil requirements providing a high level of protection of public interests, such as safety, consumer interest and environmental protection. It also sets out the principles of CE marking.

Decision 768 deals with the conformity assessment procedures themselves and has a 40-page series of annexes specifying different procedures that can be selected for application when Directives are prepared.

Effects on Directives

The above document were issued in 2008, and have applied form the beginning of 2010, so of course you have had plenty of time to learn them by heart, but the implications for the Low Voltage and EMC (and eight other) Directives are still not finalized. The introductions to the draft Directive revision documents are virtually identical and cite the problems that need to be addressed:

- the presence of non-conforming products on the market, leading to a certain lack of trust in CE marking;
- competitive disadvantages for economic operators complying with the legislation as opposed to those circumventing the rules;
- unequal treatment in the case of non-compliant products and distortion of competition amongst economic operators due to different enforcement practices;
- differing practices in the designation of conformity assessment bodies by national authorities;
- problems with the quality of certain notified bodies;
- Inconsistencies in legislation applying simultaneously to one product, making it difficult to correctly interpret and apply that legislation.

I think few of us would argue with that.

Changes to Directives

The revision documents include very many purely editorial revisions of references and dates, which somewhat obscure the more important proposed changes. A new Regulation on European Standardisation sets out a horizontal legal framework for European standardisation, so some words are no longer needed in each Directive on this subject.

A new provision specifies the steps to be taken when a non-compliant apparatus is found. The full ‘safeguard’ procedure – leading to a Decision at Commission level on whether a sanction is justified - is launched only when another Member State objects to a sanction. If there is no disagreement, all Member States must take the same action.

A provision that may prove controversial is that a manufacturer and an importer must put their name **and address** on the product (or on the packaging if that is not possible). Addresses are liable to change very often, so they do not seem to have much value for market surveillance purposes. Importers and distributors are to have virtually the same obligations as manufacturers, including, for importers, providing a name and address. Indeed they may, under some circumstances, be deemed to be manufacturers (e.g. if they apply their own brand name), with respect to ensuring conformity, preservation of documentation, including the Declaration of Conformity, and informing the surveillance authority if they become aware of any violation of the provisions.

Manufacturers, importers and distributors (‘economic operators’) must on demand disclose the sources of their merchandise and the purchasers of it.

DoCs must be provided in a language acceptable to the Member State in which the product is marketed, and a single DoC is required even if several Directives apply to the product. A colour picture of the product is required if the LVD applies.

Will it work?

There is a 2 year transitional period after adoption of the new Directives (whenever that will be), and by that time at least some Member States may be able to afford the costs associated with these new provisions. Otherwise, nothing much can change.

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PRODUCT GALLERY

New flame retardant EMC shielding gasket from Kemtron

Kemtron, the British manufacturer of RFI/EMI shielding gaskets, materials and components has launched a flame retardant, low smoke, low toxicity EMC shielding gasket. Tested and approved to the international standard UL94V-0 by Underwriters Laboratories for flame retardancy, file number E344902. Also tested for smoke density to BS 6853:1999: Annex D.8.3 and oxygen index to BS EN ISO 4589-2:1999 confirming the material meets to requirements for minor internal use on vehicles category 1a such as gaskets for electronic enclosures, making it highly suitable for applications in underground transportation, trains and other safety critical applications.

The material is a nickel coated graphite loaded into silicone elastomers, product code SNG-FR, the gasket provided a highly electrically conductive path between mating flanges of an electronics equipment enclosure giving a high level of RFI/EMI shielding. The material can be supplied as an extruded strip in various profiles, "O" rings or flat die cut gaskets.

Tel: +44 (0)1376 348115
info@kemtron.co.uk
www.kemtron.co.uk

New TESEQ Burst/EFT Coupling Clamp is Future Proof

Teseq, a leading developer and provider of instrumentation and systems for EMC emissions and immunity testing, has released the CDN 3425, a Burst/EFT coupling clamp which meets current and forthcoming standards. The ergonomically designed CDN 3425 offers high performance at a competitive price and features innovative safety and calibration accessories

The CDN 3425's principle function is to couple Burst/EFT pulses to data lines. It may also be used to couple to mains lines where no CDN is available; for example high current lines >200 A.

Teseq continuously monitors the activities of the EMC standards committees to ensure new and existing products meet the requirements of all test procedures. The new TESEQ CDN 3425 is fully compliant with the specifications of IEC 61000-4-4 Ed. 2.0 2004 and meets the requirements of the latest draft of IEC 61000-4-4 Ed. 3.0 expected to be published in April 2012.

An optional INA 3825 safety cover with interlock function to be connected to NSG 3000 series generators is also available and an INA 3425 calibration kit as specified in IEC 61000-4-4 Ed. 3.0 2012 will be available as an option early 2012.

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Rohde & Schwarz drive test solution now offers complete MIMO measurements in real LTE networks

MIMO technology can increase the capacity of LTE networks. The latest R&S ROMES software version for the proven drive test solution from **Rohde & Schwarz** allows network operators and infrastructure manufacturers to collect important MIMO data during a drive test. The data can be essential in determining where an investment in MIMO pays off in their coverage area and where MIMO can be implemented smoothly and efficiently.

When used with the R&S TSMW network scanner with its two integrated receivers, the R&S ROMES software can measure the MIMO channel matrix for both 4x2 and 2x2 systems. From the matrix, the software calculates a parameter known as the condition number, which indicates the capacity gain that can be achieved with MIMO. A GPS receiver assigns this data to the exact position and clearly displays it on a map. The R&S ROMES software performs MIMO measurements on all bandwidths up to 20 MHz. Interference can be detected over the entire bandwidth used by the LTE signal.

MIMO-specific measurements are saved in the complex channel matrix with a time component, the phase shift. The measurement data can be exported for later field-to-lab applications. Using fading emulators, a complete mobile radio network can be reproduced in the lab simulating real field conditions.

Network operators can test all their mobile radio networks with a single instrument because the R&S TSMW combined with the R&S ROMES drive test software covers LTE as well as UMTS, GSM and CDMA standards. The R&S TSMW supports all frequencies from 30 MHz to 6 GHz. The test solution therefore covers existing and future frequency bands, which makes it a cost-effective investment for today and tomorrow.

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contact.uk@rohde-schwarz.com
www.rohde-schwarz.com

CapCad™ takes the catwalk for capacitor modelling

Just announced by Europe's leading MLCC manufacturer, **Syfer Technology**, is a web-based software package designed specifically to help designers select the optimum multilayer capacitor devices for their next design.

Called CapCad™, the software tool is easy and fast to use, and provides circuit designers with a readily accessible capacitor comparison facility. CapCad™ includes SPICE models with various parameter values that reflect typical performance at the chosen frequencies. Importantly, engineers can select the temperature range relevant to the application, and adjust it as necessary, to note how it may affect the expected performance of the design.

In operation, the user has the ability to plot 2-port Scattering Parameters, Impedance, Q Factor or Equivalent Capacitance over any frequency span from 1MHz to 40GHz. CapCad™ also includes a Smith Chart utility, plus the S-Parameter data can be copied and converted in Touchstone format (s2p).

The modelling software supports Syfer's High Q range of multilayer capacitor devices. It can be used to compare several devices at one time, and allows designers to model the cumulative effect of multiple devices in one design.

Although the data presented by CapCad™ cannot be construed as a specification or guarantee of actual performance, it is based on calculated models to represent typical performance. Device modelling is regarded by engineers as a useful application development tool, particularly for high frequency products being designed into complex applications. CapCad™ is an important element in Syfer's customer design and development support programme.

The software tool is available free of charge, downloadable from the company website: **www.syfer.com**.

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Excellent EMC Books

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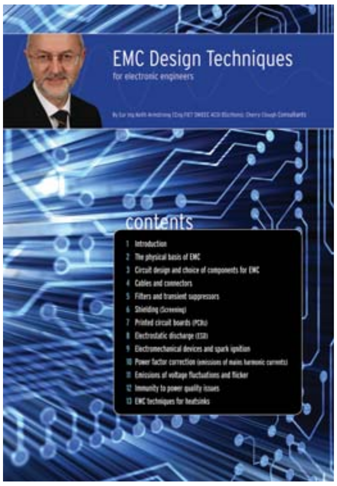

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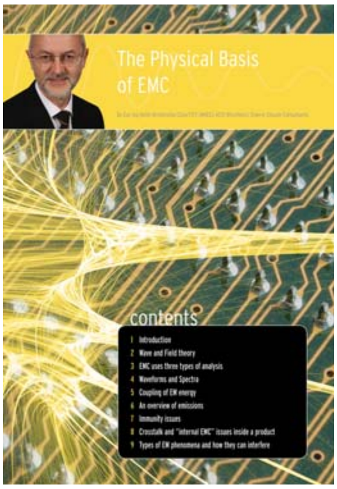

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Find out more on our web site:
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More than just a book. It is a true learning aid. Graphics in full colour. Designed to lay flat for easy learning. Written in a clear concise no nonsense style. Destined to become the Standard for EMC PCB Design. 168 A4 pages.

This book is about good-practice EMC design techniques for printed circuit board (PCB) design and layout. It is intended for the designers of any electronic circuits that are to be constructed on PCBs, and of course for the PCB designers themselves. All applications areas are covered, from household appliances, commercial and industrial equipment, through automotive to aerospace and military.

This is a book for electronic and PCB engineers who need to employ good EMC and SI techniques to save time and money when designing with the latest technologies, to make reliable and compliant products.

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It is difficult for textbooks to keep up to date with fast-changing PCB technology and EMC techniques, which is why most of the references are recent conference papers and articles available via the Internet.

EMC for Product Designers
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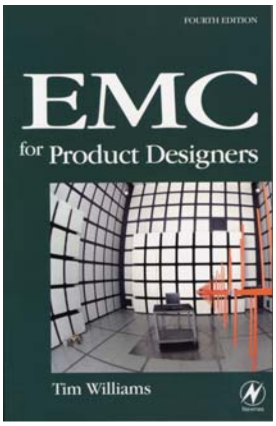
Cost £41.00 plus p&p. ISBN 978-0-75-068170-4



This book is almost certainly regarded as the bible on EMC Design across all International borders.

Brilliantly written and extremely informative, it is divided into three parts, Legislation & Standards, Testing and Design plus a number of interesting and useful Appendices.

Every EMC product designer should buy this latest edition.

New range of Hipot and Insulation Resistance Testers

Telonic Instruments have introduced a new range of high quality Hipot (Flash) and Insulation Resistance testers manufactured by Japan based Kikusui. Designated the TOS5300 the three models in the range are designed for use in Withstanding Voltage and Insulation Resistance testing to help ensure the safety of Electrical/ Electronic components/equipment. Incorporated is an innovative PWM amplifier that achieves high stability and has an input voltage regulation of.3 per cent. The instruments offer control over the rise and fall time for the test voltage and a stable output which is unaffected by mains voltage variations, plus the ability to select 50 or 60Hz test frequency. Upper and lower current limits can be set within the range of 0.01mA to 110mA in AC mode and 0.01mA to 11mA in DC mode. AC test voltage can be set from 0.05kV to 5kV while D.C test voltages can be set from 0 to 6.2kV.

There are three models in this versatile range:

1. TOS5300 which is for withstanding voltage AC testing up to 5kV.
2. TOS5301 has AC and DC withstanding voltage test capability with AC up to 5kV & DC up to 6kV.
3. TOS5302 has 5kV AC withstanding voltage test capability, plus an insulation test function with test voltages from 25V to 1000V.

All models will operate from any global AC input voltages and frequencies; and are equipped with a USB interface. They also benefit from easy to use controls and a large L.C.D. panel, which feature on the front panel. These testers weigh approx. 15kg's and measuring between 330 x 150mm and 420 x 330mm.

These products have applications right across Industry and Research Labs.

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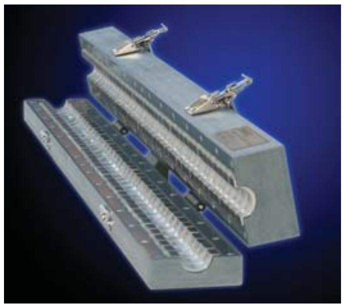
www.telonic.co.uk

New TESEQ Common Mode Absorption Device (CMAD) ensures reproducible emissions measurements

Teseq, a leading developer and provider of instrumentation and systems for EMC emission and immunity testing, has introduced a new line termination clamp as required by CISPR test methods.



Reproducible emissions measurements require a defined line termination for the frequency range where connected lines provide a significant influence on the emissions. The key parameter is the asymmetrical impedance (common-mode impedance) which can be seen as the common-mode impedance to the reference ground. Line impedance stabilisation networks (LISNs) are commonly used for conducted emission measurements. As well as providing the coupling function for the measurement receiver LISNs provide the line termination and decouple the equipment under test (EUT) from the mains or auxiliary equipment.

In the past a suitable line termination was not available for radiated emissions measurements above 30 MHz. LISNs are typically used for this application but they are undefined above 30 MHz.

The new TESEQ CMAD (Common Mode Absorption Device) is specified in CISPR 16-1-4 and its use will be defined in the forthcoming version of CISPR 16-2-3. It improves the asymmetrical line termination in the frequency range 30 MHz to 200 MHz and improves measurement reproducibility. The CMAD needs to be clipped on lines leaving the test chamber. No more than three CMADs should be used for one setup.

Teseq's CMAD 20A conforms to the new requirements of CISPR 16-1-4. It replaces the existing CMAD 20 series, which were developed for CISPR 22 Edition 4.0 2033, but do not conform to CISPR 16-1-4.

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AR's Newly-Revised 600A225 Amplifier is smaller and more powerful

AR RF/Microwave Instrumentation is revising one of its amplifier families, the A225 family, making models smaller yet more powerful with wider frequency ranges. The A225 family now offers models with power up to 16,000 watts and covers 10 kHz to 225 MHz.

Model 600A225, one of the newest members of the family, is a 600 watt RF power amplifier that covers the 10 kHz – 225 MHz frequency range. It's equipped with a digital control panel that provides both local and remote control using IEEE, RS-232, USB and Ethernet interfaces. The digital control panel uses a 3.75" diagonal graphic display, menu-assigned softkeys, a single rotary knob, and four dedicated switches to offer extensive control and status reporting capabilities.

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Modelling for the Protection of Facilities

Paul Duxbury, CST UK Ltd

This article is intended to provide an overview and summary of the presentation which I gave at EMCUK 2011 in the session on "EMC in Buildings and Infrastructure". As such, it doesn't go into full detail on all the topics but, hopefully, covers the salient points which were discussed during the presentation.

Introduction

An article in the New York Times in April 2009 stated that "*Due to the proliferation of wind farms and the increasing heights of the turbines … there is a rising number of lightning-related incidents.*" It then went on to explain that the National Fire Protection Association had updated its handbook on lightning protection systems, specifically including a section on wind turbines, which states that "*While physical blade damage is the most expensive and disruptive caused by lightning, by far the most common is damage to the control system.*" As such, the ability to correctly model the electromagnetic effects of lightning strikes on such structures is important in improving their resilience to the effects of lightning strikes.

In this article, two different aspects of the modelling of lightning strikes to wind turbines will be considered. The first of these will be the heating effects caused by the current flow in the carbon fibre composite materials which are typically used in the construction of the blades and, the second, being the electromagnetic coupling to the cables inside the gearbox / generator housing and, the towers. If the current flow in, and hence heating effects of, the composite materials can be understood, there is the hope that the physical blade damage caused by the lighting strike could be minimised. Likewise, the simulation of the electromagnetic coupling to the cables allows appropriate levels of protection to be designed in rather than relying on a 'belt and braces' approach.

Lightning Waveform

Before considering the effects of a lightning strike, it is worth spending some time understanding the characteristics of the time domain waveform which is used when performing lightning strike analysis. The lightning waveform, which is referred to in many standards, consists of various components and the one which is typically used is Component A which is double exponential in its form with a peak amplitude of 200kA. As can be deduced, this is a high intensity transitory current waveform.

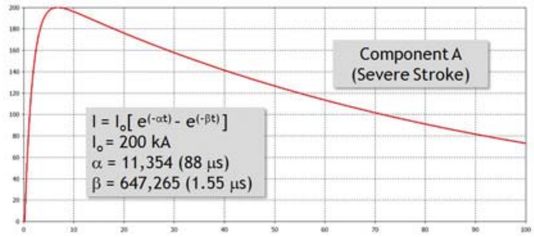

Figure 1. Typical Component A lightning strike waveform

Due to the rise and fall times of the double exponential, lightning is a relatively low frequency phenomena. Typically, most of the energy is below 10MHz and, as such, the wavelengths associated with the waveform are typically greater than 30m.

Carbon Fibre Composite Overview

The second aspect to consider is how carbon fibre composites (CFC's) are constructed as this will lead to a clearer understanding of the electromagnetic effects.

A series of carbon fibre threads are wound together to make a yarn. Multiple yarns are then weaved together to make sheets. These sheets are then glued together with epoxy to make the final layered CFC. As the direction of the yarns, or weave, on an individual sheet is typically in a single direction, different orientations of the weave are used for the individual layers. This has the effect of increasing the overall strength of the CFC panel.

From the electromagnetic and thermal viewpoint, this means that for each of the layers, the resulting conductivities are highly anisotropic.

Orientation	$\sigma_{electric}$	$\sigma_{thermal}$
Longitudinal	high	high
Transverse	low	low
Through	low	low

Figure 2. Relative conductivities for a layer of carbon fibre composite

Lightning Strike to Composite Panel

When applying a lightning strike to a panel, the aim of the analysis may be to firstly determine the current distribution as a result of the strike and secondly, to determine the thermal distribution. This information will allow designers to assess if the panel is likely to delaminate or not.

Delamination of the layers occurs due to the decomposition of the resin between the layers. As the temperature increases (~600°C), there is then dielectric breakdown of pyrolysis gases which causes an expansion between the layers. As the gases expand, the carbon layers are forced apart and, as the temperature increases to approx 3000°C, sublimation of carbon causes the charred fibres to break.

As such, it is the thermal heating of the CFC due to the lightning strike, rather than the lightning strike itself, which can result in the structural failure of the panel. Modelling the full complexity of this is very difficult but, by understanding this process, and the temperatures which may be achieved, protection mechanisms can be designed in with the aim of reducing the heating effect and potential damage.

In this example a simple 4 layered CFC panel is constructed, as shown in figure 3, where the weave is in a different orientation for each of the 4 layers (0, 90, 45 and 315 degrees respectively). The panel is surrounded by a metallic bracket which provides a discharge path for the current.

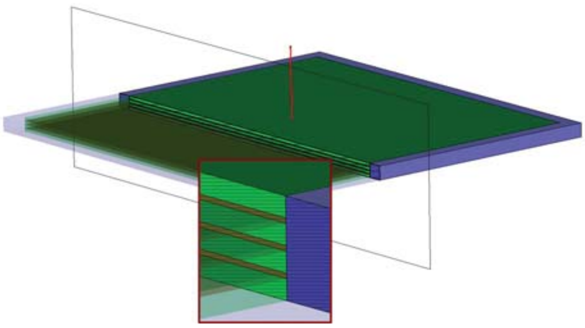

Figure 3. Construction of simple CFC panel

As opposed to directly driving the problem with the double exponential lightning waveform, a stationary current was initially injected at the centre of the top layer of the CFC panel. This was due to the fact that the diffusion characteristics of the panel allowed a stationary current to establish itself much more quickly than the duration of the lightning strike. As such, the current distribution on this panel can be regarded as essentially static.

As the thermal properties of the different materials are known, it is then possible to calculate the thermal loss distribution for the panel due to the current distribution. Finally, a transient thermal analysis can be applied, using the double exponential waveform, to determine the transitory heating of the different layers.

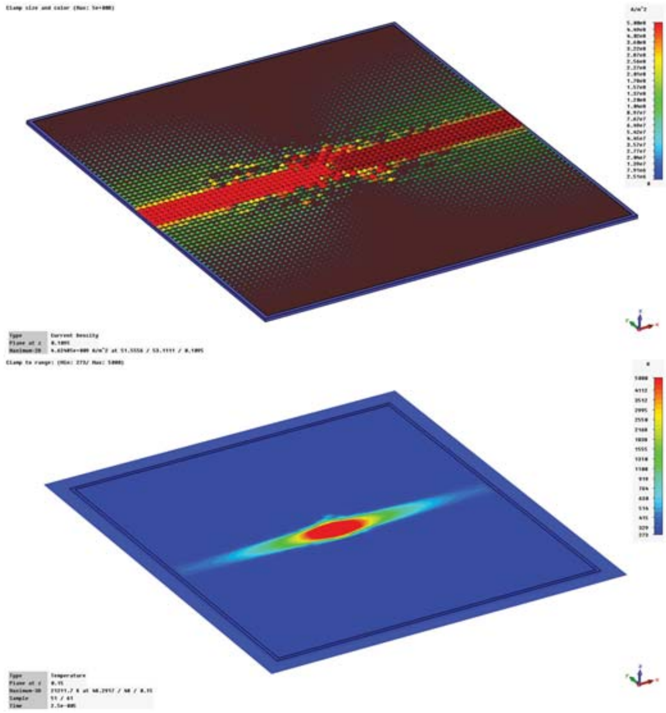

Figure 4. Current and thermal distribution on layer 1, top, of the CFC panel

The results of this analysis show that the current and thermal distribution on the different layers aligns with the weave of the layers. This analysis however does not take into account the damage mechanisms previously discussed but, does gives information on the distributions before damage occurs. This can then be used in the design of appropriate protection mechanisms.

Lightning Strike to Wind Turbine

In this section we consider the analysis of a lightning strike to a wind turbine but, the approach which is outlined is general and could be applied to most 3D structures.

The first aspect to consider here is that when moving from the CFC panel to a full turbine, there are some major challenges of scale. These are related not only to the thicknesses of the CFC compared to the size of the turbine but also, length of the cables within the turbine and the cross sections of the individual conductors within the cables.

The turbines, including the span of the blades, could be several 10's of meters in size with total cable lengths of possibly hundred's of meters but, with cross sections of the conductors as small as 1mm. This presents a significant challenge of scale for any modelling technique – a solution to this will be discussed later.

When applying a lightning strike to a 3D structure, it is important that the lightning channel is correctly modelled. Depending on the type of strike, different approaches may be used. For example, a plane wave could be used if you were interested in the effects of a nearby strike. Alternatively, and typically when modelling this is much more common, the current due to the lightning strike is directly injected onto the structure.

In this example, as shown in figure 5, the lightning strike is applied at the tip of one of the blades and, the current induced into the internal cables is calculated. Initially this is done by modelling the cables using an integrated wire model which represents the cables as simple single conductors. By terminating the cables correctly, this allows the induced currents to be calculated.

Figure 5. Model of wind turbine showing lighting injection point, internal cable routes and gearbox housing

While the integrated wire approach is very efficient, and very representative for modelling the feed and ground cables, it does not allow for the induced currents on individual conductors within a more complex bundle, consisting of for example twisted pairs and screened cables, to be calculated. Figure 7 shows a typical bundle cross section which might be found within a wind turbine.

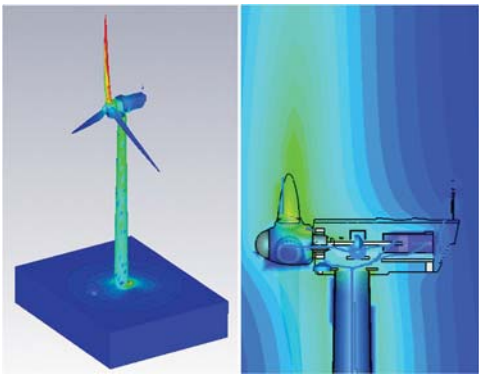

Figure 6. Surface current distribution on, and magnetic field distribution around, wind turbine at a moment in time due to lightning strike

To be able to include the effects of, and coupling to, complex bundles, it is necessary to perform a full transient bidirectional co-simulation between the 3D time domain fields and the cables. This ensures that the cables fully interact with, and modify, the surrounding fields and allows the induced current on any of the conductors within the bundle to be calculated. This is especially important if the bundle is running through a cavity as the presence of the bundle will have a loading effect on the cavity. Also, it ensures that the coupling to, and re-radiation from the bundles is fully accounted for.

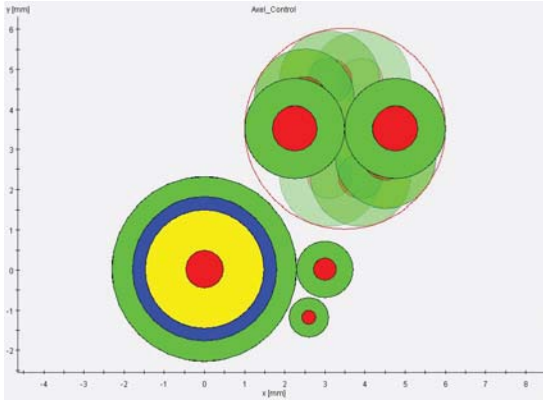

Figure 7. Typical bundle cross section including a coaxial cable, twisted pair and single conductors

In figure 8, the currents which have been induced in the different conductors, in the frequency domain, can be seen. It is important here to be aware that these were achieved as a result of injecting a Gaussian pulse onto the turbine blade as opposed to the normal double exponential. A Gaussian pulse is more typically used for radiated susceptibility analysis when the response of the structure in the frequency domain is required as opposed to a lightning strike when the time domain response is more typically required.

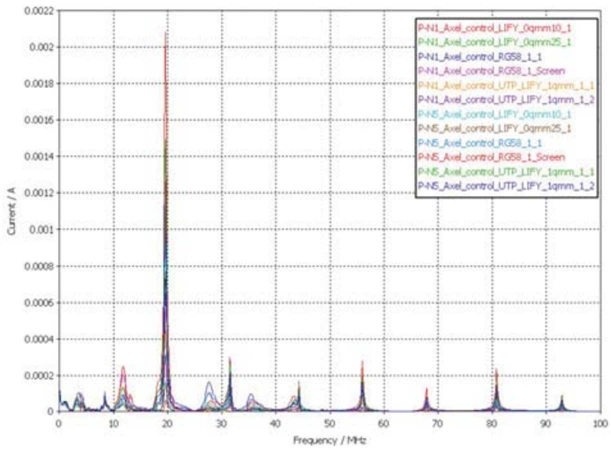

Figure 8. Induced currents in the frequency domain following a transient co-simulation excited with a Gaussian pulse

What these clearly show is that there are a series of resonant characteristics associated with the bundle and, that there is a very strong resonance at 20MHz. Further analysis of the results would be needed to determine the cause of this but, it is likely to be related to either a cavity or cable resonance.

As the bidirectional co-simulation between the 3D fields and the cables in CST STUDIO SUITE™ includes circuit analysis, for the correct termination of the different conductors, this also allows the effect of adding protection devices such as transient suppressors to the ends of the cables to be easily assessed.

Summary

As has been discussed, the analysis of a CFC panel or a 3D structure require different computational approaches. In the case of the thermal heating of the carbon fibre composites, a staged approach is used firstly obtaining the current distribution, followed by the temperature distribution and then, potentially, the deformation of the material (although the analysis of this is not discussed here). Whereas, for the coupling to the cables, due to the significant aspect ratio between the large dimensions of the wind turbine (several metres) and the small cross-sections of the conductors in the cables (typically millimetres), and as the fields inside the housing and the currents on the cables interact, a full co-simulation approach between 3D time domain modelling and 2D transmission line modelling is used. This allows the time domain currents which are coupled to the individual conductors in the cables, and therefore seen at the interface to the electronic control units, to be obtained.

Ultimately, the example presented here is a complex problem and one which it is difficult to simulate in its entirety as a single analysis. However, it is possible to model the significant phenomena which are of concern; the thermal characteristics of the CFC panels and, the coupling to 3D structures including simple or complex cable bundles. All of this leads to an improved understanding of the lightning effects and, and improved design of mitigation methods.

Acknowledgements

I would like to acknowledge and thank the customers whose models formed the basis of the examples shown in this article. I would also like to acknowledge the contribution of various colleagues within CST in the development and rework of the examples. The models and results in this article were created using CST STUDIO SUITE™.

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Bringing License Free Wireless Products to Market in the EU

By Tim Jarvis, RadioCAD Limited

Summary

This article is the first part of two covering unlicensed wireless products sold and used in the European Union (EU). This article starts with a brief history of wireless regulation as seen from a British perspective. It provides useful background to wireless regulation to those unfamiliar with the topic. The article then proceeds to introduce the recommendations and specifications that govern spectrum use and product approvals for wireless Short Range Devices (SRDs).

In the second article in this series Tim explains in some detail the reference documents introduced here and how to best use them by employing some real world product examples.

Part 1

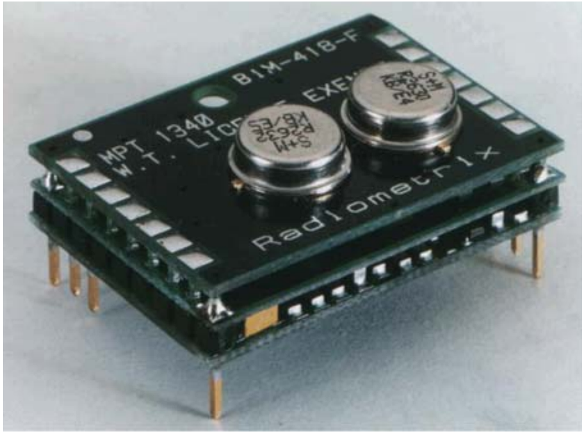
A brief history of spectrum regulation

The first Wireless Telegraphy Act was enacted in the UK in 1904, just three years after Gugliemo Marconi's first transatlantic test transmission. Before the act, wireless transmissions were unregulated. After the act the spectrum was regulated and licenses issued by the British government. These were priced to cover the costs of running the department that regulated the spectrum.

Subsequent Wireless Telegraphy Acts passed into law in 1906, 1949, 1967, 1998 and 2006. The spectrum regulator authority was firstly The Wireless Telegraphy Board from 1918, and then the General Post Office (GPO) from 1949.

The Ministry of Posts and Telecommunications (MPT) was formed by the Post Office Act in 1969. The MPT took over from the General Post Office Engineering Department, which was set up in 1949 to bring together all radio regulatory work. In 1974 the MPT becomes the Radio Regulatory Division of the Home Office and then, in 1983, the same division of the Department of Trade and Industry (DTI), being renamed the Radiocommunications Division in 1986. Amongst its other responsibilities the division writes and maintains standards for license free telemetry such as MPT1340[1], the predecessor to those 433.9 MHz license free devices we all know and love; and MPT1329[2], the standard that once regulated license free telemetry around 459 MHz, an allocation we'll meet again in the next issue.

The first license free wireless products were marked with the MPT standard number and the words "W.T. license exempt", which simply meant that they didn't need the user to apply for a license under the Wireless Telegraphy (W.T.) act.



License exempt products are always low power and hence referred to as Short Range Devices (SRDs). The most frequently used power limits being: 10mW, 100mW and 500mW. It's very rare for a product that transmits at more than 500mW to not require a license in the EU.

The 1990s heralded the biggest changes to wireless in Europe. The decade kicks off with Margaret Thatcher's deregulation of the whole UK industry in the Broadcasting Act 1990. The same year sees the birth of the Radiocommunications Agency. The agency takes over spectrum regulation and the production and maintenance of MPT standards from the Radiocommunications Division of the DTI.

In Europe there is a drive to harmonise both spectrum allocation and radio standards. CEPT (see below) forms the European Telecommunications Standards Institute (ETSI) in 1988. The Radio and Telecommunications Terminal Equipment (RTTE) directive[3] becomes European law in 1999 and the European commission empowers ETSI-ERM (ETSI's Electromagnetic compatibility and Radio spectrum Matters technical committee) to create and manage harmonised standards for wireless products under the RTTE directive. These new European Norms (ENs) rapidly take over from national standards such as the MPT series.

The RA is dissolved and OfCom takes over its responsibilities (somewhat inadequately) in December 2003.

CEPT

CEPT (Conférence Européenne des Postes et Télécommunications) is the unified Posts and Telecommunications regulatory body for its 48 signatory countries: Albania, Andorra, Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Bosnia and Herzegovina, Croatia, Cyprus, The Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, The Former Yugoslav Republic of Macedonia, Malta, Moldova, Monaco, Montenegro, The Netherlands, Norway, Poland, Portugal, Romania, The Russian Federation, San Marino, Serbia, The Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and the Vatican City.

In addition to forming ETSI, CEPT forms the European Radiocommunications Office (ERO) and the European Telecommunications Office (ETO). In 2010 both are merged into ECO the European Communications Office[4]. ECO produces various recommendations for harmonised spectrum allocations across the CEPT member countries (a geography larger than Europe). For license free SRDs their recommendation is ERC REC 70-03[5] (published annually).

Routes to market in Europe

With the introduction of the RTTE Directive (1999/5/EC) the process of introducing new wireless products to the market is much simplified. Prior to its introduction formal type approval was the only route to market. For each target country a manufacture had to determine the applicable market access standard (in the UK it would be an MPT standard), then find an approved test house to test and report, then the report was then sent to the government regulatory body for approval and after some weeks the manufacturer would receive a type approval certificate. This process had to be repeated again and again for each target country.

This formal route to market now only remains for products that have no applicable European Norm but do have an applicable national standard. In 2012 there are effectively no such product types and the UK's MPT standards have long been obsolete. There are now just two principal routes to market in Europe:

(i) Manufacturer self-declare
(ii) RTTE Notified Body opinion

One can see if a manufacturer has used a notified body because the body's four-digit number will appear following the CE mark. A list of RTTE Notified Bodies can be found in the Europa Nando (New Approach Notified and Designated Organisations) Information System[6]. If there is no number following the CE mark the manufacturer has used the self-declaration route. The exclamation mark in a circle is a warning about the use of the product. It's perfectly acceptable to use a harmonised EN to approve a product that uses a frequency that isn't harmonised. The exclamation mark says beware, you may be able to buy this product in any EU member state but you might not be able to use it.

In practice the exclamation mark gets affixed even to wireless products that do use harmonised frequency allocations because even harmonised allocations tend to get different national conditions and restrictions applied as we will see.

So to be sold into the EU a product has to meet the appropriate product standard and be suitably marked. Before a purchaser can use the product however he/she has to obtain a license to use it. For license exempt wireless products the situation is problematic. A user buying a license-free wireless product in the EU might reasonably expect that he can use that product anywhere in the EU, but often this is not the case.

It's been relatively easy to harmonise product standards across the EU because these standards apply to products as yet unsold. However it is much harder to harmonise spectrum allocations with their incumbent and sometime intransigent users, so there remain many uniquely national allocations.

What wireless technology should I use in my product?

When it comes to short-range wireless there are many technologies and frequencies available. If you want to sell a new product freely across Europe and all the CEPT signatory countries then you need to consult ERC REC 70-03 first. The recommendation has thirteen annexes covering many product types. If your production doesn't fit into one of the specific types then the first annex catches it. It is simply titled "NON-SPECIFIC SHORT RANGE DEVICES". Each annex lists all the frequencies that have been harmonised for use by product type(s). It specifies power limits, channel bandwidths, etc. At the close of the annex there is a list of ETSI ENs that should be used to certify the product's radio performance under the RTTE directive. Appendix 1 following the annexes contains big national implementation tables. The tables have columns for all the CEPT signatory countries (except the UK which publishes its license free SRD allocations separately in OfCom publication IR2030[7]). The table indicates whether or not a country has adopted each harmonised frequency allocation. Y means it has and N means no, whereas L means there are limitations. These limitations on the use of each allocation per country are detailed in appendix 3.

In the next issue I will employ some product examples to help demystify ERC REC 70-03 and explain how use it.

I want to self-declare but which harmonised standards apply to me?

OK so now we've picked our technology and our frequency and we've started to develop our product. What standards must we apply to demonstrate compliance with the RTTE directive?

The EU commission publishes harmonised ENs applicable to the RTTE directive on the Europa website[8]. This is termed the RTTE 'reflist', short for list of reference standards. The standards for wireless products fall into three basic categories[1]:

(i) Those dealing with safety, e.g. human exposure to radio waves
(ii) Those dealing with EMC
(iii) Those dealing with the proper use of the spectrum

[1] There are also standards in the reflist applicable to wired telecommunications equipment but we are not concerned with these here.

SRDs and Safety Standards

In addition to electrical product safety as covered by the Low Voltage (LVD)[9] and other directives, radio transmitters operating on or near human beings may be subject to Specific Absorption Rate (SAR) testing. There are two EU directives covering human exposure to ElectroMagnetic Fields (EMF):

(i) Recommendation 1999/519/EC[10] covers exposure of the general public (non-binding)

(ii) Directive 2004/40/EC[11] covers exposure of workers.

The RTTE reflist standards addressing human exposure to EMF are EN 50371[12], and EN 62311:2008[13]. If your SRD transmits at 10 mW ERP human EMF exposure should not concern you, but manufacturers of body worn transmitters with RF output >20 mW will need to look at these standards.

SRDs and EMC

The RTTE directive takes precedence over the EMC directive[14]. For all products containing wireless devices this means that the EMC directive does not apply. In its place the EMC provisions of the R&TTE directive apply. For SRDs this means standard EN 301 489-3[15] should be used, although other RTTE reflist EMC standards including other parts of EN 301 489 may also apply.

The EN 301 489 series of EMC standards have a lot in common with CISPR's IT equipment EMC standards (as adopted by Cenelec), EN 55022[16] and EN 55024[17]. The 301 489 series adds exclusion bands for transmitters (emissions) and receivers (immunity).

SRD Radio Performance

Radio performance is governed by article 3.2 of the RTTE directive that simply states "radio equipment shall be so constructed that it effectively uses the spectrum allocated to terrestrial/ space radio communication and orbital resources so as to avoid harmful interference". On these few words hang the vast majority of the ETSI specs in the RTTE reflist. For example the generic specifications dealing with SRD use of the radio spectrum are:

(i) EN 300 330[18] (SRDs operating from 9 KHz to 25 MHz)

(ii) EN 300 220[19] (SRDs operating from 25 MHz to 1 GHz)

(iii) EN 300 440[20] (SRDs operating from 1 GHz to 40 GHz)

It's part two of most radio performance specifications that appear in the RTTE reflist. Part one contains all the measurement methods and limits referenced by the second, mandatory part.

OEMs using bought in wireless modules usually expect that ETSI radio performance standards to have been applied by the module manufacturer. As a rule the OEM applies the safety and EMC standards and the wireless module manufacturer applies the radio performance standard(s). However this is a somewhat simplistic assumption.

For example consider an OEM developing a desktop paging system. For the transmitter he develops the POCSAG paging software and integrates a bought in 300 220 approved transmitter module. The OEM applies EN 60950-1[21] for safety and EN 301 489-2[22] for EMC and uses the module's EN 300 220-2 declaration in his declaration of conformity. Job done?

There are two problems with this simplistic approach: (1) EN 300 224[23] is the applicable standard for radio paging and not EN 300 220. (2) Furthermore both EN 300 220 and 300 224 specify limits for Effective Radiated Power (ERP) and radiated spurious emissions. Both depend on the antenna system, product design and product enclosure design. However the OEM, and not the module manufacturer, executed the antenna and enclosure design.

In the next issue No. 99, we'll look at these complexities in more detail using some representative product examples.

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[4] http://www.cept.org/eco

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[12]EN 50371:2002 - Generic standard to demonstrate the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz - 300 GHz) - General public - Cenelec
[13]EN 62311:2008 - Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz) – Cenelec
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[16]EN 55022:2006 Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement + Amendment A1:2007 - Cenelec
[17]EN 55024:1998 Information technology equipment - Immunity characteristics - Limits and methods of measurement + Amendment A1:2001 and A2:2003 - Cenelec
[18]ETSI EN 300 330-2 V1.5.1 Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive
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[20]ETSI EN 300 440-2 V1.4.1 Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive
[21]EN 60950-1:2006 Information technology equipment - Safety — Part 1: General requirements - Cenelec
[22]EN 301 489-2 V1.3.1 Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 2: Specific conditions for radio paging equipment
[23]EN 300 224-2 V1.1.1 Electromagnetic compatibility and Radio spectrum Matters (ERM); On-site paging service; Part 2: Harmonized EN under article 3.2 of the R&TTE Directive

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EMC design of high-frequency power "switchers" and "choppers"

Suppressing RF emissions from converter inputs and outputs

One of a number of "Stand Alone" articles on the EMC design of switch-mode and PWM power converters of all types

By Keith Armstrong, Cherry Clough Consultants Ltd, www.cherryclough.com

Issues 93 – 97 of The EMC Journal carried earlier parts of this "Stand Alone" series – my attempt to cover the entire field including DC/DC and AC/DC converters, DC/AC and AC/AC inverters, from milliwatts (mW) to tens of Megawatts (MW), covering *all* power converter applications, including: consumer, household, commercial, computer, telecommunication, radiocommunication, aerospace, automotive, marine, medical, military, industrial, power generation and distribution; whether they are used in modules, products, systems or installations.

Hybrid & electric automobiles, electric propulsion/traction; "green power" (e.g. LED lighting); and power converters for solar (PV), wind, deep-ocean thermal, tidal, etc., will also be covered.

Issues 93 – 95 used a different Figure numbering scheme from the rest, for which I apologise.

I will generally not repeat stuff I have already published, instead providing appropriate references to material published in the EMC Journal [14] and my recently-published books based on those articles [15].

7 Suppressing RF emissions from inputs and outputs

Suppression is sometimes called attenuation, and sometimes called EMI mitigation. Suppressing low-frequency emissions (mains harmonics and other noise emissions below 150kHz) will be covered in a later article.

7.1 The necessity of using good EMC design from the start of a project

The design techniques described in the previous parts of this "stand-alone series" [13], [42], [64], [65], and [66] help reduce the RF noises created by rectifiers, switchers or choppers, and are mainly only intended to be effective above the 11th harmonic of the switching frequency, so that the switching is still "hard" enough to be thermally efficient.

But most of these techniques usually cannot provide enough suppression to comply with emissions limits, plus they leave the harmonics below the 11th to create noise emissions. So we need to suppress conducted and radiated emissions using filtering and shielding.

This article focuses on suppression using filtering – but it is important to remember that conducted noise radiates away from the conductors and can cause radiated test failures. Just because a conducted emission test only goes up to 30MHz does not mean that filtering is not required above 30MHz – all conductors connecting to a power converter must be filtered to the highest frequency at which it generates too much noise, whatever the frequency.

The highest frequencies at which a power converter might need filtering (or shielding, which isn't only for radiated emissions) can easily be 2,000 times its switching rate. So a 1kHz switcher or chopper can easily emit excessive noise to over 2MHz (I have seen 5kW 50Hz bridge rectifiers on their own fail emissions tests at over 4MHz), and a 100kHz switcher can easily emit too much at over 200MHz.

For commercial and financial success we want our products to use the least amount of EMI suppression they can, to keep their overall cost of manufacture low.

But it is no use having a low overall cost of manufacture if it means delaying the product launch by months to achieve the most cost-effective EMI suppression! Time-to-market has, since 2000, become the most important issue for a financially successful electronic product.

This is shown by the industry responses to Question 6 in [67], see Figure 7.1-1, and I have seen other reports from similar prestigious organizations that show the same for most electronic applications.

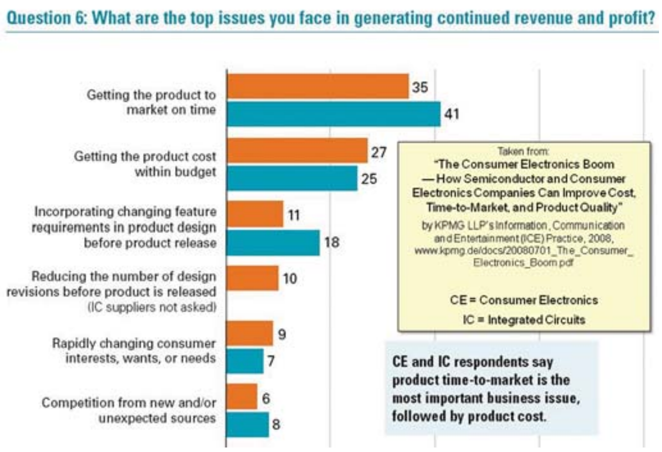

Figure 7.1-1: Time-to-market and cost

Reducing time-to-market (with an EMC-compliant product) whilst simultaneously achieving the most cost-effective EMI suppression, requires the use of good EMC engineering design *right from the start of a new project*.

I have seen switch-mode power converters that required five-stage mains filters that were responsible for more than 33% of the overall bill of materials (BOM) cost, and also about 33% of the converter's overall size (volume) and weight. These filters typically took six months to design before the product could be sold as complying with its relevant emissions standards. The resulting six-month delay in the time-to-market is the sort of delay that can – in these fast-moving times – turn a potentially very profitable product into a loss-making financial black hole.

One thing these power converters had in common was that their designers ignored all the stuff I have been covering in my previous articles in this series. They simply made a power converter that somehow met its functional specifications, then bunged it in a test lab to measure its emissions – which of course it failed – then bodged around with filtering and shielding, cycling repetitively through the test lab, until they managed to get something that passed its emissions tests.

The sad thing is that if they had used the material on good EMC engineering design techniques that I've been describing in the EMC Journal since 1999 (never mind the previous articles in this series), they would have probably met their functional specifications more quickly, would have needed no more than one iteration through the EMC test lab, and their filters would have represented no more than 15% of the product's BOM cost, size and weight. Time-to-market would have been as short as if no EMC compliance was required, and possibly less.

See Chapter 1.1 of [5] for more on how using good EMC design techniques from the start of an electronic design project improves competitiveness whilst reducing financial risks.

Despite the use-good-EMC-design-from-the-start approach being a "no brainer", what I find in practice is that design engineers are increasingly being made to focus on achieving the lowest BOM cost for every tiny part and assembly within a product – an approach that *almost guarantees* difficulties in achieving functional specifications, difficulties in achieving EMC compliance, much delayed time-to-market, and an increased overall cost of manufacture. [12] may be relevant here.

I blame project and other managers who don't take the trouble to learn about EMC, although so few people write about the commercial and financial benefits of good EMC design that I suppose it is not *entirely* their fault.

I suppose it's time I got back to the subject of this article. But first I'll repeat that the design techniques discussed in [13], [42], [64], [65] and [66] all help reduce the cost, size and weight of filtering and shielding, reduce the overall cost of manufacture (even though the BOM costs of some PCBs and assemblies will increase), and considerably reduce time-to-market.

We need to be EMC-savvy from the start of a new project so that we don't have to use more EMI filtering and shielding than is necessary, and so that we save time.

7.2 The DM and CM noise current loops

Figures 7.2-1 through 7.2-4 use the example of an AC-AC inverter variable-speed motor drive with a three-phase (3ϕ) mains supply and a 3ϕ motor, copied from a figure in a REO (UK) Ltd booklet on suppressing motor drives.

This example shows a set of high-value (several milliHenries, mH) inductors in series with its mains input to suppress emissions of mains harmonics up to 5kHz, and this will be covered in a later article in this series. Right now, we are focusing on suppressing RF emissions.

Despite this high(ish) power industrial AC/AC example, the basic noise suppression principles described in this section apply to any/all types of switching power converter, including DC input (which doesn't use an input rectifier) and/or DC output (which might use different types of switching circuits or output rectifiers), for example DC/DC converters on printed circuit boards (PCBs).

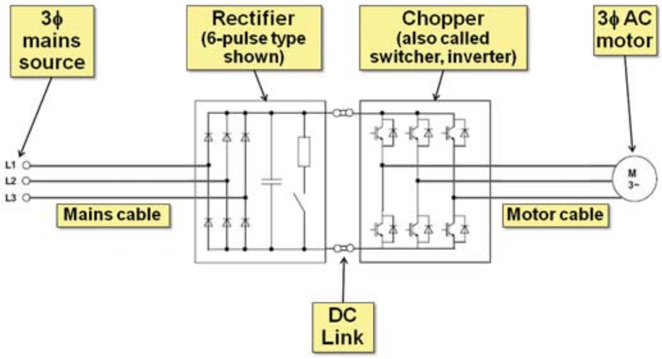

Figure 7.2-1: Example of a variable speed/frequency 3ϕ motor drive (VSD, VFD)

Figure 7.2-1 shows the basics of the system, which – like most high-power VSDs – places its rectifier in a different metal box from that of its chopper, with the connection between them called the DC Link. DC Links can be cables or busbars of any length, although long DC Links are a bad idea for EMC, as discussed later in this section. VSDs or other types of AC input power converters or inverters rated under 10kW usually combine their rectifier, DC Link and switcher or chopper in one box.

Figure 7.2-2 uses the same VSD as 7.2-1, showing the stray capacitances that exist between the units and from them to nearby metalwork. These strays are shown "lumped" for convenience and simplicity of drawing, when in fact they are really distributed all over the length/area of the various parts.

For a powerful VSD installation, the nearby metal structures include cable trays, heatsinks, enclosures (e.g. cabinets), concrete rebars, structural steelwork, cable armour, etc.

For power convertors mounted on a PCB, the nearby metal structures include heatsinks, metal enclosures, and the traces and planes in the PCB's laminations.

I haven't shown any safety earth/ground connections in these figures, because where such connections are used their earth/ground conductors are so long that they have very high impedance at RF, so they don't have much effect on the major paths of the common-mode (CM) RF noise currents – which flow via displacement currents in the stray capacitances shown in Figure 7.2-2.

See Chapters 5.7 of [4] and 2.7.7 of [5] for more details on why connections to the safety earth/ground electrodes in the soil are generally not important for EMC. Chapters 4.6.8 of [5] and 3.1.4 of [37] also show why so-called "earth/ground loops" are not a problem when electronic design is done correctly.

However, the details of the VSD's nearby metal structures and how they are electrically bonded together and connected to the VSD *are* very important for the control of CM current loops, whether these metal structures are connected to safety earth/ground or not, see later.

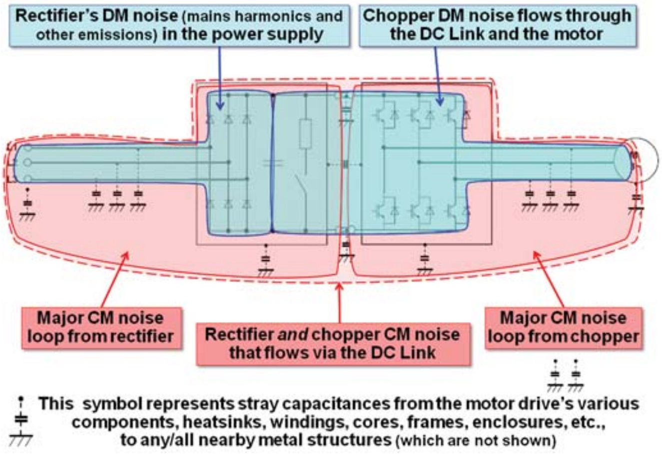

Figure 7.2-2: Example VSD showing noise current loops

Figure 7.2-2 sketches the differential-mode (DM) RF noise currents in blue, and CM RF currents in red.

All currents, including unwanted/stray noise currents flow in closed loops (from Ampere's Law), and I have sketched the DM and CM noise currents flowing in Figure 7.2-2 with simplistic shapes. The coloured areas within these shapes indicate the electromagnetic near-fields associated with each loop. See Chapters 2.4 of [4] or 2.4 of [5] for more on near-fields and far-fields.

Notice that the DM noise current loops are confined to the mains power input and motor drive output cables. But the CM noise current loops flow through various stray capacitances (or direct connections) to all nearby metal constructions (not shown), then along those metal structures until they can return via stray capacitances (or direct connections) to complete their loops – using the smallest loop areas they can find.

The figures in this section (7.2) can be misleading, because they make the mains input and motor output cables appear to be quite short, when in reality they can be very long. The length of the mains cable from the AC power source (generally a large transformer stepping-down from a high voltage, e.g. from 33kV AC rms to 230V rms, but sometimes a generator) to the power converter is almost always several tens of metres, and could easily be a hundred metres or more.

The motor drive cable from the VSD's output could be very short. Shorter is generally better for EMC, with mounting the motor drive directly onto the frame of the driven motor usually the best, but in steel rolling mills I have seen 10MW VSDs driving very large motors over cables much longer than 100m.

The CM currents in the scheme shown in Figure 7.2-2 flow over loops that extend all the way from the source of the AC power (e.g. the HV transformer) through the VSD to the motor. These loops encompass very large areas indeed, with a high probability that they will pass through some other equipment or systems and interfere with them.

I have seen large factories containing dozens of plastic injection machines, each the size of the largest railway locomotive, where the entire metal structure of the factory was "polluted" with CM noise generated by a single 100kW motor drive powering just one of the machine's compressors.

We suppress the DM and CM noise current loops using filters comprising capacitors, inductors, RF chokes, either individually or in combination. The principle of filtering is to provide the DM and CM noise currents with loops that have much smaller areas – which they will naturally prefer to take.

For more on this very important understanding see Chapters 5 of [4] or 2.7 of [5], also [33] (for systems and installations) or [32] (for PCBs).

It is not sufficient just to buy a filter, even a costly high-spec one, and expect it to work in isolation. For filtering to work as expected we need to use "RF Bonding", so that the DM and CM noise currents are diverted by the filter into very small loop areas, which they naturally "prefer", thereby reducing the levels of noise currents flowing in the input and output cables – which we call emissions.

Figure 7.2-3 shows what we aim to achieve with these techniques. Input and output filters provide the DM and CM noise currents in the mains input and motor output cables with low-impedance paths to flow in, and RF bonds between the filters' metal enclosures and the metal enclosures of the VSD (rectifier and chopper) provide the smallest practicable loop areas for them to flow in.

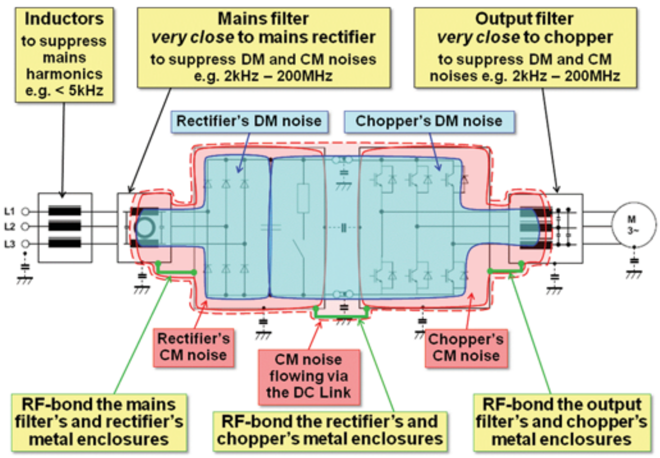

Figure 7.2-3: Example VSD fitted with filters and RF-bonded together

As before, the DM noise current loops are shown as blue outlines filled with light blue, and the CM noise current loops as red outlines filled with light red. When properly designed and assembled, all the noise current loops are contained within the filters and the units comprising the VSD. They do not extend beyond the mains filter into the (long) mains cable that goes to the AC mains source, or beyond the output filter into the (potentially long) motor cable. (Of course, nothing is perfect, see 7.3.)

Because of the way it is drawn, Figure 7.2-3 doesn't visually indicate by how much the area affected by the DM and CM noise has been shrunk by the addition of mains and output filters. Without the filters the noise from the converter extends to the entire branch of the input power distribution system, and the entire route of the output cable to the motor load.

For the example 3ϕ VSD motor drive used here, this could easily include most, perhaps all, of a factory building. And in the case of a PCB mounted DC/DC converter in (say) a Personal Computer (PC) it could cover the whole area served by the input DC rail, plus the whole area served by the output DC rail.

But – with the filters – the area exposed to the DM and CM converter noise is restricted to the area covered by the filters and converter itself. Because all currents (including stray noise currents) flow in closed loops that "prefer" to be as small in area as they can be, best results are achieved by placing the filters and converter circuits adjacent to each other – as physically closely as possible – as shown on Figure 7.2-3.

"RF Bonding" means using electrical connections (i.e. bonds) that have low impedance up to the highest noise frequency to be suppressed. "Low impedance" in this context is always <<1Ω, preferably < 10mΩ.

Effective RF bonding also requires the use of multiple bonds spaced much less than one-tenth of a wavelength (λ) apart from each other at the highest frequency to be suppressed, e.g. << 3 metres apart for filtering up to 10MHz, << 300mm apart for up to 100MHz. If the dimensions of the unit to be RF-bonded is << λ/10 at the highest noise frequency to be suppressed, then a single electrical connection might be acceptable for its RF bond.

For greater suppression at any frequency (up to the highest), the impedance of the RF bonds should be lower, and the spacing between the multi-point bonds should be less.

RF bonding is what almost all EMC textbooks and articles call "EMC earthing/grounding" or "RF earthing/grounding". These are confusing terms because they sound as if they have some relationship with safety earthing/grounding, which they do not.

This confusion of terminology has caused huge problems, delays and costs for very many electronic manufacturing companies, system integrators and electrical installers. This is why I have learnt to use the term "RF Bonding" instead, and strongly recommend it to all.

How to achieve RF bonding in practice is described in detail in the following:

- in general: Chapter 5 of [4] or 2.7 of [5]
- for PCBs: Chapter 3 of [37]
- for complete electronic products: Chapters 4.6, 5.2, 5.3, 6, 7.4.4 and 13.7 of [5]
- for items of equipment comprising several electronic units in one metal box: Chapters 2 and 4 of [68], and 6 of [70]
- for systems and installations of any size: Chapters 5.7 (starts on page 84) of [69], and 5 of [70]

We see from the above references that the length of the conductors used to create RF bonds are very important indeed. For example a typical 4mm diameter conductor (or 4mm wide PCB trace) has an impedance of roughly 0.8µH/metre, so for its impedance not to exceed 1Ω at 10MHz it must not be longer than roughly 20mm, and preferably very much shorter than this.

Replacing our 4mm diameter wire (or 4mm wide trace) bonding conductor with a 25mm wide braid strap (or 25mm wide PCB trace) reduces the inductance to roughly 0.4µH/m, so for suppressing noise up to 10MHz it must be no longer than 40mm, and preferably a lot shorter.

For frequencies of up to 100MHz, our 4mm diameter wire (or 4mm wide PCB trace) must be much shorter than 2mm, and our 25mm wide braid strap (or PCB trace) must be much shorter than 4mm – so the best idea here is usually to screw, bolt, solder, weld or otherwise directly fix together the metal enclosures/ chassis/frames/PCB 0V planes/etc. that are to be RF-bonded.

Figure 7.2-3 shows the filters, rectifier and chopper units RF-bonded together, but sometimes this is impractical and it is necessary to RF bond them to their local metal structures instead, usually those that used to support them – such as a cabinet or frame.

In this case it is necessary to convert their local metal structures into an "RF Reference" to carry the CM currents flowing between the units in a way that achieves a very small loop area. This technique is shown in Figure 7.2-4.

When we RF bond together the metal bodies of converter's various units, plus their input and output filters, as Figure 7.2-3, this actually creates an RF Reference without RF bonding to any local metal structures as shown in Figure 7.2-4.

In this situation, the highest frequency up to which this type of RF Reference can maintain << 1W is set by its shielding effectiveness.

Where the various units comprising the converter and/or their filters don't have well-enough shielded metal boxes to maintain an impedance of << 1Ω up to the highest frequency to be suppressed, it is usually necessary to also RF bond them to their supporting, and other local metalwork. A combination of Figures 7.2-3 and 7.2-4.

I have spent many happy days in large installations, adding RF bonds all over filtered VSDs and their local metal structures to stop them interfering with sensitive instrumentation (e.g. temperature, weight and flow measurement). The more RF bonds one adds, and the shorter they are, the lower the VSD's EMI.

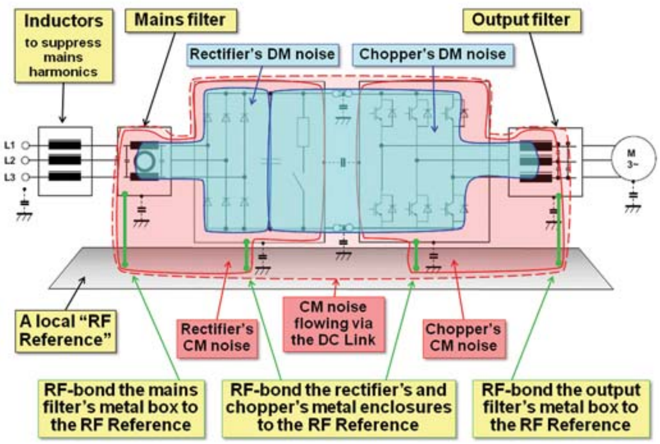

Figure 7.2-4: Example VSD fitted with filters and RF-bonded to an RF Reference

An RF Reference is what almost all EMC textbooks and articles call an "EMC earth/ground" or "RF earth/ground" – confusing terms because people shorten them to just "earth" or "ground", just as they shorten safety earth/ground to "earth" or "ground" despite them being very different things indeed.

As before, this confusing terminology has caused huge problems, delays and costs in the past, so I use the term "RF Reference" instead, and strongly recommend its use.

How to create an RF Reference in practice is described in detail in the following:

- in general: Chapters 5.7 and 5.8 of [4] or 2.7.7 and 2.7.8 of [5]
- for PCBs: Chapter 4 of [37]
- for complete electronic products: Chapters 4.2.3, 4.5, 4.6.2, 5.3 and 7.4 of [5]
- for items of equipment comprising several electronic units in one metal box: Chapters 2 and 4 of [68] and 6 of [70]
- for systems and installations of any size: Chapters 5.5 (starts on page 69) of [69], and 5 of [70]

As the above references show, an RF Reference is a metallic structure that provides a low impedance up to the highest frequencies to be suppressed. This impedance must always be << 1Ω, preferably < 10mΩ, with lower impedances being associated with higher levels of RF suppression. The above list of references describe how to achieve this at low (sometimes no) cost.

RF References can be made by RF bonding existing and/or additional metal items together to create some sort of mesh, or (better still) by RF bonding metal sheets together. Ideally, an RF Reference would consist of a single sheet of metal that underlies – and extends beyond by as much as practical – all of the units and filters that are to be RF-bonded to it. Like the sketch in Figure 7.2-4.

Better than the ideal metal sheet RF Reference is to use an internal surface of an overall shielded enclosure that contains all the converter units and their filters, and achieves good shielding effectiveness at least up to the highest frequency to be suppressed. Achieving good shielding effectiveness for a metal box with cables or other types of conductors entering and exiting it, is not a trivial issue, and many people get it badly wrong by missing just one tiny detail.

Shielding will be covered in a later article in this series, but in case you need to know right now, the necessary techniques are fully described in the following:

- for PCBs: Chapter 2.2 of [37]
- for complete electronic products: Chapter 6 of [5]
- for items of equipment comprising several electronic units in one metal box: Chapter 5 of [68] (starts page 55) and 6 of [70]
- for systems and installations of any size: Chapter 5.12 (starts page 133) of [69], and 6 of [70]

Another essential characteristic of an RF Reference is that it must be much closer to whatever is going to use it than one-tenth of the wavelength at the highest frequency to be suppressed. This is often written as << $\lambda/10$ at f_{max}, but where the surrounding medium is air, gas or vacuum (rather than oil, water, etc.) this can instead be written as $30/f_{max}$. Where f_{max} is given in MHz, the result is metres, but if f_{max} is given in GHz, the result is millimetres. For example, for an f_{max} of 10MHz in air – $\lambda/10$ is 3m, and for an f_{max} of 100MHz in air – $\lambda/10$ is 300mm.

Don't forget these are maximum values, ideally we want to be at least ten times closer to the RF Reference, i.e. < 300mm for up to 10MHz, and < 30mm for up to 100MHz.

RF References that are further away than $30/f_{max}$ or $\lambda/10$ are no use at all as RF References. They might well be a perfect RF Reference for some other item of equipment, but they are too far away to be our RF Reference.

Using metal structures as RF References when they are further away than $30/f_{max}$ (MHz gives metres) or $\lambda/10$ will generally amplify emissions – not what we want.

A particular problem arises with DC Links. They carry quite large amounts of DM and CM noise currents, and some systems use a single high-power rectifier unit to feed DC power to one, two or more power converters some distance away.

But Figure 7.2-3 shows that to suppress the DM and CM noise currents that flow through a DC Link requires RF bonding between the rectifier unit and any/all of the switcher/chopper units it powers. And to achieve <<1Ω bonding impedance these units would have to be very close together – so such DC Links must be very short indeed.

Ideally, the rectifier and switcher/chopper units would have their metal enclosures directly screwed or bolted together at multiple points << $\lambda/10$ apart at the highest frequency to be suppressed. Alternatively, they could be RF-bonded to their RF Reference.

Where neither approach is practical, or the DC Link must be long, then the DC Link should be filtered as it exits the rectifier, with this new filter RF-bonded to the rectifier itself, and/or both of them RF-bonded to their RF Reference.

Also, all of the switchers/choppers supplied by this DC Link should each be individually filtered at its DC power input, with each of these new filters RF-bonded to their switchers/choppers, and/or both filter and switcher/chopper RF-bonded to their own RF Reference.

The additional cost/space/weight of the additional filters required for a long DC Link might make it more cost-effective to provide each switcher/chopper unit with its own mains rectifier, to keep the DC Link short and contained within that one unit.

Alternatively, a shielded DC Link could be used, with the shield RF-bonded to the rectifier's RF Reference and also RF-bonded to the RF References of each/every switcher/chopper that is supplied by this DC Link.

Shielding can also be used to replace filtering at a converter's AC or DC output. Sometimes it is most cost-effective to combine shielding with filtering.

Shielding techniques for cables and busbars will be discussed in a later part of this series, but if you can't wait that long, see the following:

- for PCBs: Chapter 2 of [37]
- for complete electronic products: Chapter 4 of [5]
- for items of equipment comprising several electronic units in one metal box: Chapter 3.7 of [68] (starts page 31) and 7 of [70]
- for systems and installations of any size: Chapter 5.7.6 through 5.7.10 (starts page 97) of [69], and 7 of [70]

7.3 Designing or choosing effective filters

7.3.1 An introduction to filter design based on noise current loops

Filters are constructed from capacitors, inductors and chokes, and – as shown in 7.2 above – using filters along with RF bonding and an RF Reference creates small-area loops for the DM and CM noise currents to flow in.

The laws of physics and electromagnetism ensure that the noise currents "prefer" to flow in these small loops, diverting the noise currents away from the much larger loops created by the mains power supply and motor cables. The presence of the small loops significantly reduces the levels of noise currents that flow in these large loops, reducing the likelihood of failing emissions tests and/or causing EMI in real life.

This section (7.3) looks into some filtering techniques. Instead of the complex circuit used as the example in section 7.2, with their complex noise current paths, this section uses figures based on the simple block diagram shown in Figure 7.2-1, and shows the DM and CM current loops as very simple shapes, using blue for DM and red for CM as in section 7.2.

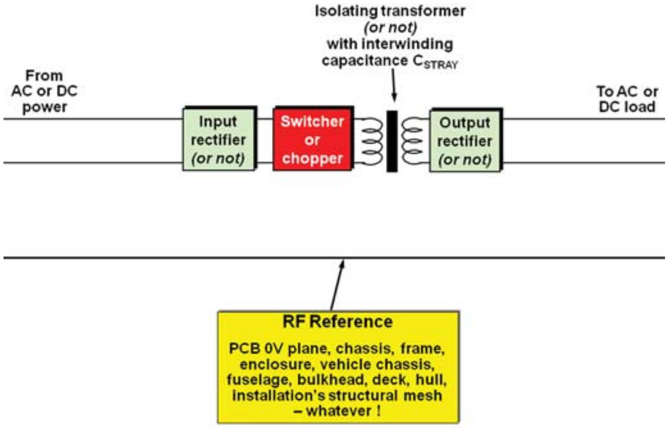

Figure 7.3-1: Example circuit for this section

But, just as in section 7.2, these figures used in this section are equally relevant for all types of switch-mode power converters – from every kind of DC/DC convertor mounted on a PCB, through every kind of AC/DC power supply, to every kind of DC/AC or AC/AC inverter up to any number of MW.

Many of the DC inputs or outputs on low-power converters mounted on PCBs are "single-ended" circuits, i.e. their return paths flow in what is often called the 0V (or zero-volt) conductors.

Where such a converter's PCB has external metalwork, this metal should be RF-bonded directly to the 0V conductors and the whole lot treated as the RF Reference, with the figures in this section (and in 7.2) modified accordingly. (If this text is not clear enough, please let me know and I'll draw appropriate figures in a future article).

But where the PCB's 0V return path must be galvanically isolated from its structural metalwork, then we continue to use three-conductor systems (i.e. separate conductors for the send, return, and RF Reference) like those sketched in Figures 7.2-3 and 7.2-4.

Most EMC books describe EMC filtering, so perhaps I need not go into it in any more detail in this article, in particular:

- in general: Chapters 5.7 and 5.8 of [4] or 2.7.7 and 2.7.8 of [5]
- for PCBs: Chapter 4 of [37]
- for complete electronic products: Chapters 4.2.3, 4.5, 4.6.2, 5.3 and 7.4 of [5], and 13 of [71]
- for items of equipment comprising several electronic units in one metal box: Chapters 2 and 4 of [68] and 6 of [70]
- for systems and installations of any size: Chapters 5.5 (starts on page 69) of [69], and 5 of [70]

However, these books do not describe how filtering achieves noise suppression in terms of current loops and their impedances – so I thought it would be helpful to write a little about filters in that way. Considering the paths taken by currents, whether wanted or stray/noise, is a very powerful way to visualise EMC design issues, and can also be used to analyse EMC design qualitatively, even quantitatively.

AC currents, whether wanted or noise or stray, divide amongst alternative current loops according to their admittances. Admittances are merely the reciprocal of impedance, so the loops with the highest admittance (i.e. lowest impedance) carry the most current.

It is exactly the same way that DC currents divide amongst parallel resistor loads – the highest currents flowing in the highest conductance (in Siemens, S) i.e. the lowest resistance (in Ohms, Ω).

But for AC currents the important issue is the admittances (reciprocal of impedances), which of course vary with frequency.

7.3.2 Filtering with capacitors only

Figure 7.3-2 shows an example of filtering using only capacitors, which aim to create low impedances for the noise currents, to provide them with small loop areas.

Capacitors between the send and return conductors for a converter's input (or output) aim to provide lower impedance loops for the DM noises than if they flowed in the cables all the way to the power source (or load).

Capacitors from the send and return conductors to the RF Reference, aim to do the same for the CM noise currents – provide lower impedance loops for the CM noises than if they flowed in the input (or output) conductors all the way to the to the power source (or load) and back via various metal structures (chassis, frame, installation structural metalwork, etc.).

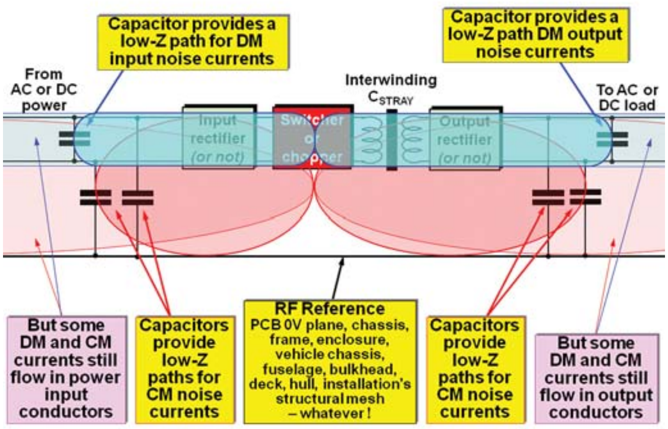

Figure 7.3-2: Example of capacitive filtering

Both DM and CM filtering capacitors need to have low impedances over the noise frequency range to be suppressed – which means they must have a high-enough value of capacitance to create a low-enough impedance at the lowest noise frequency, plus a low-enough value of ESL (equivalent series inductance) to have a low-enough impedance at the highest noise frequency to be suppressed.

(Chapter 3.8 of [5] describes the stray (sometimes called parasitic) impedances associated with capacitors, which limit their usefulness for RF suppression above some frequency. Other limitations of capacitors (e.g. ripple current, temperature) are also covered.)

The way the filter capacitors are connected to the circuit conductors is also important, because all leads, traces, busbars, etc., have inductance. Their inductance adds to the ESL of the capacitors themselves, increasing the overall impedance at the highest noise frequency and making it less effective as an alternative current path.

Figure 7.3-3 sketches various types of capacitors used in filters, with varying effectiveness as filter capacitors depending on the inductive impedance created by their method of assembly.

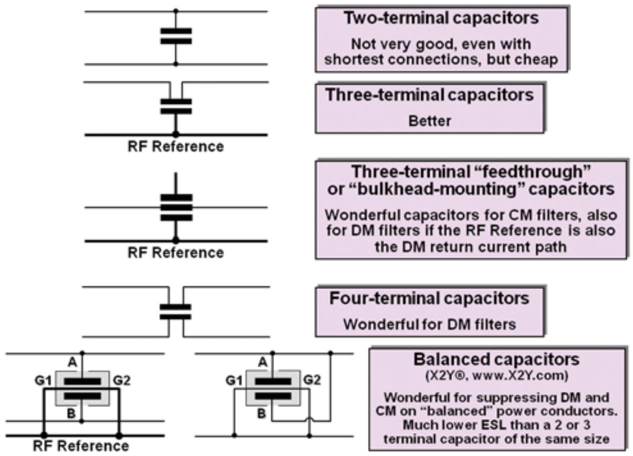

Figure 7.3-3: Examples of types of filter capacitor

For example, if we assume that the typical impedance of the CM noise current loop for a long cable is 150Ω, and if we wanted to achieve a 20dB reduction in emissions at the highest frequency of 100MHz, we need to use a filter capacitor that achieves a total loop impedance of 15Ω. (I am ignoring the source impedance of the noise for the sake of simplicity, as it does not alter the point I am trying to make with this example.)

This total loop impedance is the vector sum of the capacitor's own reactance and the overall inductance and resistance in the current loop. A 10nF capacitor at 100MHz has a reactance of about 0.16Ω, but a 10mm square current loop has an inductance of about 0.04μH and a reactance at 100MHz of 25.2Ω. The vector sum of both reactances is about 25Ω – dominated by the loop inductance

Clearly, the most we can expect from this capacitor filter assembly is an attenuation of roughly 25/(25 + 150) – i.e. about -14dB, and not the 20dB we wanted. To get 20dB we'd have to reduce the loop's inductance by about a half.

This example shows that once the easy job of choosing a capacitor value is done, it is the total loop inductance that really matters when filtering with capacitors. To get a 20dB reduction in emissions at 100MHz we must provide a current loop that – including the size of the capacitor – is equivalent to a square of side 7mm.

It would be the same for 40dB at 10MHz, 60dB at 1MHz, or 80dB at 100kHz – using capacitive filtering they would all require current loops that were equivalent to a 7mm square current loop, or smaller.

Similar examples show that current loop inductance is a problem when capacitively filtering DM noise sources too.

Filter manufacturers are well aware of this issue, and for good performance use three-terminal feedthrough or through-bulkhead types. These have very low ESL and when mounted on a metal wall or bulkhead that is part of their RF Reference (for CM noise) – and for DM noise also acts as the return conductor. Their overall loop impedance is set by the impedance of the RF Reference and any RF bonding.

Providing they are mounted correctly on well-designed and correctly assembled RF Reference, three-terminal feedthrough or through-bulkhead capacitor filters can achieve very high levels of attenuation to well beyond 1GHz.

For good suppression at frequencies of 100MHz and above, the metal plate through which the feedthrough filters are mounted, will almost always need to be a shielded enclosure as well as the RF Reference.

Clearly, component choice, and the design of RF bonding and the RF Reference are very important for capacitive filtering! For full details on these important issues, read the Chapters on filtering listed in 7.3.1 above.

Capacitive CM and DM filtering is especially effective when the conductors they are suppressing have high-Z resonances, and <u>especially useless</u> when their conductors have low-Z resonances.

Even feedthrough filters can struggle to divert noise currents away from the external conductors, when those conductors are suffering low-Z resonances. So we now need to discuss conductor resonances.

7.3.3 Resonances in Input and Output conductors (PCB traces, cables, busbars, etc.)

In real life, the CM impedance of a long conductor (e.g. a cable) varies considerably depending on its proximity to conductors and dielectrics, and both CM and DM impedances in conductors vary greatly when they resonate. Their first resonance is generally when they are a quarter of the wavelength long, for example: at 100MHz, the first (quarter-wave, i.e. high-Z) resonance occurs in conductors just 750mm long, at 10MHz in conductors 7.5m long, and at 1MHz in conductors 75m long.

Remember, when a converter is powered from an AC or DC power distribution network, its power input cable is as long as the network itself. It is not merely the length of the cable used to connect to that network. So almost all AC mains power input conductors are longer than 75m.

Exactly the same situation applies to converter AC or DC *outputs* that provide power to AC or DC distribution networks – the actual conductor length is much longer than the cable used to connect the converter to the network.

Chapters 4.7 and 7.6 of [5] shows how to design conductors as matched transmission lines, which do not resonate. Resonances occur in all transmission lines that are not correctly terminated, but few people (if any) design their converters' AC or DC inputs or AC or DC outputs as matched transmission lines, so they all suffer from unwanted (and unhelpful!) resonances.

Chapters 3.2 of [4] or 2.5.2 of [5] show how mismatching causes these resonances, but does not give a range for the impedances this causes. In fact, conductor resonances can produce impedances as low as their overall resistance (usually tens or hundreds of mΩ) and as high as their leakage resistance (usually tens of MΩ).

For example, a typical straight 10m length of cable connected to the input or output of a power converter, on its own in free space, will resonate with high and low impedances alternately, at 7.5, 15, 22.5, 30, 37.5, 45, 52.5, 60, 67.5, 75, 82.5, 90, 97.5……etc. MHz, all the way to well over 1000MHz (1GHz).

Bending or coiling the cable, or routing it near metal or near (or in) damp soil (or other dielectric materials) will "tune" all of its resonances to different frequencies. Also, in the case where AC or DC power is supplied from a distribution system shared with other equipment, the connection and disconnection of the other equipment (e.g. switching lights on or off) will tune power cable resonances to different frequencies.

And don't forget that power conductors can have other resonances in their DM and CM noise current loops, as their series inductance interacts with their shunt capacitances, "tuned" in this case by any filter capacitors connected to them. With the large values of capacitors connected to power distribution networks these days – mostly to reduce the RF emissions of switch-mode power converters – these resonances generally occur in the range up to about 100kHz.

The result is that – unless the input or output conductors have a fixed relationship to each other and to nearby metalwork (including other conductors) and dielectrics, and a fixed configuration and characteristics for all supplies and/or loads – we should assume that we can get low-Z or high-Z resonances at *any* frequency.

Unfortunately, when converters are tested for their EM emissions, they use a standardised AC or DC power supply impedance, a standard length and layout of cables, and they might replace the intended reactive load (e.g. motor, solenoid, PCB with decoupling capacitors, etc.) with a resistive load (this is almost always done for DC-output convertors). So we cannot be confident that we have tested for resonances that could occur in real life and possibly cause big problems.

There are ways of making emissions (and immunity) testing more realistic, to reduce project and financial risks. Some of them (e.g. using the real load instead of resistor bank) can be used within the standard test methodology, but many of the other ways would mean deviating from the standard test.

7.3.4 Filtering with inductors/chokes only

So now let's look at filtering with inductors, or "chokes" as they are usually called when suppressing RF.

Figure 7.3-4 shows our example block diagram fitted with inductive (choke) filtering only. RF chokes aim to create high impedances at the noise frequencies we want to suppress. We put them in series with the external conductors we are trying to suppress, to reduce the amount of noise current that flows in them.

A big advantage of choke filtering, is that it doesn't need an RF Reference. However, as we will see below, choke filtering on its own is almost never provides the noise suppression we need over the whole frequency band, so we need to combine it with capacitive filtering as described in 7.3.4 – which *does* need an RF Reference, if only for suppressing CM noise.

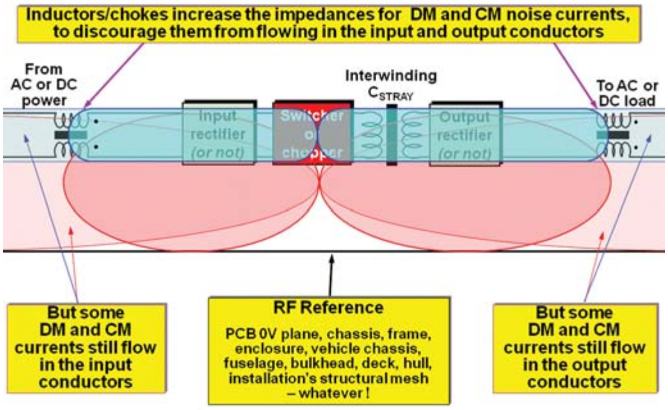

Figure 7.3-4: Example of inductive (choke) filtering

Figure 7.3.4 shows CM chokes and says that they filter DM and CM. An ideal CM choke only creates impedance for CM currents, and has no DM impedance. But all *real* CM chokes have some leakage inductance that creates impedance for DM currents, and for well-made wound CM chokes this is typically 1% of the CM inductance.

Some manufacturers of RF power chokes make CM chokes that have large DM inductances, sometimes called CM+DM chokes. Their big advantage is that where both CM and DM chokes are required – as they often are on the power inputs of switch-mode power converters – they can save a component (or two).

To have any appreciable effect, a choke must create an impedance at least as large as that seen by the noise current loop including the impedance of the noise source itself.

For example, if the impedance of the noise source plus the loop to be suppressed was 50Ω, then to achieve 20dB of suppression the choke must have sufficient self-inductance to create at least 500Ω over the range of frequencies to be suppressed.

For high levels of suppression and/or very high frequency suppression, the stray capacitance from a choke's input to its output can significantly reduce its effectiveness. For example, just 3pF of stray input-to-output capacitance will have a reactance of about 530Ω at 100MHz, and because this appears in parallel with the choke's self-inductance it limits the choke's impedance to no more than this, no matter how high the value of its inductive reactance.

(Chapter 3.8 of [5] describes the stray/parasitic impedances associated with inductors and chokes that limit their ability to suppress RF above some (often surprisingly low) frequency. Other limitations, such as peak current and operating temperature are also covered.)

Inductors (chokes) are wound components that inevitably suffer from stray capacitance. For this reason, most RF chokes for use on conductors carrying power struggle to achieve more than 1kΩ over more than a decade of frequency.

Clearly, component choice, and the design of metalwork, are very important for choke filtering at RF. For full details on these important issues, read the Chapters on filtering listed in 7.3.1 above. Chokes intended for use below about 10MHz are often specified by their CM and DM inductance values, but chokes for use above about 10MHz tend to show their CM and DM data as graphs of impedance versus frequency.

Conductor resonances were described in 7.3.3, and whilst their low impedance resonances cause difficulties for capacitive filtering, their high-impedance resonances cause difficulties for choke filtering.

Also, real noise sources might have impedances of between 10mΩ (or less) and 10MΩ (or more). For example, below 1MHz, the DM noise emitted from a rectifier's mains power input is generated mostly by the ripple voltage on the rectifier's storage capacitor. In the case of a DC input converter, it is the ripple on its DC input capacitor.

These ripple voltages have very low impedances, comparable with the ESL and ESR of the capacitors, which are usually just a few tens of nH and a few tens of mΩ respectively. The result is that the DM noise source impedance for the AC or DC power input is usually around a few tens of mΩ at 100kHz, and around a hundred mΩ at 1MHz (or more).

At the other extreme, in an isolating power converter the CM noise emitted by a rectifier's mains power input comes from stray capacitances between the AC rectifier and off-line switching devices, and their metal enclosure or other nearby metalwork. These strays can be as low as 100pF, which would create a CM noise source impedance of around 15kΩ at 100kHz and 1.5kΩ at 1MHz.

This range of noise source impedances means that, for the example isolating power converter input circuit at frequencies below 1MHz, choke filtering is generally most effective on DM noise emissions, and capacitive filtering is generally most effective on CM noise emissions.

Figures 7.3-5 and -6 give examples of different ways of using chokes in RF filters, and are (hopefully) self-explanatory. Please let me know if they are not and I'll write some text about them in a future article.

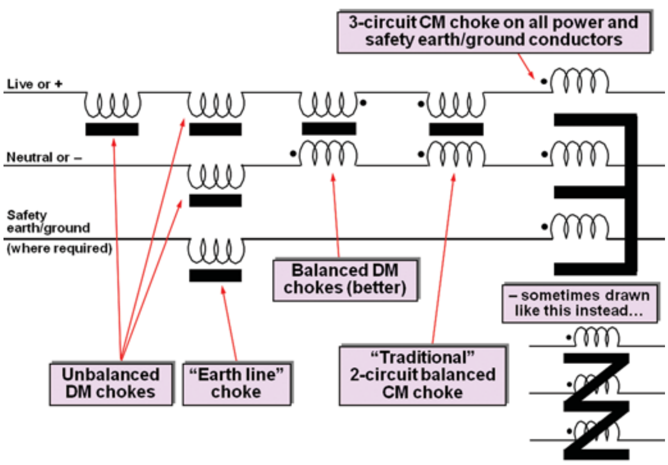

Figure 7.3-5: Different kinds of inductors (chokes)

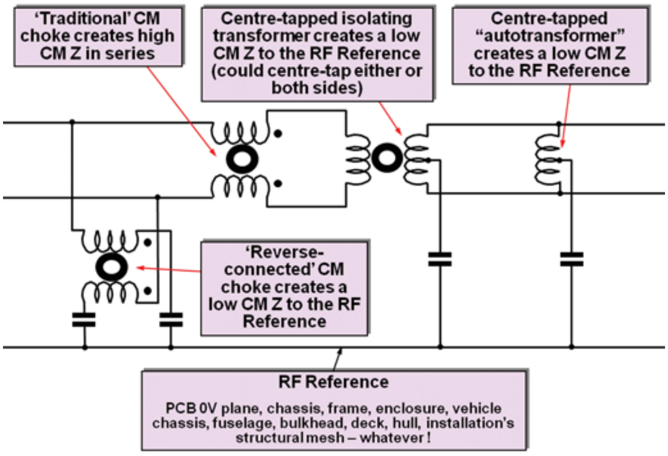

Figure 7.3-6: Examples of alternative CM chokes

7.3.5 Combing capacitive and inductive (choke) RF filtering

CM currents are often the main causes of emissions problems above 1MHz, and Figure 7.3-7 shows the use of so-called "earth-line chokes" to add extra impedance into the unwanted CM noise current loops in the external cables.

At frequencies where the CM filter capacitors don't achieve a very low impedance alternative internal noise current loop, or where the external conductors are for some reason creating a low impedance, this choke will help divert more of the noise current through the internal loop created by the filter capacitors.

Although an "earth-line choke" is a single circuit (i.e. unbalanced) DM choke, because it is in series with the safety earth/ground conductor it can help to suppress the CM noise that is returning from long external conductors via the safety earth/ground conductor.

However, where a converter has many return current paths for its external CM noise current, adding an earth-line choke into its safety earth/ground conductor may have disappointingly poor results.

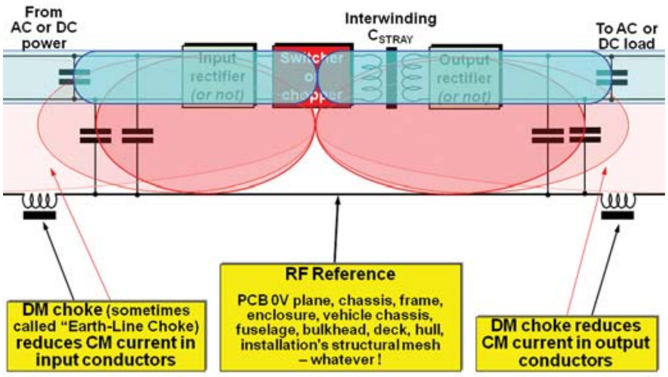

Figure 7.3-7: Example of combined capacitive and inductive filtering using "earth-line chokes"

A good way to increase the impedance of the external CM noise current loop, is to remove all connections to the safety earth/ground – creating an (effectively) infinite series impedance. Of course, we only do this where it cannot compromise safety compliance!

I have often done this, with good effect, where designers had assumed that the safety earth/ground electrodes created a sort of "infinite sink" for RF noise, so they had connected their product to the external safety earth/ground network in the hope that their RF noise emissions would be somehow absorbed in this sink. Of course, as 7.2 shows, all currents (even stray noise currents) flow in closed loops, so it is impossible (in this universe) to create any kind of current sink.

Understanding this, I was able to remove the safety earth/ground connections and significantly reduce CM emissions, to the amazement of the designers, who had assumed it would make CM emissions worse.

It's a good feeling to be able to amaze people in this way, especially when solving EMC problems in a few minutes that they had been wrestling with for weeks, sometimes months. But in fact everyone reading this article can easily learn to understand how Maxwell's equations relate to good practical EMC engineering design techniques, and then work *with* the laws of physics to quickly get wonderful EMC (and SI and PI) performance whilst reducing the overall cost of manufacturing EMC-compliant products, equipment, systems and installations. For more on this see [4] (general), [32] (for PCBs) or [33] (for systems and installations).

Figure 7.3-8 shows a different way of achieving the same effect as using earth-line chokes – by fitting CM chokes into the input and output conductors. Because there are often many alternative routes for stray CM currents in external conductors to return, using CM chokes in this way generally provides better suppression than using earth-line chokes.

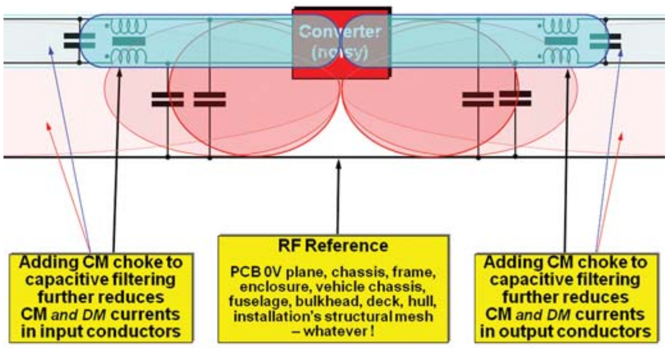

Figure 7.3-8: Example of combined capacitive and inductive filtering using CM chokes

Notice that in Figure 7.3-8 the DM capacitors have been moved to the other side of the CM chokes from the CM capacitors. This is so that the DM inductance inevitably provided by real CM chokes adds some impedance to the DM noise sources in the converter. Where these DM sources have very low impedance (as they usually do below 1MHz, see above) this small but significant additional DM noise loop impedance increases the suppression achieved by the DM capacitor.

However, for high levels of DM suppression below 1MHz it is usually necessary to fit a DM choke as well as a CM choke, to increase the DM noise loop's impedance by a lot more than can be had from a CM choke. Alternatively, we might use a CM+DM choke if we can find one with the CM and DM inductances and other characteristics we need (there is not a great deal of choice).

The noise current paths sketched in blue and red on Figures 7.3-7 and -8 show the combined effects of using capacitive and inductive filtering. As discussed earlier, when using ordinary low-cost components (e.g. wired or PCB-mounted, rather than feedthrough types), neither method is capable of achieving very high levels of suppression on its own and combining them generally achieves higher levels of suppression.

But we see the major benefits of combining capacitive and inductive (choke) filtering when we consider the problems of resonances: in the sources of the DM and CM noise currents, and in the external input and output conductors. Where there are low-Z resonances (e.g. mΩ) capacitor filters are more ineffective, but choke filters are more effective. And where there are high-Z resonances (e.g. MΩ) choke filters are more ineffective, but capacitor filters are more effective.

Combining capacitive with choke filtering therefore helps us suppress emissions over a wide frequency range despite the inevitable resonances in both the noise sources and conductors. Where we can't get sufficient suppression from the simple combined filters shown in Figures 7.3-7 and 7.3-8, which we call "single stage" filters, we can cascade any number of filter stages to achieve the suppression we need.

Figure 7.3-9 shows an example of a three-stage filter, and most filter manufacturers offer AC and DC power filters with one, two and three stages as standard products, with some offering even more stages. Multi-stage filters can have advantages over single-stage filters that I will discuss in a later article.

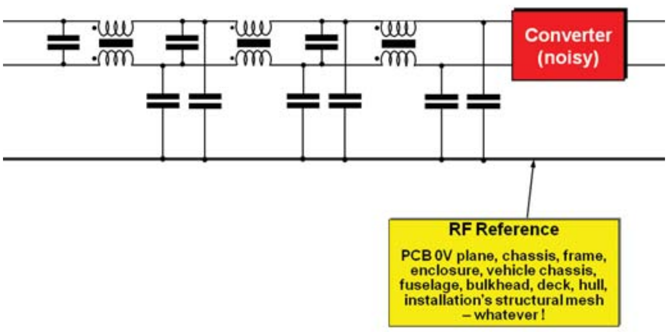

Figure 7.3-9: Example of a 3-stage mains input filter

It is worth pointing out that having more stages in a filter does not (on its own) automatically achieve higher levels of noise suppression at least cost. A filter made with high-performance high-cost components, such as feedthrough capacitors, can provide the same (or better) suppression at the same (or less) cost as a filter with more stages that uses "ordinary" low-cost components.

All mains filters intended for use on 50/60Hz supplies can be used with the same ratings on 16T!Hz or DC (but not "PWM DC"), at a power converter's input or output. They might also be able to be used with reduced ratings on AC supplies at frequencies above 60Hz, usually up to at least 400Hz (e.g. aircraft generators). Ask the supplier if he can specify the filter's ratings for the power frequency required.

However, 50/60Hz mains filters are all unsuitable for any pulse-width-modulated (PWM) outputs, whether they are AC or "DC". In future articles in this "stand alone" series, I will delve into good EMC filtering design practices in more detail.

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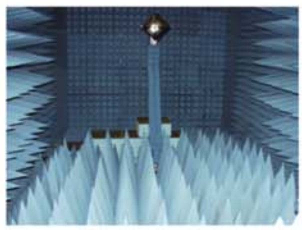

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