the emc journal
Issue 87 March 2010

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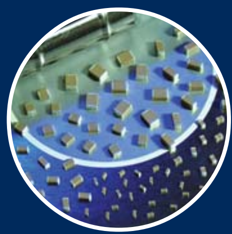

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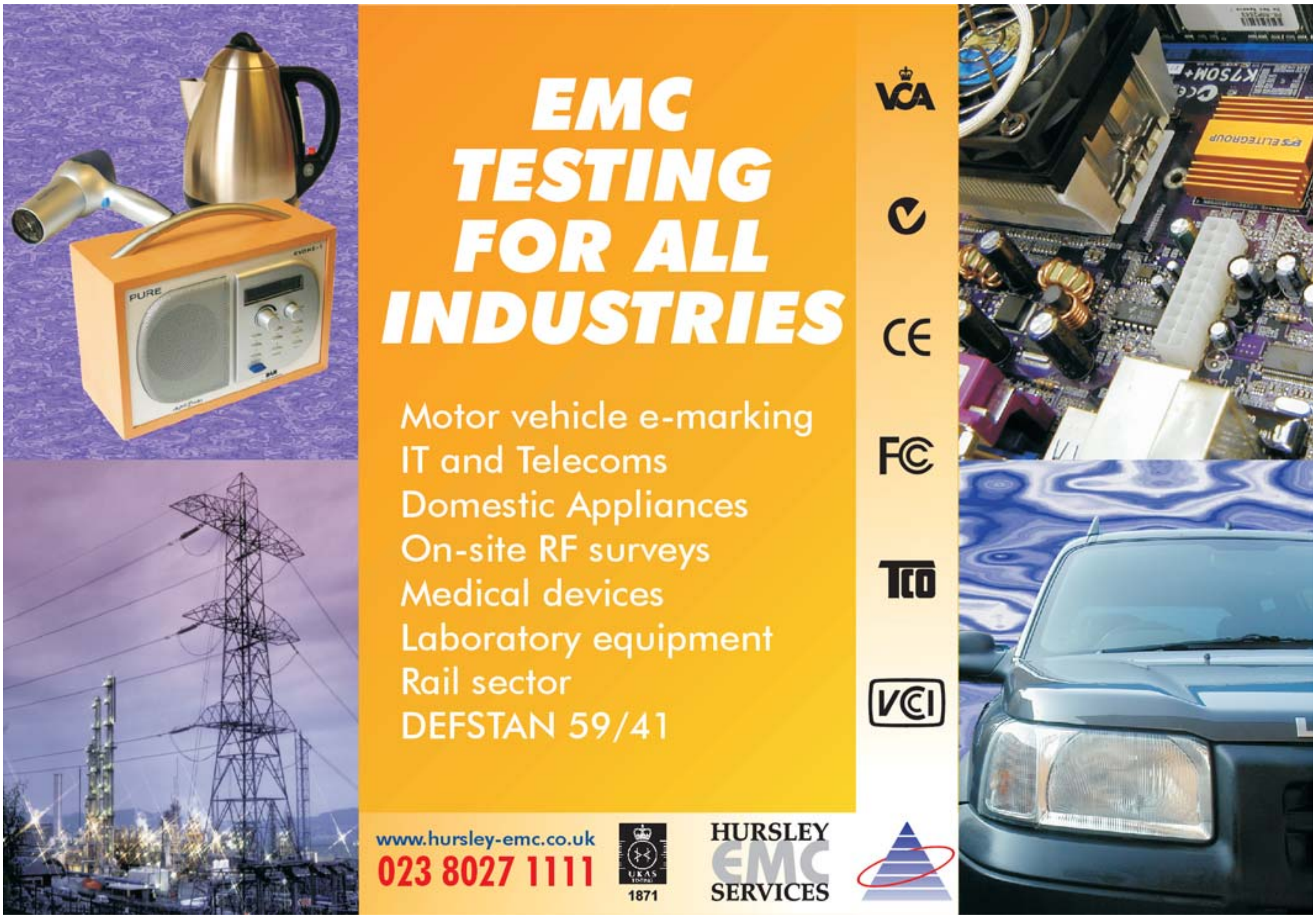

What's In This Issue

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IMPORTANT: Please note our new Fax Number 01208 851630

Feng Shui in the anechoic chamber

Mei Tse Ting

Feng Shui is an ancient Chinese practice of architectural layout and design which is aimed at improving life situations through the harnessing of positive energy. It rests on a set of concepts which can be described as follows:

- Qi (or ch'i): sometimes translated as "life force" or just "energy", Qi energizes locations and situations, in either a helpful or unhelpful fashion
- Yin and Yang: the two opposite polarities of the life force, the continuous interaction of which is responsible for creation. Yin is passive and Yang is active, but one cannot exist without the other
- The five elements: water, wood, fire, earth, metal
- The four cardinal directions: north, south, east and west, represented by the four animals, the Dark Turtle, the Red Phoenix, the Green Dragon and the White Tiger
- The Ba Gua, eight areas representing fundamental principles. Each of the areas has an element, colours, and symbolic trigram associated with it.

The correct application of these principles and concepts will result in good health and a successful lifestyle for those who live and work in buildings which respect them. The purpose of Feng Shui is to channel the Qi within a building or other space so that it nourishes and supports the activities which are carried out there. To this end, the design of the space should acknowledge the principles that are embodied in the concepts set out above.

EMC tests

EMC testing for radio frequency emissions and immunity is an activity which is carried out according to ritual at a special location known as an anechoic chamber. Many of these chambers can be found on industrial estates around the country, although some are found elsewhere, including farms and country houses, suggesting that the application of this ritual has a universal aspect. The ritual involves a number of stages:

- A preliminary invocation of "calibration", in which specially tuned instruments are set up by a trained practitioner
- The object which is to be at the centre of the ritual is placed in a particular position within the chamber and carefully prepared by the practitioner, with prescribed distances fixed to prevent it from moving during the ritual proper
- All casual observers retire to a second chamber where they observe the proceedings on television
- On the practitioner's command, computer software creates a complex sequence of actions involving the calibrated instruments, the ritual object and certain mechanical contrivances which are moved in fixed patterns within the chamber
- During this part of the ritual, which may take minutes or hours, the observers wait with concentrated attention for a result to appear on the computer screens
- At the end of the ritual the result is known. The ritual object is removed from the chamber and returned to its owners, who may or may not have observed the ceremony.

Although the EMC testing ritual is carried out many times a month at many locations, it is difficult to ascribe a particular religious significance to it. On the other hand, the outcome is known to determine the happiness and creative satisfaction of many people. For this reason it would be useful to apply the principles of Feng Shui to the activities in the anechoic chamber. If the Qi within the chamber could be actively harnessed during the ritual the quality of the outcome would be dramatically improved.

The site

The first concern is exactly where the EMC ritual should be conducted. Ideal sites are where there is a confluence of yin and yang energies in the landscape. The Green Dragon from the east and the White Tiger from the west should meet so that their characteristics complement each other. The energy arriving from the south, symbolized by the Red Phoenix, is heavily yang and therefore warm, energetic and fortunate, whereas the northern energy of the Dark Turtle is yin and although it is calming, an excess would be a depressive influence on the activities at the site. Steep-sided hillsides allow the Qi to flow too fast, but flat land or a depression will cause it to stagnate. The ideal site has the Green Dragon to the left and the White Tiger to the right, facing south with ground rising behind to the north and falling away in front.

Anechoic chambers are often not sited in compliance with these aspects, and so we must recognize the inadequacies and provide some mitigating features. If re-location, re-orientation and landscape alteration are not options, then appropriate adjustments can be made to the immediate surroundings. For instance, if the approach to the chamber's building suffers from an excess of yang energy, then the path can be curved to slow down the flow or it can be blocked by barriers such as hedges, water features or screens. Conversely, if the nature of the energy is heavily yin (from the Dark Turtle, say, or from a nearby marshy area) then enhancing the yang aspect of the approach is indicated. This can involve introducing light or movement into the approach path, for example from flags or wind-chimes.

The door

The approach to the anechoic chamber ends at its door. In EMC testing, the door must remain closed for the duration of the ritual. This traps the Qi inside, and therefore features should be provided within the chamber to allow it to circulate freely while the door is closed, and this we will discuss next. But the importance of the door becomes all the greater during the preparatory phase, and afterwards. Beforehand, the Qi must be encouraged to flow into the chamber in a balanced fashion, so that the energy within is neither stagnant nor excited but is harmonious with the ritual. After the ritual, any imbalance in the energy must be allowed to drain away, so that the next performance is unaffected.

Therefore the direction that the chamber door faces, and its outside surroundings, must be considered carefully. The facing direction will naturally enhance the characteristics of the representative animal. A north facing door will encourage the entry of sluggish, yin energy while south facing will call up heat and drought. A western approach will be aggressive and overly destructive, while eastern would be gentle yet creative. The nature of the approach should then be adjusted to mitigate the undesired characteristic. A southern aspect would benefit from shade creation such as overhanging trees to control the powerful heat from this direction. A western entrance needs to control the aggressive drive of the White Tiger energy, so should incorporate a greater degree of curves, bends and barriers than for the other directions. But the opposite is true of a northern door: here the slow-moving Dark Turtle Qi must be encouraged to speed up. There should be no obstacles, and a straighter, more direct approach is best.

An east-facing door is the most fortunate as the Green Dragon energy will encourage harmony during, and a positive outcome from, the ritual. An open, expansive aspect will be appropriate for this direction.

The internal layout

The EMC testing ritual has aspects that unavoidably impact on the Feng Shui principles within the chamber. For instance:

- the whole of the chamber has to be constructed of metal. If this were not rebalanced, of itself this would heavily skew the quality of the Qi within the chamber.
- pyramidal absorber may be applied to the chamber walls. This inherently favours the sharp, aggressive type of Qi. Wedge-shaped absorbers, or those with covered tips, are less aggressive; ferrite tiles, on the other hand, encourage a quite different form of Qi, which is smooth and slippery.
- EMC antennas are angular, being composed of long thin rods or flat surfaces; with the exception of the LF loop, which being circular has a different energy again.

These considerations point to the need to include softer, yin shapes to counteract the hard, yang tendencies. Rounded sculptures or flowing drapes would be appropriate. But more than this, the layout of the areas within the chamber must respect the Ba Gua if the ritual is to be conducted harmoniously. The Ba Gua can be thought of as the “energy map” of a space. There are different schools of application of the Ba Gua within Feng Shui; here we will concentrate on the approach which is more appropriate for Western-style applications. To define the Ba Gua of the anechoic chamber, we take the following steps:

1. Create a grid with nine rectangles that will fit over the floor plan.
2. Align the lower row of the grid with the wall that includes the chamber door.
3. Assign each of the nine rectangles to particular Feng Shui areas (these areas are adapted from the classical Feng Shui practice, which applies to personal life), as shown in Figure 1.

As the lower part of the grid is aligned with the wall of the main door, the door will be in one of the three areas marked 1, 6 or 8.

Now we have to consider how best to lay out or enhance the internal area of the chamber to be in harmony with its Feng Shui. Although the object of the ritual (that is, the item to be tested) would naturally be found at the heart of the Ba Gua, physical constraints usually mean that it has to go closer to the walls. If this is the case then the best location for it would be towards area 4, “prosperity/wealth”, so that the Qi that is focussed in this area and therefore impinging on the object brings a positive result to the ritual. In that case, the measuring or field generating antenna would go towards the opposite corner of the chamber, which is area 6, “allies”. Again this would be a favourable position since the antenna will act in a helpful fashion rather than hostile, predisposing the ritual to a positive outcome. A reverse orientation, i.e. object in area 6 and antenna in area 4, would not be so effective.

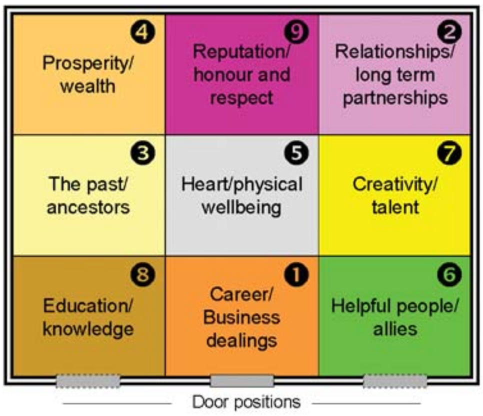


Figure 1 The Ba Gua referred to the chamber door

Other axes (1-9, 8-2 or 3-7) are less favourable. In particular the 3-7 axis should be avoided as area 3, “the past”, will be exerting a negative influence in preventing the ritual moving forward to success. Axis 1-9 is reasonable; the test object should go in area 9 so that it is respected by the antenna, which in area 1 will be taking the ritual in a businesslike way. Axis 8-2 would be a better layout if the purpose of the ritual was for investigative purposes; here the test object should be placed in area 8, so that the ritual contributes to knowledge about it, with the antenna in area 2, forming a partnership with the object.

Areas of the Ba Gua where the test object and measuring antenna are not found should have items placed therein which harmonise with the flow of Qi around those areas. The walls and door of the chamber are unavoidably made of metal, as is the measurement antenna, and this would lead to an imbalance if not corrected. The other four elements – water, wood, fire and earth – should be added in appropriate locations. These should be chosen according to their corresponding directions:

- Wood corresponds to the east and south-east
- Fire corresponds to the south

- Earth corresponds to the centre, the north-east and south-west
- Water corresponds to the north
- (Metal itself corresponds to the west)

These elements can be included either as actual items or symbolically. So to take an example of a chamber whose door is west facing: on the opposing wall or to the right there should be a wooden item such as a table or cupboard, or a wooden sculpture. On the left hand side there should be a water feature, such as a goldfish bowl or a small fountain. Pot plants, representing earth, can be placed against the far left or near right corners. The fire principle can be represented (taking note of safety implications) by a red colour or a triangular shape on the right hand wall.

The heart area of the chamber must not be empty, although there is no specific part of the test ritual which is placed here. The solution to this problem is to permanently have a small crystal, representing the earth element, in the centre; hanging from the ceiling will be an easy way to locate it without disrupting the ritual layout.

To sum up, the layout of this example can be as shown in Figure 2.

Clearly the best layout of the chamber will depend on a number of factors, including its facing direction and the practicality of particular orientations of the measurement axis. Further research is needed to discover whether the implementation of these principles has a measurable effect on the characteristics of the chamber which are necessary for the ritual, particularly on the normalized site attenuation and the field uniformity. It is to be expected that a layout which enhances and harmonizes the flow of Qi will have a positive effect on these characteristics.

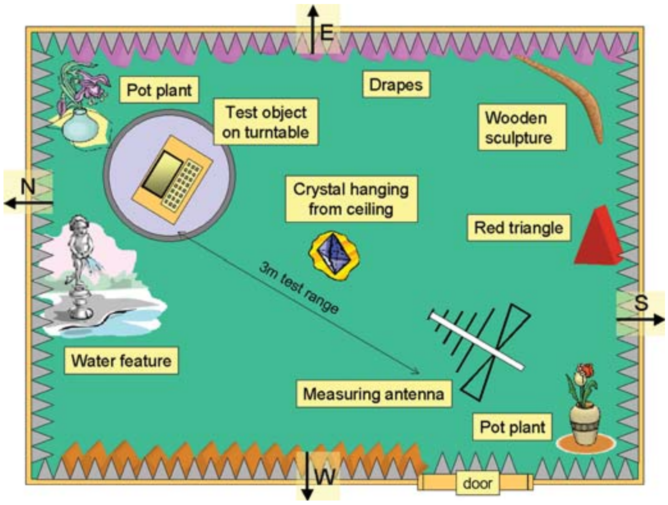
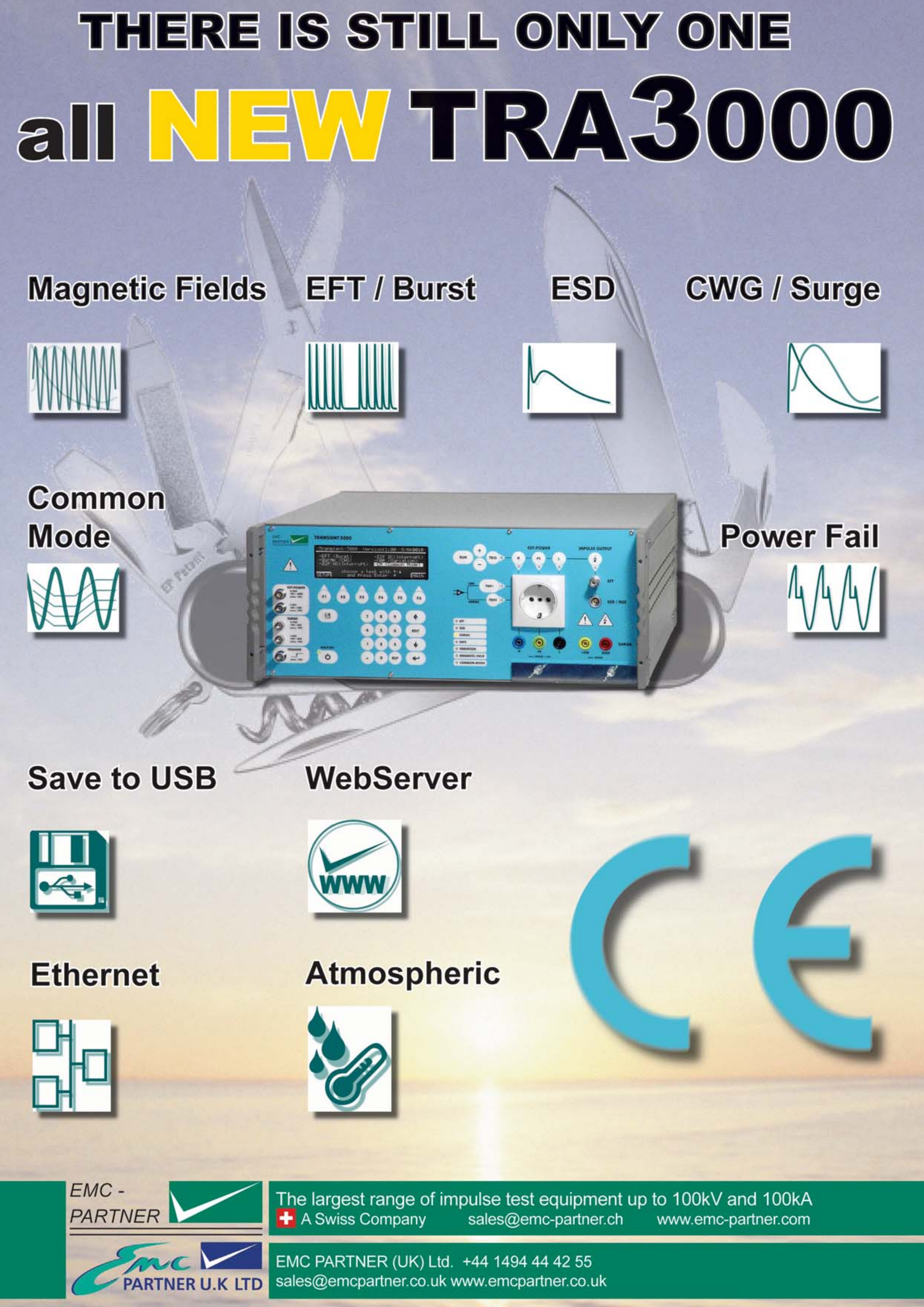


Figure 2 Example layout with west facing door

The author is a Feng Shui consultant and EMC test engineer



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News

Hi Tech Radios for Royal Air Force Search and Rescue Helicopters

Royal Air Force pilots flying Sea King HAR 3 helicopters are to get new state of the art radios which will maintain the RAF's airborne Search and Rescue capability until the aircraft goes out of service. The new radios will replace the obsolete ARC-115 VHF and ARC-116 UHF Air Traffic Control radios, which have been installed since the aircraft was built.

The MoD has procured over 40 R&S M3AR series radios from Rohde & Schwarz Ltd to equip the Sea King HAR 3 fleet and the training Flight Simulator.

Based on software defined radio technology, the R&S_M3AR's are multi-band transceivers covering the 30 to 400_MHz range and can be set up for either 8.33_KHz or 25_KHz channel spacing. They provide a completely future-proofed investment for customers. Meanwhile, pilots will appreciate the R&S_M3AR Series' excellent voice quality, simplicity of operation and channel setting features, which have the potential to reduce their mission workload.

Tony Arnold, the Sea King Project Team Project Officer commented: "In addition to providing reliable Air Traffic Control communications, the new radios will provide aircrew with new voice communications capabilities in the VHF Land and Maritime Frequency Bands. The Sea King Project Team's holistic approach to the HAR 3's obsolescence problems has also resulted in a modification that introduces a fully integrated and state of the art communications and Homing System that will take the aircraft through to the end of its service life. This will save the MoD circa £2M before the 2017 aircraft Out of Service Date."

Keith Randall, Rohde & Schwarz UK's Sales Manager for Radio Communications noted: "Rohde & Schwarz' R&S_M3AR VHF/UHF Airborne Transceivers are the product of decades of experience in the design and development of airborne radio equipment. They were an ideal choice for the Sea King MK 3s due to their low cost of ownership and drop-in compatibility with the ARC-115/116s. This made them straightforward and cost-effective to integrate."

www.rohde-schwarz.com

SC21 – The new standard for Aerospace, Defence and Security sub-contractors

Cove Industrial Enterprises Ltd are delighted to announce their signing up to the SC21 programme. (Supply Chains for the 21st Century).

SC21 was launched at the Farnborough International air show and is a change programme designed to accelerate the competitiveness of the Aerospace, Defence and Security industries by raising the performance of its supply chains.

The benefits of SC21 to our organisation are gained through improving our performance and raising our profile within the supply chain by working closely within the guidelines of SC21, whilst we already supply an exceptional service to our customers, SC21 will help us further to:

a) Achieve improved levels of on time delivery to our customers
b) Enable us to further improve our right first time performance

It means doing what we already do but in a more efficient and co-ordinated way.

By achieving SC21 we aim to save money by reducing waste, and to increase our customer base by being recognised as a supplier of exceptional quality and service levels. We will stand out to the industry as only one of a very few sheet metal work companies which have taken this initiative.

Whilst we are already well on the way as a result of our MIETrak system, our quality system and not least, our collective skill base, the program will inevitably mean some alterations in the way we do things, and will involve the entire workforce, not just our management or QA staff. The result is that we will gain an important edge over our competitors and add strength by reducing the amount of waste (time & materials). It will also feed into the supplier improvement programs we have running with some of our present customers.

We will need to use the services of an external training provider to acquire some of the techniques and skills to gain accreditation. Sigma Management Developments Ltd will be working with us over the next few months to assist us in obtaining this standard. (Sigma Management Development Ltd has been selected by the Society of British Aerospace Companies and the Farnborough Aerospace Consortium to assist companies such as ourselves in achieving this award)

www.cove-industries.co.uk

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Hero image, The EMC Journal
Circle top, Syfer Technology, page 21
Circle middle, Link Microtek, page 19
Circle bottom, TTi, page 20

Secretariat for EMCIA

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Electromagnetic Compatibility Industry Association

The Trade Association for the EMC Industry.
Web: www.emcia.org

The EMC Journal
Free to readers worldwide
March 2010 - Issue No. 87
Published every other month
First Issue March 1995

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Rainford EMC Systems appoint new Sales Manager for Asia

John Noonan (Managing Director) welcomes David Metcalf to Rainford EMC Systems

Rainford EMC Systems continued growth has been enhanced by the appointment of David Metcalf to the Sales and Marketing team. David will focus on consolidation and expansion of the Company Operations throughout Asia.

John White (Sales Director) stated 'David has been in the shielded anechoic chamber business since the early 1980's and has attained considerable knowledge and experience in this unique and demanding industry. We are extremely pleased to have secured his services and look with anticipation towards further establishing Rainford EMC Systems as a World Leader in the Design, Manufacture and Installation of High Quality EMC Test Facilities.'

AR names Timothy Rainear Regional Manager, North America

AR RF/Microwave Instrumentation has announced the appointment of Timothy J. Rainear to the post of Regional Manager, North America.

Tim Rainear comes to AR with over 20 years of experience in the sales & marketing of technology solutions. Most recently Tim was consulting as the VP of Business Development at an early stage start-up company based in Cambridge, MA. His extensive technical background enabled him to investigate and penetrate several key commercial markets for this DARPA-backed, analog signal processing company. He successfully engaged with key decision-makers in such diverse industries as medical ultrasound, base Sstation power amplifier linearization and CMOS and CCD image sensors. He also positioned the company for a significant licensing agreement with a major military prime contractor.

Prior to his work at this stealth-mode start-up, Tim was Director of Sales for Northeastern US and Canada for Mathstar Inc, a high performance reprogrammable logic company. His tenacious pursuit of video and imaging applications as well as the mil/aero market space resulted in design wins at NASA, DRS and Northrop. He also, identified and won a major production

program at a private cable equipment manufacturer resulting in a new revenue stream of nearly $1M/year for Mathstar and a brand new line of products for the customer.

Before joining Mathstar, Tim held Director level sales roles for TriQuint Semiconductor (RF and optoelectronics components) and LightSpeed Semiconductor (structured ASIC start-up). In both positions, Tim hired, trained and managed numerous manufacturer rep firms while maintaining an impressive funnel of opportunities throughout his broad sales territory.

www.ar-worldwide.com

Cove Industrial Enterprises hosts SRCG Meeting

Established in 1964, Cove Industrial Enterprises has been extensively involved in the ruggedized enclosure business, since the early days of the Tempest specification. CIE continue to attend industry meetings regarding EMC to ensure we are at the forefront of design criteria for the military and aerospace industries.

Having participated in several Southern Regional Compliance Group meetings, we were offered an opportunity to host one of the events in December 2009.

Subjects discussed included:

- Introduction to Cove Industries by Gordon Day, Chairman,
- An Update on the EUP Directive and Growth of Eco Design (Vic Clements, Oakmead Consulting)
- Combining PCB Enclosure and Cable modelling for EMC Assessment of an Automotive Module (Paul Duxbury, CST)
- National Measurement Office Activity on RoHS, Batteries and EUP (Chris Smith, NMO)
- Earthing and EMC (John Woodgate, John Woodgate & Associates)

The meeting was followed by a guided tour around our facilities which included the design and production area, full paint shop and finishing area. Visitors were surprised to learn that we like to get involved in projects from the start including prototype design, often just from a sketch of what the customer is trying to achieve, be it cosmetic or rugged, or a mixture of both. We can manufacture the complete enclosure including paint, silk-screening and engraving.

"It was refreshing to be introduced to a manufacturing company that understands the importance of EMC requirements and design needed to meet the latest standards for the electronics industry.

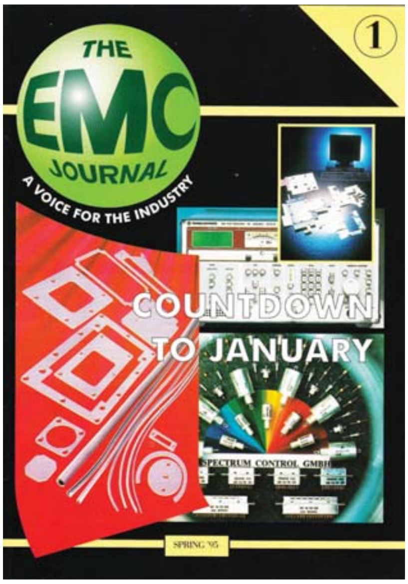
We were also very impressed with the manufacturing facilities that covered prototype design to the finished enclosure plus the in house knowledge available to address the varying disciplines' of the different electronic industries including military and aerospace' Ron Harrison - Ericsson"

To find out more about how we can help you or learn how we are implementing the Aerospace, Defence and Security industries' SC21 Programme, please call us on 01252 512 919 or visit our website www.cove-industries.co.uk.

If compliance to the EU and other world area regulations relating to the electronics industry is an issue for your company, then please come along to one of the future SRCG meetings. Contact Alan Warner on 01202 885399 or at aws-emc@talktalk.net.

News and Information

15th Birthday



The first issue of The EMC journal was published March 1995 and launched at Nepcon NEC Birmingham.

Who would have thought at that time that it would outlive Nepcon, now regrettably defunct. Not on its own, New Electronics used to produce an EMC Edition (no longer does), as did Electronic Engineering, which ceased trading way back, as have Approvals, Compliance Engineering, Conformity and IPC Magazine

Thanks to a lot of hard work by the same team Lynne, Pam and Alan plus very loyal advertisers and editorial contributors, The EMC Journal is still going strong despite this recession, the last one and one before that.

We are looking forward to celebrating our 100th Issue in a couple of years time and The EMC Journal is expanding its horizons...don't miss the announcement in the next issue or keep up-to-date by registering on our web site www.theemcjournal.com

Orange Book Of Knowledge

2009 marked the second time in three years that AR's Orange Book of Knowledge was among the Top 10 downloads at RFGlobalnet.com.

The resource book, which contains articles and application notes on a wide range of topics related to EMC, Wireless Communications and related fields, has become a "must-have" for professionals involved in EMC testing and wireless communications.

AR's Orange Book of Knowledge is available free from AR sales associates and at RF Globalnet.com. For a free download, go to **http://bit.ly/cdLeu6.**

York Courses

York EMC Services are running the following courses.

EMC: Fundamentals of Design and Testing: 19 - 23 April 2010
EMC: Fundamentals of Design & Testing is a highly recommended, unique five-day course that will provide you with the essential knowledge required to help manage EMC and achieve EMC compliance with specifications, standards or legal requirements. We have provided EMC Continuing Professional Development to industry for over 20 years and this is the course from our portfolio that we would recommend for those with little or no EMC experience. If you would like any further information regarding this course then please visit: **http://www.yorkemc.co.uk/cpd/emc/fundamentals/**
Course Fee - £1750 + VAT
Course location - University of York and York EMC Services laboratory, Castleford

Advanced EMC Measurements - 17 - 19 May 2010
This 3 day course is primarily aimed at engineers undertaking EMC testing with a view to extending their understanding of the complex issues involved. Whilst EMC measurements are generally performed by specialists in EMC test houses, the engineers whose equipment is tested will also benefit from this course by extending their understanding of the tests performed on their equipment.

This in-depth course illustrates a wide range of electromagnetic compatibility (EMC) measurements and introduces the techniques associated with performing electromagnetic compatibility measurements in a variety of test environments. Engineers making or specifying EMC measurements. Design engineers and others wishing to understand the EMC measurement process. If you would like any further information regarding this course then please visit: **http://www.yorkemc.co.uk/cpd/emc/measurements-testing/**
Course Fee - £1295 + VAT
Course location - York EMC Services' Castleford Laboratory

Discounts are available for group bookings (conditions apply) and for YECC Corporate Club Members. Please contact us for more details

When booking please quote the following reference MS20100225

In addition to our wide range of standard courses we can offer bespoke course delivered at any venue. We also offer solution focussed EMC, LVD and Telecoms Testing from our accredited labs in Yorkshire, Scotland and Bristol, EMC Consultancy and a range of EMC instruments aimed at validating EMC measurement systems. Please visit our website **www.yorkemc.co.uk** for further details or contact us to discuss to discuss how we can help you to manage EMC in your application.

emcia Member

ANSYS ANSOFT UK Signal Integrity 'Info Day' Wednesday 14 April 2010 Apollo Hotel, Basingstoke

Today's high-speed systems achieve multi-gigabit data rates by replacing legacy, shared parallel buses with gigabit-speed point-to-point serial buses.

Ensuring signal fidelity at gigabit speeds requires a new generation of design strategies and tools to accurately characterise signal transmission.

This Info Day will present Ansoft solutions to help engineers to model, simulate, and validate high-speed channels and complete power delivery systems typical in modern high-performance electronics.

Multiple presentations will show how engineers can understand the performance of high-speed electronics precisely simulating jitter, equalization, EMC/EMI, Switching Noise, impedance profiles, and power delivery loss by using Ansoft tools such as SIwave, DesignerSI, HFSS, and ANSYS Icepak.

For more information and to register for the event go to **www.ansys.com/uksiday**

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Banana Skins...

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

562 New Porsche Panamera: EMI locks people inside

Recalls and service campaigns are often triggered by issues experienced by owners. The Drive team learnt that first-hand after spending a few days with the new Porsche Panamera.

After days of fault-free motoring, the Panamera's electronics were tripped up when it was parked in a semi-industrial area in Sydney's north.

Its sensor key was not recognised and getting any response from the car was almost impossible, even though the battery was fully charged.

After five minutes of trying to lock and unlock doors (in an effort to reset the system or immobiliser) a phone call was made to Porsche Assistance. It was then that the locks thunked closed — and refused to open. Three people were trapped — wife and child included. Door handles did not work, buttons did not respond and with no ventilation the cabin heated up quickly.

After half an hour — including a phone call to the police — the decision was made to smash a window. *(See photograph below, Editor)*

It took another 90 minutes to drag the car on the tow truck, with its electronic handbrake refusing to release. *(See photograph below, Editor)*

Porsche has since tracked the problem to radio interference, presumably from TV and radio towers in the area. Similar problems had apparently occurred in four other Panameras around the world, although this was the first time people were trapped in a car.

Porsche subsequently tried a software update but it failed. More recently the company ordered a radio suppressor unit designed by the factory in Germany to further shield the electronics from interference; it was trialled this week and worked.

Porsche now intends to fit the suppressor units to all Panameras as part of a mandatory service campaign.

While Porsche has stopped short of a recall, it has contacted Panamera customers (the car has only been on sale a few months so there are only about 50 on the road) and informed them of an imminent fix.

"It's a very serious matter given that we had people locked inside the car and we have reacted as quickly as possible and have found a solution which involves the fitment of a radio suppressor unit," says Porsche Australia public relations manager Paul Ellis.

Ellis says service campaigns are common among all brands and are often completed at regular services; the owner may not even be aware.

"This is obviously a phenomenon and is in no way a reflection on inferior build quality of the Panamera. External interference is not something that can be completely eliminated and you do get black holes where interference is possible. It's just unfortunate that this event transpired the way it did."

(Braham Bloom of EMI Solutions spotted an article on this, written by Toby Hagon, on page 7 of the "Weekend Drive" section of his local paper, the Sydney Morning Herald (Weekend Edition Feb 27-28 2010),
and very kindly sent it to me. Chris 557
Zombolas of EMC Technology Pty Ltd saw a shorter version of the same article, also by Toby Hagon, in his weekend paper, The Age, dated 27 February. http://theage.drive.com.au/motor-news/road-test-throws-up-a-realworld-drama-20100226-p84l.html, which referenced the Sydney Morning Herald as its source. The article copied above is the one from The Age, because I could not find a weblink to the original article and didn't want to have to type it all out by hand. Chris Z also wrote: "North Sydney is where the TV broadcast transmitters are located. (They have hundreds of other lower power transmitters as well). We have measured 3-6 V/m in the area surrounding the towers but that was a few years ago before digital transmissions commenced. Absolute and undeniable evidence of unforeseen problems caused by low level common interference sources.*")*

563 Mystery of the 'Windermere triangle' solved

A mystery phenomenon that has left motorists in a popular tourist town unable to unlock their cars has been solved.

For around 18 months, drivers parking up in one of the Lake District town's busiest shopping areas have found their electric key-fobs will not work.

Telecom watchdog OFCOM decided to investigate and sent field engineer Dave Thornber to Windermere with specialist scanning equipment.

He discovered that motorists' key fobs were being jammed because they were on the same wireless frequency as the till in the nearby Lazy Daisy Lakeland Kitchen cafe.

Mr Thornber said: "People thought it was a spook or some newly installed traffic lights but it is the till and the way waiting-on staff input meal orders."

He added: "We used what is called a spectrum analyser to make a sweep of the locality."

"The source of the interference was a wireless order taker in the cafe."

"The device used the same frequency as modern car key fobs which operate central locking."

"The key fobs use a very low power source to protect the life of the batteries inside and so their use was drowned out by the power of Lazy Daisy."

Some car owners complained that when they tried to open their cars they activated electric windows instead, others simply got no response at all. Motoring organisations were called in and batteries replaced but to no avail.

Cafe owner Tom Benton said: "Working with OFCOM we have adjusted the till frequency so it does not jam the locks anymore."

Mr Benton added: "I am just glad the whole mystery of the Windermere Triangle has been solved and there will not more people standing around their cars unable to drive off." "People have been talking about it for months."
(Sent in by Matthew Wilson, Product Design & Production Manager, GB Electronics (UK) Ltd., www.gbelectronics.com/ who saw this in his Daily Telegraph newspaper on Friday 26th February, see: www.telegraph.co.uk/news/uknews/7325141/Mystery-of-Windermere-triangle-solved.html. Also sent in by Claire Ashman, Assessment Manage of UKAS (United Kingdom Accreditation Service), who found a similar article on the BBC News, 2nd March 2010 at: http://news.bbc.co.uk/go/pr/fr/-/1/hi/england/cumbria/8545104.stm. The Daily Telegraph had previously carried a story on this: "Drivers mystified by secret of 'Windermere Triangle'" on 12th Feb 2010, see: http://www.telegraph.co.uk/motoring/news/7215551/Drivers-mystified-by-secret-of-Windermere-Triangle.html. This was of course before Ofcom's intrepid ghostbuster Dave Thornber had arrived on the scene, sirens wailing, fearlessly doing battle with weirdness armed only with what the BBC said was "a sophisticated gadget called a spectrum analyser" (much to Claire's amusement!).)

564 Some recent NASA Aviation Safety Reports

ACN: 754696 (5 of 50): Synopsis: In an apparent PED interference event, a PAX's portable Garmin GPS Model NUVI 660 allegedly interfered with a B7373 Classic's (no glass) DME Navigation update function.
(PED stands for passenger electronic device, a PAX is a passenger, PAX is multiple passengers, and DME stands for Distance Measuring Equipment, a type of radar fitted to aircraft – Editor)

ACN: 702630 (13 of 50) Synopsis: Captain of an A320 reports VHF interference on ZOB ARTCC frequency from a cellphone aboard his plane.

ACN: 681689 (15 of 50) Synopsis: A B757-200'S L fuel gauge blanked after takeoff and became operable prior to landing. Crew suspects possible PED interference.

ACN: 673795 (16 of 50) Synopsis: B737-800 flight crew experienced several TCAS RAs allegedly generated by a Wi-Fi enabled laptop computer.
(TCAS is the Traffic alert and Collision Avoidance System, designed to reduce the incidence of mid-air collisions between aircraft. An RA is a Resolution Advisory message generated by the TCAS when it detects a potential problem. See: http://en.wikipedia.org/wiki/Traffic_Collision_Avoidance_System)

ACN: 661013 (17 of 50) Synopsis: Flight crew of CRJ-700 reports that aural interference in VHF communications ceased when PAX were asked to ensure all forms of 2-way communications were turned off.

ACN: 609264 (26 of 50) Synopsis: B737-300 crew had erratic LOC signals on ILS runway 13 and runway 7 at JAX. A PAX was using a 'Palm Pilot' at the time.
(ILS is Instrument Landing System, see: http://en.wikipedia.org/wiki/Instrument_landing_system)

ACN: 600964 (29 of 50) Synopsis: Flight crew of MD80 experience misaligned heading info on FMS display. Suspect PAX operated electronic devices.
(FMS is the Flight Management System and controls navigation, see http://en.wikipedia.org/wiki/Flight_management_system)

ACN: 597486 (31 of 50) Synopsis: A false TCASII RA sends a DC9 flight into a climb to avoid a potential target 5 miles south-east of BUNTS International, NTXN, PA. A flight attendant had caught a lady trying to call her daughter on her cellphone at the time the flight "pulled up".
(TCASII is a version of TCAS, Traffic alert and Collision Avoidance System, see earlier)

ACN: 579608 (35 of 50) Synopsis: DC-9 Flight crew received a false TCAS RA during departure climb and increased their rate of climb to avoid a false target apparently generated by a PAX laptop computer.

ACN: 576709 (36 of 50) Synopsis: A B737-700 crew, on approach to BWI runway 10, attributes being off course to possible unauthorized use of cellphones prompted by a cabin announcement. The inability of the crew to both be on the ILS frequency because of the approach design, also may be a contributing factor.

ACN: 576147 (37 of 50) Synopsis: MD88 crew has static on the #1 VHF communications radio. The static stopped when the PAX were directed to turn off their electronic devices.

ACN: 535960 (47 of 50) Synopsis: CL65 crew had a possible PAX originated RF Interference with an autoflight system during vectors of the approach.

ACN: 533786 (50 of 50) Synopsis: B727 FLC experienced erratic VOR NAV course indicator possibly due to PAX use of an electronic device.
(VOR means VHF Omni-directional radio Range, a type of radio navigation system for aircraft, see http://en.wikipedia.org/wiki/VHF_omnidirectional_range.)
(The above are all synopses taken from the July 29, 2009 update to the NASA ASRS Report, http://asrs.arc.nasa.gov/docs/rpsts/ped.pdf, downloaded 17 February 2010. The full reports are available in the same download. I don't know where earlier "updates" are archived, or even if they are archived at all, but I have copies of all the ones that have been referenced in earlier Banana Skins if anyone needs them - Editor.).

565 Solar Storms Could Be Earth's Next Katrina

Photo by Bob Martinson/AP
The northern lights dance over the Knik River near Palmer, Alaska. Activity on the surface of the sun creates this natural light show, but severe solar storms could devastate Earth's power and water utilities, and knock out communications.

Government officials are concerned that a massive solar storm could leave millions of people around the world without electricity, running water, or phone service, according to a report by National Public Radio. The impact is likely to be far worse than in previous solar storms because of the growing dependence on satellites and other electronic devices that are vulnerable to electromagnetic radiation.

Solar Storms Could Be Earth's Next Katrina by Jon Hamilton, February 26, 2010

A massive solar storm could leave millions of people around the world without electricity, running water, or phone service, government officials say.

That was their conclusion after participating in a tabletop exercise that looked at what might happen today if the Earth were struck by a solar storm as intense as the huge storms that occurred in 1921 and 1859.

Solar storms happen when an eruption or explosion on the surface of the sun sends radiation or electrically charged particles toward Earth. Minor storms are common and can light up the Earth's Northern skies and interfere with radio signals.

Every few decades, though, the sun experiences a particularly large storm. These can release as much energy as 1 billion hydrogen bombs.

How Well Can We Weather The Solar Storm?

The exercise, held in Boulder, Colorado, was intended to investigate "what we think could be close to a worst-case scenario," says Tom Bogdan, who directs the Space Weather Prediction Center in Boulder. The Center is a part of the National Oceanic and Atmospheric Administration.

"It's important to understand that, along with other types of natural hazards, (solar) storms can cause impacts," says Craig Fugate, Administrator of the Federal Emergency Management Agency (FEMA), who also took part in the tabletop exercise.

Bogdan and Fugate say that eventually there will be another storm as big as the ones in 1921 and 1859 — a sort of solar Katrina.

But the impact is likely to be far worse than in previous solar storms because of our growing dependence on satellites and other electronic devices that are vulnerable to electromagnetic radiation.

In the tabletop exercise, the first sign of trouble came when radiation began disrupting radio signals and GPS devices, Bogdan says.

Ten or 20 minutes later electrically charged particles "basically took out" most of the commercial satellites that transmit telephone conversations, TV shows and huge amounts of data we depend on in our daily lives, Bogdan says.

"When you go into a gas station and put your credit card in and get some gas," he says, "that's a satellite transaction."

Disabled Satellites Are Just The Beginning

The worst damage came nearly a day later, when the solar storm began to induce electrical currents in high voltage power lines. The currents were strong enough to destroy transformers around the globe," Bogdan says, leaving millions of people in northern latitudes without power.

Without electricity, many people also lost running water, heat, air conditioning and phone service. And places like hospitals had to rely on emergency generators with fuel for only two or three days, Bogdan says.

In many ways, the impact of a major solar storm resembles that of a hurricane or an earthquake, says Fugate.

But a solar Katrina would cause damage in a much larger area than any natural disaster, Fugate says. For example, power could be knocked out almost simultaneously in countries from Sweden to Canada and the U.S., he says. So a lot more people in a lot more places would need help.

Individuals don't need to make any special preparation for a solar storm, Fugate says. The standard emergency kit of water and food and first aid supplies will work just fine.

"If you've got your family disaster plan together, you've taken the steps, whether it be a space storm, whether it be a system failure, whether it be another natural hazard that knocks the power out," Fugate says. *(Copied from: www.interferencetechnology.com/lead-news/article/solar-storms-could-be-earths-next-katrina.html, 3rd March 2010, and www.npr.org/templates/story/story.php?storyId=124125001&ft=1&f=1001)*

566 **Severe lightning in Kentucky**

Recently there were several severe storms in Kentucky. A real nasty one that produced an abnormal amount of intense lighting passed about 20 miles south of us.

www.wkyt.com/news/headlines/82320257.html is a link to TV news coverage, which is only about half accurate about the damage: "A single lightning strike from a thunderstorm damaged three homes in Boyle county Thursday night. The homes are located on Lebanon Road. The lightning bolt left a trench a foot wide and, in some places, a foot deep. After that, it traveled through a phone line and caused damage to three homes. The bolt busted up a concrete driveway outside one home. It also damaged phone and water lines. Another home also had a phone jack busted off and melted carpet. Fortunately, no one was hurt during the storm."

I know one of the residents whose home was hit. All of the electrical outlets, switches, breaker box and every electrical or electronic device was simply fried. They were home during the strike and the static field was so strong that all of their hair stood straight out as though they were connected to a Van de Graaff generator.

I visited the home yesterday as inspectors were deciding if the home was salvageable.

They had removed large sections of the drywall and not only were the electrical fixtures fried, a 5' section of "Romex", three conductor power cable commonly used in the US that has hot, ground and neutral, has lost its ground wire! The remaining cable is full of burnt pinholes and there is copper bits buried in the 2x4 studs.

I watched as the pulled up the carpet and the concrete slab floor had the most interesting dendrite pattern. Large sections of the concrete will just lift out and much of the concrete is "pulverized". The foundation may have similar damage, or perhaps the lightning cut a underground trench which let water carry the dirt supporting the foundation away. One corner of the home sags over a foot.

What is interesting is the ground was saturated by the rain we have had in the last two weeks and the soil has not frozen. The earth path from the attachment point only approximates the buried telephone lines that it "followed". The actual attachment point was a small metal junction box that looks like a madman with an arc welder attacked it. The amazing thing is there are over 100 telephone lines in the box and the lightning path did not lead to the closest home. That home and most of the others only needed the exterior demarcation, or Network Interface Device, replaced.

Given the path length, and the massive damage, this strike has to be near the upper limits. I have some ~4" x 4" fused globs of sand and soil and a couple of globs of yellow clay that look as though they were fired in a kiln. My wife is an artist and this even impressed her.

The clay is very sponge like, very porous, were, I guess, the water boiled out. I expected to find only wet sand, clay and soil. A galvanized metal culvert had to be replaced as the lightning ran across the surface of the soil for maybe 25' and "exploded" the metal pipe.

There is a pronounced dip in the road where the pipe has failed. Looking in with a flashlight, hand torch, I could see thousands of dendritical burns, some of which had burned through the metal wall, exposing the dirt and gravel.

The state's chief fire marshal was there and he told me that in his 30 year career he had seen nothing close to this level of damage. *(Kindly sent in by Terrence Fugate, WN4ISX, on 26th January 2010. Terry's amateur radio gear was his only communication link with the outside world for three weeks after Hurricane Katrina.)*

567 Overrun accident on Shonan Monorail officially caused by EMI

In 24 February 2008, there was an overrun accident on Shonan Monorail at Kanagawa, Japan. When the train started from a station on the scheduled time, it suffered unintended rapid acceleration. The train continue to accelerate even though the operator had not set the train's master controller to acceleration position.

When the train came near to the next station, it could not be decelerated enough even with its emergency brake activated, and caused an overrun. The train finally stopped, fortunately with no casualties, after collision with a rail point.

On 26 June 2009, an accident investigation report, RA2009-6, was issued from the Transportation Safety Board. The Board concluded that the accident was caused by roughly the following reasons:

(1) Poorly grounded VVVF inverter (which drives the train) on the train caused excessive noise, which could be coupled to nearby wires;

(2) A cable for an unused monitor board was still connected to the CPU, and the cable was not properly protected from possible incoming noise;

(3) Noise on the cable could cause interrupt signal to the CPU;

(4) The CPU didn't mask (disable) the unexpected interrupt, so the corresponding interrupt handler in the software could be activated due to the noise;

(5) Somehow, once activated, the interrupt handler (not expected to be activated in normal situations) disabled all other interrupts after that, which made the acceleration/deceleration process no longer work at all;

(6) The integrated watchdog timer couldn't recover the system due to a defect in the control software.

The moral of this story: especially for safety related systems, careful design and verification of the system, including its software, from an EMC point of view, is essential.

Reference for readers who can read Japanese: Accident investigation report RA2009-6, http://araic.assistmicro.co.jp/railway/report/detail.asp?ID=1744, or go direct to this PDF at: http://araic.assistmicro.co.jp/railway/report/RA09-6-1.pdf

(Kindly sent in by Tom Sato from Japan, on the 17 Jan 2010. The photograph below shows rescuers using an emergency chute to remove passengers from the crashed monorail train. I'd like to remind readers of the IET's very practical 2008 Guide to EMC for Functional Safety, www.theiet.org/factfiles/emc/emc-factfile.cfm, which can be purchased as a colour-printed book from www.emcacademy.org/books.asp -Editor)

568 Car door locks unstable when older car alongside

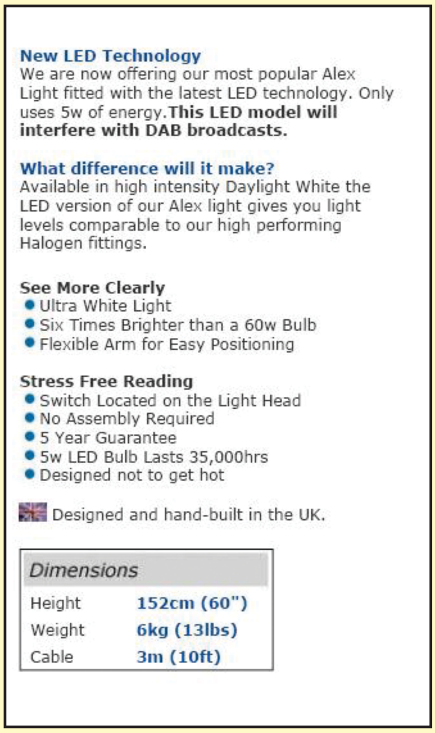
I would be very interested in seeing the risk analysis for any of the vehicles you mention in your article and more specifically for any system component that has changed from a hydraulic to electronic controlled. I can see issues with any system used for critical safety such as steering or braking. I am quite sure that a risk analysis for EMI has not been done to establish pass/fail criteria.

My own experience with a Ford car fitted with electronic door locking has convinced me that the EM environment is basically uncontrolled. Whenever an older car stopped beside me, the doors locked and unlocked until the vehicle passed by. Eventually after two sets of replacements the problem was fixed and I am sure was EMI related.

(Kindly sent in by Braham Bloom of EmiSolutions, Sydney, Australia, 21st February 2010.)

569 LED Reading light specified as interfering with DAB

Just found this on the web – a British made light that will interfere with DAB - who certified this one? Visit: www.seriousreaders.com/mall/productpage.cfm/SeriousReaders/_780001/255469/Alex%20LED%20Table%20Light.



(Kindly sent in by Peter Kerry, an independent EMC consultant in the UK.)

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

Things can only get better

In the forty-plus years that I have been involved in standards work, I don't recall any previous time at which there were as many bad situations in standards development as there are now. Apart from PLT, which is in a class of its own (or is it?), it was decided, no doubt with the best of intentions, to write *new* standards for EMC and safety of multimedia products, i.e., audio, video and ICT. In my experience, whenever 'revolution' has been preferred to 'evolution' there have been tears before bedtime. But those who are unprepared to learn from history are required to repeat the course until they are.

CISPR 32/EN 55032: emission standard for multimedia products

The project has taken so long that, under IEC rules, it had to be re-started. The latest committee draft is dated 2009-03-20 and comments were due by 2009-06-26. The Compilation of National Committee comments runs to 103 pages, so there is obviously much more work to be done. Most people involved thought that this would be the simpler of the two EMC standards to produce! The comments are not just fairly trivial editorial issues; there are fundamental technical issues still to be resolved, although most of the comments are about the need for additional texts and editorial and technical corrections. Many of these could have been avoided if time were given to carefully proof-read the document before circulation.

The comments were discussed at a meeting late last year. It would seem premature to go to the first voting stage (CDV), but before the meeting that was the plan. However, it has not yet appeared (at the time of writing).

CISPR 35/EN 55035: immunity standard for multimedia products

This project also ran out of time and had to be re-started. A draft dated 2008-06-27 was circulated, with a closing date for comments of 2008-10-03. This leads over the CISPR 32 document in the comment volume stakes, with 109 pages! But it has run out of time again, and a new document is expected, but not for some considerable time.

Because of the huge number of different functions incorporated in multimedia equipment, the standard gives requirements for each function, not for products. It is not surprising that this novel approach has required a great deal of new work.

PLT (just when you thought it wasn't going to feature!)

The emission requirements for PLT are being treated as an amendment to CISPR 22/EN 55022. The PLT committee produced what it said was the best document it could, but the chairman of the parent committee was not convinced that the requirement for consensus ('absence of sustained objection') had been met, so a questionnaire was circulated, asking National Committees whether they considered that the document was mature enough for the first voting stage (CDV).

This is a rare, but not unprecedented, procedure. It raises interesting points of logic. Those who support the document will say yes, circulate, and vote positively on the CDV. Those who oppose it have a dilemma - say yes, circulate, and vote negatively, or say, no, do not circulate. In the distant past, one country was notoriously cautious about CDV circulation, which at that time had to be approved at a meeting. The approach became more positive after it was pointed out that the best way of confirming their doubts abut a document was to circulate it, to see if other national committees agreed with them that the document was not sufficiently mature!

The result of the questionnaire is that 15 countries supported a CDV circulation (but with no indication that they would vote positively; two of those registered a 'qualified yes'. But 11 countries did not support a CDV circulation, so it is unlikely that a CDV would pass its vote. Three countries abstained,; UK had to abstain because there was no consensus in the UK committee!

This project has, in turn, run out of time, and work cannot formally re-start until after a meeting in October 2010. It will still take a miracle to resolve this issue! The most obvious 'miracle' is for the PLT exponents to accept a lower data rate, and therefore a lower transmit power.

Digital dividend

The plan to reassign part of the UHF TV bands (mainly 790 MHz to 862 MHz) to mobile radio have run into a big problem. The millions of TV sets in the field have, obviously, limited immunity at these frequencies and the operation of a mobile transmitter near a TV may result in, not only severe interference with TV reception but also the signal being re-radiated or conducted into a cable system connected to the TV. It is rather surprising that no-one seems to have thought of this until last year.

CENELEC has set up a new WG to consider the problem, with an intention to produce results within six months. A first meeting was scheduled for February 2010. It has been pointed out (correctly) that a technical WG is not the right forum for such issues, but that has been disregarded. Once again (as in IEC SC77AWG1) a technical group is being asked to pronounce on economic and political issues - it can't succeed!

IEC/EN 62368: safety standard for multimedia products

In IEC, improvements are still being proposed to the First Edition, which is already published. Who will try to work to it (apart from the original supporters of the project)? In CENELEC, the position is that the document cannot be a standard. It also doesn't really meet the rules for a Technical Specification, but that may be the only option. Even so, who will take notice of it, when its mandatory observance is many years away and the text will inevitably be very different from that of the present edition? But the document can only be turned into an acceptable and practicable standard if it *is* improved through experience. Catch 62368!

Control of sound level from personal music players

The CENELEC committee working on this could not agree, so the Secretariat circulated a draft. It is of poor quality and will attract many comments. One major issue is that it refers normatively to EN 50332-1 and -2, which are also badly drafted and are planned to be revised. So we will have a standard that refers to inadequate standards for major matters, until they are revised.

One big issue is that hardly any headphones and earphones on the market seem to have the low sensitivity demanded by the standard. And it may be difficult to prevent the standard being interpreted that ***all*** headphones, not just those intended for use with portable players, have to meet the standard, which will, it appears, take 99% of the present products off the European market. Of course, they could still be sold elsewhere, possibly even in the Isle of Man and the Channel Islands, and certainly outside Europe.

The way to protect hearing, from ALL sources of loud noise, not just players, is through public education: www.dontlosethemusic.com

Pity the poor standards guy

I have starkly spelled out all the horrors. It should be clearly understood that the majority of people working on standards are highly competent and have the best of intentions. But, as you have read, many have been faced with impossible, or nearly impossible, tasks, and there is relentless pressure from standards body managements to shorten processing times - it's a BIG mistake.

When large and important projects arise, such as new standards for a large sector like multimedia, everyone, quite reasonably, wants their say (except those dinosaurs who STILL haven't seen the need for joining in standards work). Committees may have 50 to 100 members, and cannot work efficiently. So they set up smaller groups, but even those are liable to have 20 or more members, in order to be representative of even just the major interested parties. It can be shown, as they say, that the most efficient committee has eight or nine members, but then they might all actually be employed by the (fictitious) Multinational Electrinology Corporation, even though they come from eight different countries.

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PRODUCT GALLERY

Agilent Technologies introduces industry's first single-box Analyzer/Curve Tracer for 40-Amps/3000-Volt power device evaluation

Agilent Technologies Inc. (NYSE: A) have introduced enhancements to the B1505A Power Device Analyzer/Curve Tracer to make it the industry's first single-box solution able to characterise semiconductor devices up to 40 amps and 3000 volts.

The high-power device market is growing rapidly each year due to the demand for green engineering and products that conserve energy. Industry segments leading the growth are hybrid and other high-efficiency cars; industrial uses such as robotics, solar cells, wind electricity and electric trains; and in information technology and consumer electronics CPU power control circuits that require a highly efficient power device for power conservation.

Power MOSFET and IGBT devices are being engineered to reduce energy loss, conserve power and decrease operating costs. Some new devices are using wide-band gap materials such as silicon carbide (SiC) or gallium nitride (GaN) to achieve high efficiency. In addition, on-wafer testing has become very important for reducing development turnaround times. The upgrade to 40A capability will increase the number of power devices and applications the Agilent B1505A can serve.

"Test and measurement of high-power devices is a growing requirement for manufacturers, yet one that demands the utmost accuracy and reliability,"• said Masaki Yamamoto, general manager of Agilent Hachioji Semiconductor Test Division. "Researchers and development engineers need to know they can be confident in their findings. On-wafer as well as packaged device 40A evaluations, are strong requirements in the marketplace because they help dramatically decrease time to market".•

The Agilent B1505A is a single-box solution that provides for ease of use and ease of analysis. Its new 40A capability comes from its ability to support two high-current source monitor units (HCSMUs) in a single device. Current owners of an Agilent B1505A with a HCSMU can easily add a second HCSMU with an accessory to enable 40A sourcing and measurement for both packaged and on-wafer devices. The all-in-one design provides a simple and clean configuration for 40A sourcing and measurement, allowing easy set-up and providing an uncluttered work environment with space for larger devices. The new design is unlike a measurement system built with multiple instruments, where complicated cabling and user safety considerations are required.

The Agilent B1505A can measure currents up to 40A and display the results in various formats including semi-log or log-log graphs with extracted parameters. The interlock feature ensures safe operation by preventing electrical shock even with the increased current capacity.

The module selector supports automatic switching between multiple types of SMU; this allows the measurement of key parameters, such as on-resistance and breakdown voltage in a single measurement sequence. The tracer test mode, which now covers 40A as well as newly developed simultaneous sweep range control in positive and negative directions, provides intuitive and easy-to-use measurement with the same look and feel of the current market-leading Agilent B1505A, introduced in November 2008.

Also provided is a new socket module to support the test adapters widely used by conventional curve tracer users. This allows current curve tracer users to reduce migration costs when replacing old curve tracers with the state-of-the-art Agilent B1505A.

Key features of the Agilent B1505A Power Device Analyzer/Curve Tracer with 40A capabilities include:

- device characterisation at 3000V and 40A in a single instrument with accuracy down to sub-pA;
- new accessories that allow clean and safe connection for 40A measurement for packaged devices and on-wafer devices;
- capacitance-voltage (CV) measurements with high DC bias up to 3000V;
- a new accessory that supports test adapters widely used in conventional curve tracer; and
- simultaneous sweep range control in positive and negative directions.

The Agilent B1505A with 40A capability will be available for order beginning May 1, 2010.

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New hand-held instrument measures RF radiation from 9kHz to 6GHz

Now available from RF radiation safety specialist **Link Microtek** is a new hand-held instrument that can make rapid and accurate measurements of electromagnetic fields over a wide frequency range from 9kHz to 6GHz.

Manufactured by Narda Safety Test Solutions, the SRM-3006 selective radiation meter can be used with a variety of isotropic or single-axis probes to carry out safety investigations on sources ranging from low-frequency industrial equipment, through radar and TV broadcast transmitters, right up to the latest generation of mobile communications services.

Results are shown instantly on the 152 x 91mm colour LCD display and can be expressed either as absolute values in a choice of

different units or as a percentage of a permissible limit value (e.g. ICNIRP reference levels). The weighting curves for all current safety standards are stored in the instrument for this purpose.

With a resolution bandwidth as high as 32MHz, the SRM-3006 is fully equipped to monitor wideband signals, and it also offers a video bandwidth facility to smooth the trace while retaining the original resolution in the background. Maximum, minimum and average values can be displayed simultaneously, if required.

As well as automatically logging date, time and GPS co-ordinates with each measurement, the instrument is able to record written or spoken comments. Results can easily be transferred to a PC via the instrument's USB or RS-232 interfaces, while the bundled PC software enables the user to customise tables and measurement routines and to carry out subsequent evaluation of measurement data.

Designed for outdoor use, the SRM-3006 features a robust, splash-proof housing and operates from either Li-ion rechargeable batteries or an external AC adapter. In addition, the instrument's high immunity to electromagnetic radiation means that it can make reliable measurements in the vicinity of strong field sources.

Both the instrument and probes are calibrated, traceable to national and international standards, ensuring that all results are reliable and reproducible.

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50 MHz function generator hits new price point

The new TG5011 from **TTi** is a combined function/arbitrary/pulse generator with a frequency range covering 1 µHz to 50 MHz. At under £900, the generator achieves a new price point below that of competitors' products offering only 20 MHz or 25 MHz bandwidth.

The generator offers high-purity sine waves with low harmonic distortion and low phase noise over the full frequency range. Square waves have a rise time of below 8 ns with low overshoot giving good wave shape right up to 50 MHz.

The frequency of these waveforms can be set with up to 14 digits and is based on a TCXO (temperature-controlled crystal oscillator) timebase with a stability of one part per million. The high resolution of the direct digital synthesis (DDS) system means that very low frequencies can be set. For example, a frequency of 1 mHz can be set with a resolution of 0.1% and a stability of one part per million.

The TG5011 incorporates a pulse generator mode which provides a wide range of pulse width and delay independent of period. Pulse period can be set between 2000 seconds and 80 ns (0.5 mHz to 12.5 MHz) and the duty cycle can be as low as one in two billion. Rise and fall times (edge speeds) are also independently variable over a wide range.

Arbitrary waveforms of up to 128k words can be generated at 14 bits vertical resolution and a sampling speed of 125 MS/s. A front-mounted USB port enables external flash memory storage of up to 1000 waveforms. The memory stick also provides a quick and convenient method for transferring waveform files to and from a PC.

Commonly used complex waveforms are provided including sin(x)/x, exponential rise and fall, logarithmic rise and fall, gaussian, lorentz, haversine and cardiac waveforms. The generator comes with Waveform Manager Plus for Windows, enabling complex waveforms to be created using a PC.

The TG5011 offers a comprehensive set of digital modulations including AM, FM, PM, PWM and FSK. The modulation source can be any standard or arbitrary waveform, or any external signal applied to the modulation input.

A wideband noise generator creates gaussian white noise with a high crest factor and a bandwidth of 20 MHz. Noise can be added to any waveform or can be used as a modulating source.

USB and LAN interfaces are provided as standard, the latter conforming with LXI class C (Lan eXtensions for Instrumentation). A GPIB interface is available as an option. All functions of the generator can be controlled from the digital interfaces, and arbitrary waveform data can be transferred via them.

The TG5011 is housed in a highly compact casing with protective buffers and a multi-position stand. With the buffers removed it is half-rack 2U size for rack-mounted applications. Despite its small size it incorporates a 3.6-inch (90 mm) diagonal LCD panel that provides a large amount of text and graphical information simultaneously and offers context-sensitive soft key control.

To view the data sheet click here http://www.tti-test.com/go/tg5011/

Tel: +44 (0) 1480 412451
info@tti.co.uk
www.tti.co.uk

New 3-channel Power Meter from AR features high-speed measurement capability and wide range

AR RF/Microwave Instrumentation has added a new power meter to its family of high-quality test instruments. The new Model PM2003 is a 3-channel power meter with exceptional high-speed measurement capability and a wide dynamic range.

Model PM2003 delivers 200 readings per second with one channel; and 100 readings per second when two channels are used. Two channels at a time can be simultaneously displayed and recorded; the third channel can be easily switched in to be displayed or recorded. Its dynamic range extend to 90dB when diode power heads are used; and to 50dB with thermocouple heads. Its power measurement range goes from -70dBm to +44dBm

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

New 68 page catalogue shows outdoor cabinet ranges

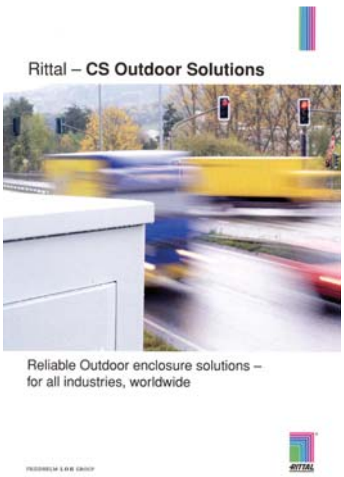
Rittal has released a 68 page catalogue, CS Outdoor Solutions, featuring their range of outdoor enclosures, many of which are available from stock.

Applications for the cabinets are from simple housings for electrical connections or "hardened" electronic equipment, through a standard offer of 4 sizes of "outdoor 19" rack" to a modular product range which allows a degree of "pick and mix" for its configuration.

Uses include roadside and railside equipment housings for messaging, signaling and control systems, some of which have been supplied for use in tunnels, where the external pressure changes make additional demands on the enclosure.

Telemetry and other instrumentation may be safely housed in the elegant structures which are designed to withstand vandal attack, and may be further enhanced with an anti-graffiti nano-coat paint finish.

Also included in the catalogue are several climate control units specifically developed for outdoor applications, featuring inbuilt heaters to combat condensation and internal icing during winter



conditions.

The line-up is completed with several pages of accessories as varied as gland plates to assist with sealing around cables entering through the bottom, and a plethora of different mounting struts, angles and plates to allow internal fitting in almost every conceivable manner.

For your copy, please call 01709 704000 or visit the Rittal website www.rittal.co.uk.

Tel: +44 (0)1709 704000
information@rittal.co.uk
www.rittal.co.uk

Slaughter's 4320, 4-in-1 Electrical Safety Tester now offers an RS-232 serial interface

The Slaughter Company is pleased to announce the addition of a RS-232 serial interface to their 4320, enhanced 4-in-1 electrical safety tester. The RS-232 is available as an optional feature and now allows direct connection of the 4320 to a PC. This provides users with the benefit of being able to set up the instrument remotely through the PC allowing quick and accurate configuration of all test parameters. In addition to this in compliance with many safety agency requirements it becomes a very simple process to download all test results directly to a PC for record keeping of electrical safety tests.

For more information and detailed specifications on this or any of the safety testes from the Slaughter Company please contact a member of the sales team at **AR UK Ltd.**

Tel: +44 (0)1908 282766
sales@uk-ar.co.uk
www.uk-ar.co.uk

emcia Member

Rohde & Schwarz extends its lead in network analysis with first four-port network analyzer up to 67 GHz

The high-end R&S ZVA67 vector network analyzer from **Rohde & Schwarz** is now also available as a four-port model. This is the first network analyzer on the market to feature four test ports for measurements up to 67 GHz. Its high dynamic range (110 dB at 67 GHz) and output power (6 dBm at 67 GHz) give the R&S ZVA67 the flexibility and performance required for characterizing components and modules in the microwave and millimeter-wave range. It allows users in research and development to determine the S-parameters of multiport devices quickly and with high precision. As an extra benefit, the analyzer's four internal signal sources reduce test system complexity and the number of instruments required, e.g. for measuring frequency-converting DUTs, because no external signal generators are needed.

The new R&S ZVA67, with its unique architecture that includes four ports, four integrated signal sources and eight receivers, enables measurements on multiport devices such as mixers, couplers or balanced DUTs, with just one instrument. With its high output power of 6 dBm and wide power sweep range of > 40 dB, the R&S ZVA67 is able to characterize the small- and large-signal behavior of active components. Linear and nonlinear measurements can be carried out using a simple test setup. This advantage becomes apparent, for example, when measuring the S-parameters or intermodulation of mixers or amplifiers, or when measuring the

group delay and phase of up- or downconverters.

Offering a frequency range up to 67 GHz, the four-port R&S ZVA67 covers the band intended for the wireless transmission of multimedia data (wireless HDMI). Additional applications can be found in the aerospace and defense sectors, including measurements on inter-satellite communications systems and point-to-point communications systems. The analyzer's wide dynamic range of 110 dB at 67 GHz also makes it a valuable tool for material measurements or microwave imaging applications.

Frequency converters from Rohde & Schwarz extend the frequency range of the four-port network analyzer to beyond 325 GHz. Due to its outstanding performance, the R&S ZVA67 enables users to advance the development of materials and technologies into much higher frequency ranges.

The R&S ZVA67 in a two- or four-port configuration is now available from Rohde & Schwarz.

Tel: +44 (0)1252 818888
contact.uk@rohde-schwarz.com
www.rohde-schwarz.com

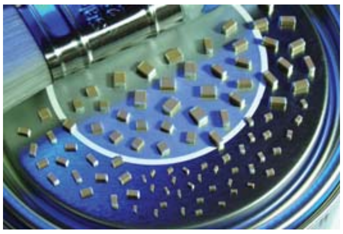
Process improvements power up capacitor range

Innovative developments in manufacturing processes and materials technology have led to significant extensions in **Syfer Technology's** range of 100V and 200V X7R surface mount MLCCs (multilayer chip capacitors).

As a result (see table below), values have increased dramatically, delivering up to double the capacitance in the same size package as previously. This ability to reduce package size or increase capacitance range will prove critical to meeting today's tight design constraints.

The range extensions are a direct result of Syfer's continuous quality improvement programmes, such as Lean and 6 Sigma, as well as material and process developments. An important area targeted for improvement is the 'wet process', where the wet ceramic and electrodes are printed layer by layer under automatic computer control. This is a critical stage in the manufacture of ceramic capacitors, and these specialist materials have been subject to on-going improvements, yielding positive results. In addition, greater control through automation, over all parts of the manufacturing cycle, has further contributed to ever-increasing capacitance values.

The improved MLCC ranges, now



with voltages up to 200V in the X7R dielectric, are eminently suitable for applications in power supplies, dc-dc converters, automotive and aerospace equipment. They are also available with FlexiCap™ terminations using Syfer's proprietary flexible epoxy polymer termination material, which make these devices considerably more resistant to damage through bending or flexing, and when under stress and temperature cycling extremes.

The surface mount capacitors are already in production and available immediately on a 5 week lead-time from Syfer's Norwich, UK manufacturing facility. The devices are fully RoHS compliant, although tin-lead finish parts are available for industries exempt from the directive. Price is dependent on type and quantity, but can start as low as £0.015 / €0.017 / $0.025.

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

Why are my detectors so slow?

David Mawdsley, Laplace Instruments Ltd

The detector in an EMC analyser or receiver is the part of the system that actually measures the level of the signal after it has been extracted* from all the other frequency components.

> *****_This extraction process is effectively a very narrowband filter which blocks all but the wanted frequency. A narrowband filter sounds simple enough, but those who work in this field know that it is actually quite a demanding task to create such a filter which has the required characteristics (bandwidth, shape, out-of-band attenuation etc,…). If you add the requirement to 'scan' such a filter across a wide frequency range, it becomes just plain impossible. So we use superhet techniques, as used in radio receivers to 'do' the scanning for us. This produces an output whose level equals the magnitude of the incoming signal at the selected frequency._

We could simply connect the output from this detector the input of an ADC and plot the results on the screen. What would we see?

As the system scans across the required frequency range, we can expect the output to vary in response to the spectrum of the incoming signal. Obviously, we will need to restrict the rate of the scan such that the bandwidth of the ADC and other parts of the system can 'keep up'.

If we stop the scanning for a moment, so we are looking at just one frequency, the output would either be steady state (which would indicate a continuous input signal) or would vary with time (indicating a non-continuous input signal, ie one that included transients or bursts or was modulated).

In essence, the above describes how a 'normal' spectrum analyser operates.

EMC receivers (or analysers) are different. A key issue is the handling of non-continuous signals.

Detectors

EMC standards specify the use of 3 (possibly soon 4!) different detectors. They all give different answers. They are Peak (Pk), Quasi-Peak (QP), Average (Ave) and, recently proposed, the RMS-average detector. The reason for this new detector is that it gives a better measure of the interference effect on digital communication services.

The diagrams 1, 2 and 3 show how the Pk, QP and Ave detectors work. Peak is quite self explanatory. There are effectively no time delays in the response, it simply indicates the highest signal level seen during the time the analyser dwells at a frequency. In effect, the detector produces its response virtually instantaneously so the Pk detector can be used for fast scanning. When the result has been acquired, the analyser moves to the next frequency and the detector is reset by discharging the capacitor. (The reset circuitry is not shown in the diagrams).

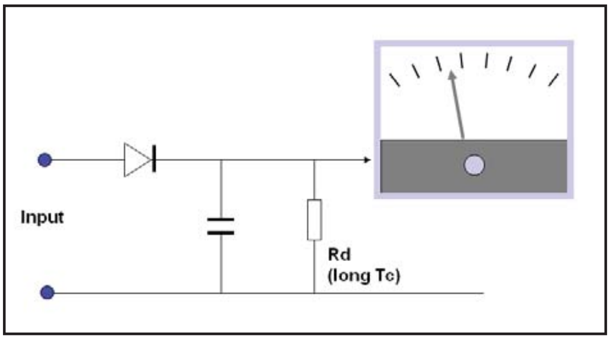


Fig 1: Peak detector

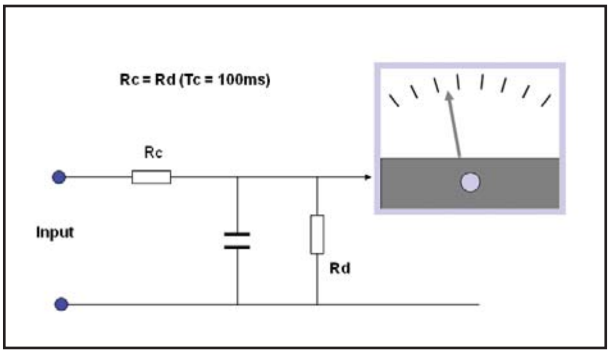


Fig 2: Average detector

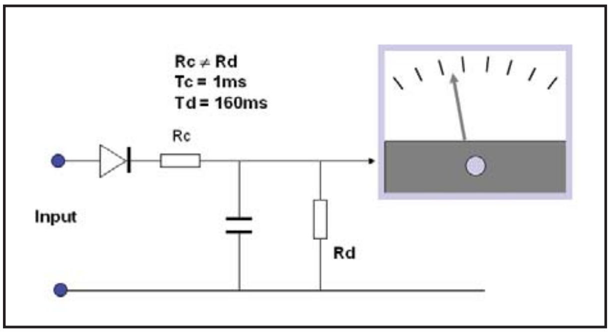


Fig 3: QP detector

Again, the average detector is quite simple. It applies a linear average to the incoming signal.

The QP detector includes features of both the above. In particular, note how the time constant for the capacitor charging is short (1ms) compared with the discharge time constant (160ms). To understand why we need these alternative detectors, consider the fact that often, interference is subjective.

Detector purpose

For example, I have a table lamp which includes a phase angle controlled light dimmer stood next to my audio system. When the lamp is on, I can hear a 100Hz buzz superimposed on my audio output… drives me nuts!

I also have in the kitchen an electric cooker with an old temperature control system that switches power via a contactor which switches every 5 seconds or so when the oven is up to temperature. The transient created by the switching of this contactor is far greater than the transient caused by the phase angle switching of the lamp. If we use a peak detector, the oven controller would produce a result far higher than the lamp, and this is a problem, because it's the lamp that is actually the worse source when considering the subjective consequences of the interference. It may seem that the average detector would overcome this problem given the relatively fast repetition rate of the lamp transients. Unfortunately, the transients are so short (in both cases) that average detectors simply do not respond and the result for both sources is practically zero. Average detectors are in fact most useful when modulated signals are included in the interference input.

Quasi-peak detectors are simply a design that happens to produce the 'right' results, ie results that approximately correlate with the deleterious effect on broadcast reception and the subjective effect.

Actual waveforms

Fig 4 shows the response of a real detector. The dark red trace is the input, the blue trace is the peak detector and the green trace is the QP detector. The timebase has been set so that the measurement of one frequency can be seen This is the dwell time and in this particular case it has been set to 400ms. All detectors are seen to be discharged at the beginning of each dwell time.

The red incoming signal is from the light dimmer and the 'spikes' at a repetition rate of 100Hz are clearly seen. Note how the QP detector is charged up by each spike due to its fast rise time, and between spikes, the slow discharge 'slope' can also be seen. From this image, it becomes obvious why EMC receivers (and analysers) are so slow when taking measurements with the QP detectors. Even with a 100Hz transient repetition rate, the detector takes some 200ms to achieve the 'correct' level. With slower repetition rates, the detector takes corresponding longer. CISPR16 specifies a 1 second dwell time for band B. Band B (150KHz – 30MHz) has an RBW of 9KHz and so the frequency step must be equal to or less than 9KHz. This means that there are at least (30,000-150)/9 results to be taken in this band. From this a scan time of 55 minutes can be deduced.

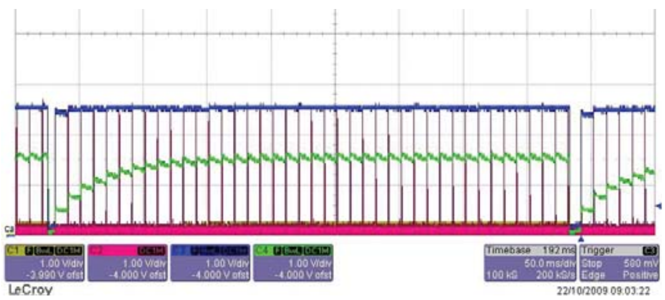


Fig 4: Oscilloscope view of detector output

Figure 5 shows a similar situation, but this time the signal comprises the broadband 100Hz transients plus a narrowband component. When the analyser is at the frequency of this narrowband component the detector output has a mostly continuous nature. The figure shows this as the middle dwell period and the average detector (yellow trace) is clearly seen, rising to match the levels of the peak and QP detector levels.. Again note the time scale for the rise time. The QP detector shows a fast rise time (as expected) and the average detector a relatively slow rise time. The measurements either side of this frequency peak show what happens as the continuous signal 'degenerates' towards the impulsive 100Hz signal with consequent drop in the average result.

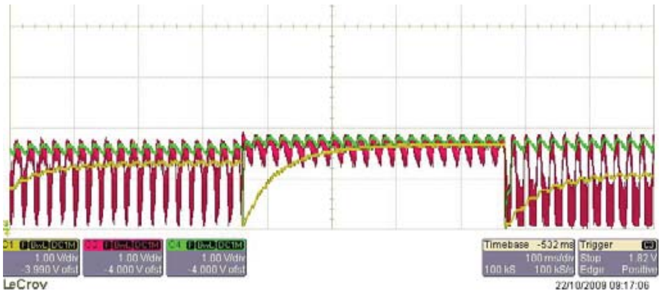


Fig 5: Detector response for steady state signal.

Scan time

The Laplace analysers actually sample the frequency every 0.6 x RBW and this is a fairly common practice, so the 55 minutes estimate (see above) becomes 92 minutes. Clearly it would be a great advantage if this process could be speeded up. We can 'adjust' the dwell time, reduce it from 1 second to (say) 100ms, at which time the results are within 10% of the final value for a 100Hz repetition rate. Obviously, if the repetition rate was slower than 100Hz, this error would increase, so reducing the dwell period is not recommended unless you know the characteristics of the signal. In order to speed up the test process however, standard practice at test labs and all those experienced in the art of EMC is to initially scan with the Pk detector. Because the Pk detector will always produce the highest result (compared with the QP and Ave detectors) it will be obvious that if this Pk result was below the limits, then the EUT is compliant. In this case no further testing is required.

Only if the Pk detector exceeds a limit will measurement with the other detectors be necessary.

In many cases, the limits are exceeded only at certain discrete frequencies. Some analysers are fitted with markers which can be 'dropped' onto these problem frequencies and which will then display the Pk, QP and Ave levels at these points. These will enable fast and accurate monitoring of these problem frequencies, virtually in real time, enabling troubleshooting and modifications to be observed immediately.

Fig 6 shows a screenshot taken from a Laplace EMC analyser with the Pk detector plot displayed and a tabular list of the measurements at the marked frequencies. These are currently showing the QP values.

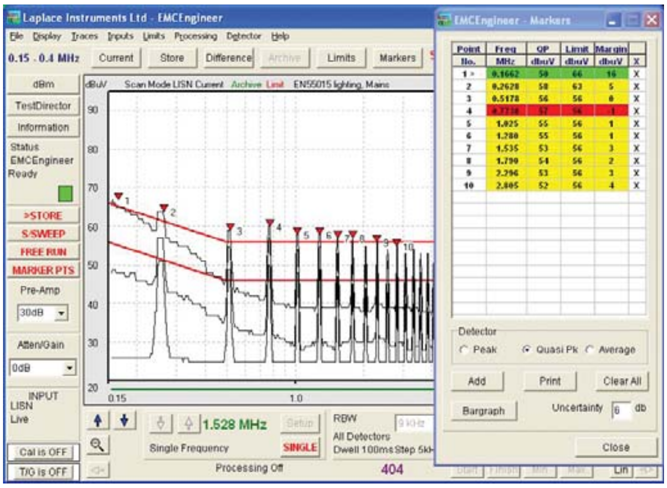


Fig 6. Marker display

For convenience, an alternative view is the bargraph plot, shown here (Fig 7) which shows immediately how the results compare with the limits. The centre line is normalised to the limit level and results are plotted +/-20dB, with the uncertainty margin clearly shown.

The buttons on the RHS allow the different detectors to be selected and displayed. Difference plots can also be shown.

There are proposals to allow the use of the RMS-Average detector as an alternative to the QP and Ave detectors with just the one limit level (which would be 4dB above the current Ave level, hence 6dB below the QP level). Where only the QP limit is applied to a band, the QP limit would be retained. The advantages are that only one detector is used for the entire frequency range (9KHz – 18GHz) and that this detector has a faster response time than the QP or Ave detectors.

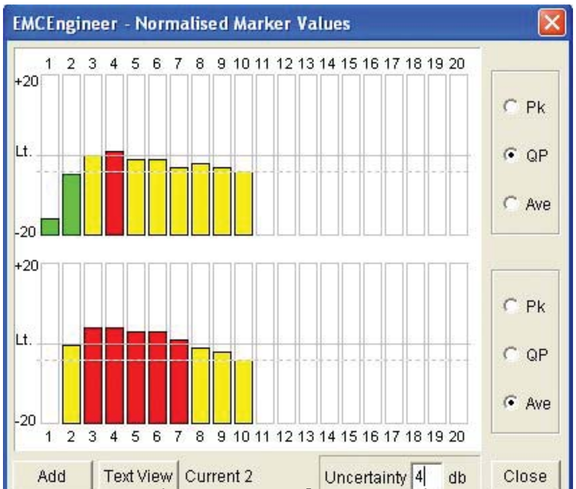


Fig 7: Bargraph presentation

Conclusion

True EMC measurements do require the use of specialised detectors, and these involve significant time constants which result in slow scan rates. Faster scanning leads to increased likelihood of error and would be non-compliant. However, techniques do exist which can provide significantly faster results without loss of accuracy, and which can provide key measurements in real time displayed in a form which allows easy interpretation of compliance status.

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The Practicalities of "A Common Framework for the Marketing of Products – Decision No 768/2008/EC" for Anybody in the Supply Chain of Goods within the EU

Summarised by Marc Hudson, Compliance Engineer, Audio Partnership PLC

1. Introduction

You would be forgiven for thinking that the title of this article suggests a new requirement to force marketing departments to do a better job. You should be so lucky!

In fact, this "decision" as Dave Imeson pointed out in the last edition of the Journal (please read if you haven't already done so!), is "a pro-forma" to be used for re-casting of existing or for new directives. It continues the aims contained in "COM(2003)240 final: Enhancing the Implementation of the New Approach Directives".

In summary: "In order to give fresh impetus to the technical harmonisation system, the Commission has recommended better ways to implement the New Approach Directives with the objective of reinforcing the free movement of goods in the context of an enlarged European Union (EU). These recommendations aim to promote safer, cheaper and more competitive European products."[1]

This decision became active back in January of this year and lays out the following key objectives:

1. To define common principles "in order to provide a coherent basis for revisions or recasts" [2] of legislation. In other words, directives such as LVD, EMC, RoHS and WEEE, etc will have to be recast to be in line with this decision. In some cases this is already being looked in to, namely RoHS 2, and it possibly becoming part of the CE marking (therefore assuming part of the EC declaration of conformity too?).
2. To introduce an up-to-date set of rules for CE marking.
3. To improve the traceability of products throughout the supply chain, regardless of their origin, right up to the manufacturer. This is due to EU authorities finding it difficult to locate manufacturers operating outside of the EU to deal with complaints and non-conformance.
4. The responsibility and consequence of non-compliant products being "placed on the market" now lies with *all parties in the supply chain* of that product.
5. As a result, we are all now required to share (when requested) accurate and complete information with national authorities about the supply chain and produce evidence of conformance for the products we sell. This also includes any assistance in market surveillance requests by the same national authorities. If non-conformance is found, then appropriate action is taken to resolve the problem (depending on the severity).
6. To bring in new provisions to deal with products in the common market that are a compliance risk (i.e. safety) to consumers within the EU. In other words, "failures-in-field".
7. To better define certain terms contained within recent EU official documentation that have previously caused confusion and different interpretation by many who have read them.
8. Re-emphasise that products placed on the market must comply with all applicable legislation. However, this should remain the obligation of the manufacturer and they should pass on the information to their supply chain.
9. Although this decision is not set in law, each Member State is obliged to respect the requirements set in this decision when reforming any legislation that is relevant. Those in the supply chains however must abide by the requirements listed.
10. All the requirements in the decision apply to all relevant companies irrespective of colleague count and company turnover.
11. Finally, this decision repeals decision 93/465/EEC.

2. Definitions

There are some terms which in the past have caused confusion so they have been defined in this decision. Some definitions to take note of are as follows:

1. "Making available on the market" means supplying a product for distribution, consumption or use in the Community market where it is at a cost or free of charge.
2. "Placing on the market" means the first time that a product is made available on the Community market. The correct interpretation is the time when that physical product with its unique serial number is first entered into the EU, whether straight to the end consumer, retail shop or even stored in an EU warehouse, or similar. Therefore, if new legislation becomes law, any batches of a product entering into the EU after the start date of that legislation must be compliant.

   It is wrong to interpret it as the first time a model in its current form is made available. As a result, the next incorrect assumption is that only when that model has changed sufficiently enough to put its compliance into doubt does it need a complete compliance reassessment.
3. "Manufacturer" is the person who manufactures a product or has that product made by a third party and markets it under his brand, name or trademark.
4. "Authorised representative" is the person who has received written confirmation from the manufacturer to act on his behalf in whatever tasks are laid out in the confirmation.
5. "Importer" is the person within the EU Community who places a product on the market from a third country.
6. "Distributor" is every other person in the supply chain other than the manufacturer or importer who makes a product

available on the market.

7. "Economic operators" is a collective term that represents the Manufacturer, Authorised Representative, Importer and Distributor.
8. "Conformity assessment" is the process showing whether "requirements relating to a product, process, service, system, person or body have been fulfilled"[2].
9. "Conformity assessment body" is the person(s) that carries out conformity assessment activities. Examples are calibration, testing, certification and inspection.

3. Obligations

What has been outlined so far is all very well, but what does it actually mean for the "Economic Operators" and what do they need to do to show conformance to this decision? The following will go into more detail for each operator in the supply chain.

3.1 The Manufacturer's Obligations

As mentioned earlier, the top of the list of requirements for the manufacturer is that the products they sell must conform to relevant regulations. This includes keeping technical documentation and the EC Declaration of Conformity on file, writing up appropriate conformity procedures, carrying out conformity assessment and then affixing the correct marking on each product they sell to the EU market. All the compliance documentation must then be kept on record for a time determined by the lifecycle of the product and level of risk of the product being sold (within the EU). However, if any form of non-compliance of a product is found, then the manufacturer must do whatever is necessary to bring it back into conformance.

The manufacturer is also expected to show that the production batches of their products are continually compliant. If any changes are made to the products or to the standards to which they are compliant to, this must be considered and appropriate action taken if the compliance is put into doubt. I have also interpreted this to mean that the factory should also have adequate systems in place to ensure that the quality of products is consistent for each batch therefore not putting compliance into doubt, even if the product is years old. This makes sense to me as they should be doing this anyway to be ISO9001 compliant!

If a "failure-in-field" (FIF) of a product causing it to be non-compliant (i.e. unsafe) is found in the market place, then the manufacture must have a procedure in place to show how they would deal with this. This procedure must contain evidence of sample testing, investigation techniques with the results, a register of non-conformance complaints from customers, evidence of communication to distributors regarding the FIF, and documentation detailing a product recall if this was required. Also, national authorities must be notified of the FIF and be told of any corrective actions taken. For the UK, this is typically the trading standards institute (http://www.tradingstandards.gov.uk/). They will then in turn contact Rapex which is the EU rapid alert system for dangerous consumer products if necessary (http://ec.europa.eu/consumers/dyna/rapex/rapex_archives_en.cfm).

A unique type, batch, serial number or something similar must be on the product itself or where this is not possible, in the packaging or any documents that come with the product. This also includes the manufacturer's name, registered trade name or registered trademark and their address. Again where this is not possible, it can be in the packaging or any documents that come with the product. The address that is used must be a valid point of contact where the manufacturer can be reached. The product must also include appropriate instructions and safety instructions in a language that can be understood as determined by each Member State concerned.

Finally, the manufacturer must make their evidence of conformance for the products they sell easily available to all in their supply chain and when requested, by national authorities. Importantly, it may be requested that the evidence is provided in a language easily understood by the national authority making the request. This obligation is compulsory. The manufacturer must then also cooperate fully with the national authority in its investigation and carry out any recommendations therein.

3.2 The Authorised Representative's Obligations

If the manufacturer has nominated an authorised representative to act on its behalf, then it must carry out any tasks related to conformance requested by the manufacturer. These tasks must adhere to the following minimum requirements:

1. Keep the EC declaration of conformity and technical documentation on file for national authorities for a time determined by the lifecycle of the product and level of risk of the product being sold (within the EU).
2. If requested by a national authority, provide any further information to show the products they represent are in conformance.
3. Cooperate with the national authorities on action to stop any risks imposed by products they represent.

3.3 The Importer's Obligations

The main responsibility of the importer is to put only compliant products on the Community market. However, they should also ensure the manufacturer has carried out their conformity assessment procedure with suitable proof of compliance, has all the necessary technical documentation in place and that the product bears the correct markings, where necessary. The importer must also keep a copy of the EC declaration of conformity (DoC) on file for the appropriate amount of time based on the product lifecycle and level of risk, as well as make sure the DoC and any technical documentation can be made available in a language easily understood to a national authority, on request.

If a product is not in conformity then the product cannot be placed on the market until compliance is granted. If the product is found to be a risk the manufacturer and appropriate market surveillance authorities must be contacted immediately. Importers must also assist with any corrective actions required and fully cooperate with any relevant national authority investigations. This must also include keeping a record of non-conformance complaints and details of any product recalls. In either case, the importer must keep distributors informed too.

The importer must also have their name, registered trade name or trademark and a contact address on the product or, if this cannot be done, on its packaging or any documentation that is supplied with the product. The importer should also make sure the product comes with appropriate instructions and safety instructions in a language that can be understood as determined by each Member State concerned.

The decision also requires that the storage and transportation conditions do not compromise the product's compliance when the product is under the importer's responsibility.

Finally, if an importer decides to bring in a product from a third country and sells it under their own name or trademark, or modifies the product in a way that puts its compliance into doubt, the importer would be regarded as the manufacturer.

3.4 The Distributor's Obligations

It turns out that distributors have pretty much the same duties as importers in this decision. To summarise, they can only sell compliant products, and ensure the correct conformity markings are on the product and appropriate safety instructions are included in a suitable language for the Member State they sell the products in. If the product is found to be non-conformant the distributor needs to contact the manufacturer or importer and they *must* contact the market surveillance and national authorities with the details, and carry out any corrective measures or any other actions required. They are also required make sure storage and transportation does not bring the products they sell into non-conformance. Distributors must also provide national authorities any requested documentation to show the products they sell are in conformance with EU legislations.

Finally, if a distributor decides to bring in a product from a third country and sell it under their own name or trademark, or modifies the product in a way that puts its compliance into doubt, the distributor would be regarded as the manufacturer.

4. EC Declaration of Conformity (DoC)

This decision demonstrates the current accepted structure for the EC Declaration of Conformity in Annex III. However, it also states the DoC must be translated into an appropriate language if requested by a Member State.

5. CE Marking

The rules for the CE mark are that it must be placed on the product or nameplate legibly and indelibly before the product is placed on the market. If this is not possible, or warranted, it must be on the packaging and accompanied documentation. The same applies for the Notified Body number if this is required too. Member States must make sure this is being correctly implemented and carry out appropriate action or deterrent when incorrect use is found.

6. Notifying Authorities and Notified Bodies

This decision sets out in detail, the requirement for each Member State to designate a "Notifying Authority" and what they must do. This also includes the requirements for "Notified Bodies". However, this is outside of the scope of this article and won't be discussed here. If you wish to read more in this area, it can be found in Article R13 through to R32.

7. Conformity Assessment Procedures

As stated before, each product must go through a conformity assessment procedure by the manufacturer to show conformance to EU legislation. This decision lists a number of modules to choose from based on the product that you make. The choice must be appropriate to the type of product, nature of the risks of the product and whether there is third party involvement for manufacturing. These modules (A through to H1) are listed in detail in Annex II of the decision. However, a summary of each module and what the manufacturer should do is shown below and on the following page:

Note: This information has been extracted and reformatted to improve readability.

TABLE: CONFORMITY ASSESSMENT PROCEDURES IN COMMUNITY LEGISLATION

A. Internal production control	Manufacturer - keeps technical documentation at the disposal of national authorities
B. Type examination	Manufacturer submits to notified body - technical documentation - supporting evidence for the adequacy of the technical design solution - specimen(s), representative of the production envisaged, as required Notified body - ascertains conformity with essential requirements - examines technical documentation and supporting evidence to assess adequacy of the technical design - for specimen(s): carries out tests, if necessary - issues EC-type examination certificate
G. Unit verification	Manufacturer - submits technical documentation
H. Full quality assurance EN ISO 9001:2000([4])	Manufacturer - operates an approved quality systems for design - submits technical documentation Notified body - carries out surveillance of the QS
H1	Notified body - verifies conformity of design ([1]) - issues ED-design examination certificate ([1])

([1])Supplementary requirements which may be used in sectoral legislation. ([4])Except for requirements relating to customer satisfaction and continual improvement.

PRODUCTION		C. Conformity to type	D. Production quality assurance	E. Product quality assurance	F. Product verification		
			EN ISO 9001:2000 [2]	EN ISO 9001:2000 [3]			
	A. Manufacturer — declares conformity with essential requirements — affixes required conformity marking	**C.** Manufacturer — declares conformity with approved type — affixes required conformity marking	Manufacturer — operates an approved quality system for production, final inspection and testing — declares conformity with approved type — affixes required conformity marking	Manufacturer — operates an approved quality system for final inspection and testing — declares conformity with approved type — affixes required conformity marking	Manufacturer — declares conformity with approved type — affixes required conformity marking	Manufacturer — submits product — declares conformity — aAffixes required conformity marking	Manufacturer — operates an approved QS for production, final inspection and testing — declares conformity — affixes required conformity marking
	A1. Accredited in-house body or notified body — tests on specific aspects of the product [1]	**C1.** Accredited in-house body or notified body — tests on specific aspects of the product [1]	**D1.** declares conformity to essential requirements — affixes required conformity marking	**E1.** declares conformity to essential requirements — affixes required conformity marking	**F1.** declares conformity to essential requirements — affixes required conformity marking		
	A2. — Product checks at random intervals [1]	**C2.** — Product checks at random intervals [1]	Notified body — approves the QS — carries out surveillance of the QS	Notified body — approves the QS — carries out surveillance of the QS	Notified body — verifies conformity to essential requirements — issues certificate of conformity	Notified body — verifies conformity to essential requirements — issues certificate of conformity	Notified body — carries out surveillance of the QS

(1) Supplementary requirements which may be used in sectoral legislation.
(2) Except for subclause 7.3 and requirements relating to customer satisfaction and continual improvement.
(3) Except for subclauses 7.1, 7.2.3, 7.3, 7.4, 7.5.1, 7.5.2, 7.5.3 and requirements relating to customer satisfaction and continual improvement.
(4) Except for requirements relating to customer satisfaction and continual improvement.

8. Summary

Broadly speaking most of what has been discussed is nothing new from what I have experienced as a Compliance Engineer in consumer electronics thus far. However, what has changed for me is that I have to be seen to make sure compliance procedures and information is on file and/or made more easily available to our customers. As one person said to me, what most companies do is great, but they don't write down what it is they actually do to show conformance (i.e. procedures).

9. References

[1] "Enhancing the Implementation of the new Approach Directives", http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/technical_harmonisation/l21001d_en.htm

[2] "A Common Framework for the Marketing of Products – Decision No 768/2008/EC"

For a copy of the decision itself, please visit: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:218:0082:0128:EN:PDF

Marc Hudson Biography

Marc Hudson is a graduate from Sandwell College with a BTEC HND in Professional Sound Engineering. From January 2003, at 21 years of age, Marc has been working in the Research and Development department at Audio Partnership PLC whose brands include "Cambridge Audio" hi-fi systems, "Mordaunt-Short" speakers and "Opus" multi-room audio\visual systems.

While being the Technical Assistant, he was given the responsibility of looking after the Safety and EMC compliance for AP's products in 2005. March 2008 saw him become the Compliance Engineer and be responsible for all the worldwide compliance requirements, including ErP, RoHS, WEEE, REACH for Europe, and similar for North and South America, China, Japan, Taiwan, Thailand and other countries. He is also given the task of researching and implementing new or revised directives and associated standards, and making sure the Technical Construction Files contain the correct compliance documentation.

These duties have required him to go to test houses around the world to ensure products meet national requirements, and meet with national officials to discuss existing and new legislation.

His current EMC project has been to source, set up and calibrate a pre-compliance radiated emissions chamber at AP HQ to allow testing of products during R&D. In time, this will expand to include all possible emissions and immunity testing.

RMS-Average detector and APD measurement function –
Two new CISPR weighting methods to better consider the impact of impulsive disturbances on today's dominant digital radio services

By Jens Medler, Rohde & Schwarz GmbH & Co. KG

Abstract

Two new weighting methods in publication CISPR 16-1-1 has been defined to better consider the impact of impulsive disturbances on today's dominant digital radio services: the RMS-Average detector and the amplitude probability distribution (APD) measurement function. Purpose of weighting along with the evaluation of the weighting characteristic and resulting definition of the weighting function for the new methods are introduced. A standardization update describes the applicability of the new detector and measurement function.

1. Introduction

Generally, weighted measurements of impulsive disturbance are made for minimizing the cost of disturbance suppression, while keeping an agreed level of radio protection.

After the introduction of AM broadcasting in the 1920s, the many radio listener reports on disturbance made disturbance suppression necessary for the first time. However, because measurement processes had yet to be developed, the initial standards were instruction guides for noise suppression.

With the foundation of the International Special Committee on Radio Interference, CISPR, (Comité International Spécial des Perturbations Radioélectriques) in 1933, systematic studies began with the goal of defining uniform weighting processes. It was recognized early on that the way broadcasting is affected depends both on the type of disturbance (broadband or narrowband) and on the radio service itself. It was dependence on the pulse repetition frequency (PRF) in particular that finally lead to the definition and introduction of the quasi-peak detector.

During definition of the weighting function, the goal was to keep the effort for disturbance suppression at a minimum, i.e. the suppression must be just good enough to provide adequate protection against conducted and radiated emission so that radio listeners are not bothered by disturbance on a subjective scale. That is why quasi-peak weighting simulates the radio receiver including the listener.

When receiving analog-modulated signals, the disturbance, i.e. the level of psycho-physical annoyance, is a subjective value. Although it can be heard or seen, it usually cannot be measured in hard numbers. Today's dominance of digital broadcasting and communications systems has caused a fundamental shift in this scenario. For receivers of digitally modulated signals, it is possible to determine the level of disturbance for which complete error correction is still possible, for example, using the critical bit error rate. This is why CISPR and ITU already started 15 years ago to study the effects of impulsive disturbance on digital radio services.

A possibility for evaluating such a weighting characteristic is to perform measurements and simulations for showing the impact of interference signals on various modulation schemes. For this purpose the interference source level to obtain a constant BER for all PRFs of interest is recorded. Based on these results a weighting function can be created. Once the weighting function is defined, a detector with these properties can be developed.

As a result of these studies [1] [2], new weighting methods were introduced in the CISPR 16-1-1 basic standard: the RMS-Average detector and the amplitude probability distribution (APD) measurement function [3] [4].

2. RMS-Average Detector

The RMS-Average detector consists of an RMS detector with a computing time equal to the reciprocal of the corner frequency f_c followed by a linear average detector with meter time constant and Peak reading.

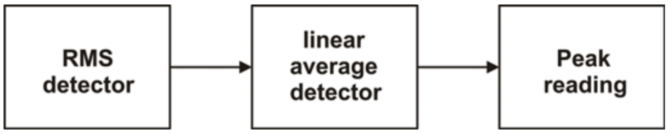

Fig. 1: Construction RMS-Average detector

For example, in Band C/D the RMS computing time is 10 ms and will give rms values of the disturbance signal within 10 ms. The 10 ms packets are then weighted using a linear average function. The peak reading function after a meter time constant of 100 ms is effective then for low repetition pulses (f_p below 10 Hz) which causes the weighting curve to approximate the asymptote of 58,7 dB as shown in Figure 1. This means, for pulse-modulated signals with a PRF lower than 10 Hz the measurement result is not the average!

A lot of weighting characteristics were determined in [2] for both GSM 900 and GSM 1800 as well as DECT, CDMA, TETRA, DRM, DAB, DVB-T, and FM modulation schemes. Looking at these results we can see that above a certain corner frequency, the weighting characteristic decreases with approximately 10 dB per decade of PRF. Below this corner frequency, the weighting characteristic decreases with a higher rate.

A. Weighting function of RMS-Average detector

A decrease of 10 dB per decade corresponds to the weighting function of an RMS detector. A higher rate of decrease (20 dB/ decade) can be achieved using the linear average detector function. This behaviour can be approximated by a combination of two detectors, the RMS and the linear average detector.

Weighting function = relationship between input peak voltage level and PRF for constant level indication of a measuring receiver with a weighting detector.

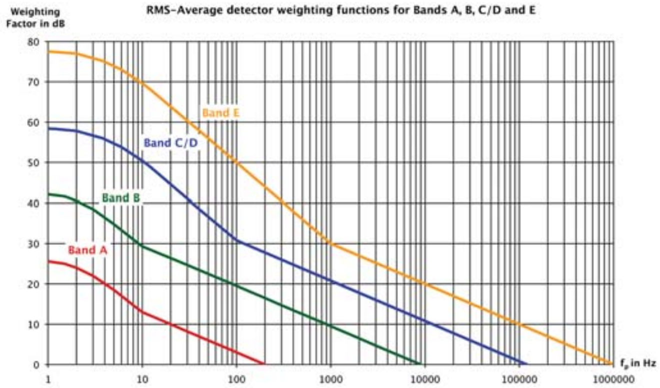

Fig. 2: RMS-Average weighting function for Band A, B, C/D and E

For CISPR Band A (9 kHz to 150 kHz) and CISPR Band B (150 kHz to 30 MHz) a corner frequency f_c of 10 Hz, whereas for CISPR Bands C/D (30 MHz to 1 GHz) a corner frequency f_c of 100 Hz and for CISPR Band E (1 GHz to 18 GHz) a corner frequency f_c of 1000 Hz was selected [2].

It is not possible to satisfy the protection requirements of all services with the same perfection, therefore the selection of the various corner frequencies between the proposed average and RMS weighting functions in each band can be regarded as a compromise. In general, the RMS-Average detector is applicable for measuring all types of continuous disturbance. Comparison measurements using the existing quasi-peak and average detectors as well as the new RMS-Average detector have shown:

- For unmodulated sinewave signals, all detectors will yield the same result.
- For Gaussian noise the RMS-Average measuring receiver will indicate a level approximately 1 dB higher than the average detector level, 6 dB lower than the quasi-peak detector (for Bands C and D) level and 10 dB lower than the peak detector indication.
- For impulsive noise the RMS-Average detector will result in levels between the average detector level and the quasi-peak detector or peak detector indications as shown in Fig. 2.

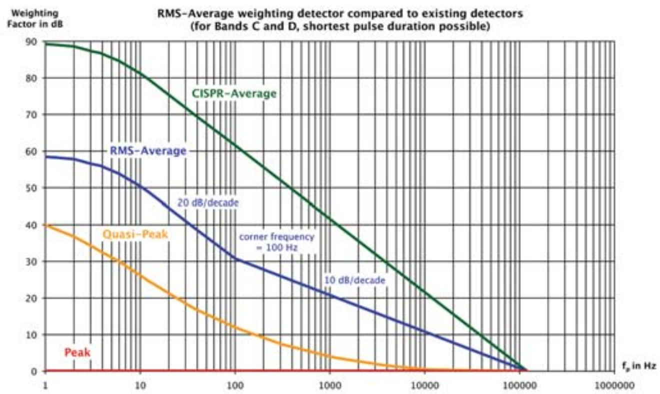

Fig. 3: RMS-Average compared to Average, Quasi-peak and Peak detector

B. Standardization Update on RMS-Average detector

With the introduction of the RMS-Average detector in basic standard CISPR 16-1-1 a long development process has been completed. The weighting function of the RMS detector was already under discussion when CISPR 1 (2nd Ed.) was published in 1972. The introductory note states: **"Subsequent experience has shown that the rms voltmeter might give a more accurate assessment"** but the quasi-peak type of voltmeter has been retained for certain reasons – mainly for continuity.

CISPR has performed extensive investigation to get experience particular about the impact of pulsed interferers on digital radio services. The results were published as background material to weighting detector measurements in Amendment 2:2006 to TR CISPR 16-3:2003 [2]. Based on these results a new weighting function was developed – the RMS-Average detector. Finally this newly proposed detector was published in Amendment 2:2007 to CISPR 16-1-1:2006 [4] based on unanimous vote.

For the first time the RMS-Average detector becomes applicable with the currently published 5th edition of CISPR 13 [6] the product standard for sound and television broadcast receivers and associated equipment.

CISPR 13:2009 (5th Ed.):

- Introduction of the RMS-Average detector as an alternative to quasi-peak and average detector for disturbance power, conducted and radiated disturbance measurements.
- Used detector must be stated in the test report.
- For re-testing the equipment the detector stated in the test report shall be used.
- RMS-Average limit is +4 dB to the AV limit value and -6 dB to the quasi-peak limit for disturbance voltage at mains terminals and disturbance power measurements.
- RMS-Average and quasi-peak limit values are identical for disturbance voltage at antenna terminals and radiated disturbance measurements.

3. APD Measurement Function

The APD measurement function can be implemented most probably using an analog-to-digital converter, a logic circuit, and memory as shown in Figure 3.

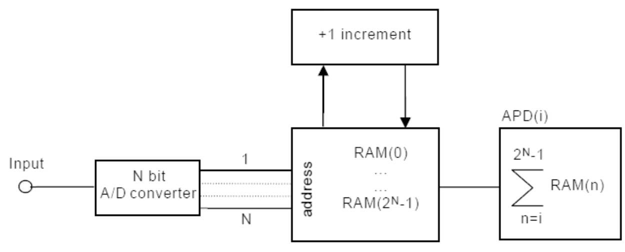

Fig. 4: Block diagram of APD measurement equipment

Usually the A/D converter is always straight behind the envelope detector and so we can say the APD is measured at the output of the envelope detector of the EMI test receiver. The amplitude resolution depends on the resolution of the analog-to-digital converter, e.g. 1024 levels for a 10-bit converter. The accuracy depends on the sample rate, CISPR 16-1-1 [3] is requesting at least 10 MSamples per second for a resolution bandwidth (RBW) of 1 MHz.

A. Weighting function of APD measurement function

The APD (Figure 4) of a given disturbance is defined as the cumulative distribution of the "probability of time that the amplitude of disturbance exceeds a specified level" [3].

The APD measurement can be used to determine a product's capability to generate disturbance signals in digital communications systems. For example, this could be used for microwave ovens, which frequently impair WLAN communications in the frequency range from 2400 MHz to 2500 MHz.

The corresponding disturbance field strength measurement of microwave ovens in the frequency range from 1 GHz to 18 GHz is described in CISPR 11 [5], which requires both peak and average limits to be met. The weighted average value is determined by reducing the video bandwidth to 10 Hz in the logarithmic mode. However, this cannot be used to determine the true average value, and the weighted average value is too imprecise, particularly for impulsive disturbance originating from microwave ovens.

In such cases, the APD function can be used as an alternative method because it can also determine the true average value. As with the conventional method, the peak detector is first used to perform a preview measurement. If the result of the preview measurement exceeds an acceptance level as defined in relation to the limit line, the APD is measured at these identified frequencies.

The APD can be measured using one of the following two methods:

- Measurement of the disturbance field strength level $E_{measured}$ in dB(µV/m), with reference to the defined probability of occurrence over time p_{limit}.
- Measurement of the probability of occurrence over time $p_{measured}$ during which the envelope of the disturbance exceeds a defined level E_{limit} in dB(µV/m).

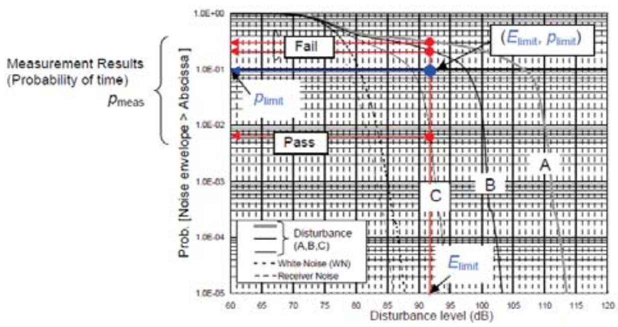

Fig. 5: APD weighting function for measuring the probability of occurrence over time (method 2)

The EUT is considered to have passed the test when both values fall below the limits as it is the case for EUT C.

B. Standardization Update on APD measurement function

CISPR has performed experiments to investigate the correlation between APD characteristics of disturbance and performance of digital communication systems (e.g. W-LAN, Bluetooth, W-CDMA and PHS). The results were published as background material in Amendment 1:2005 to TR CISPR 16-3:2003 [1]. Based on these results the APD measurement function was developed. Finally the requirements for the APD measurement instrument were published in Amendment 1:2005 to CISPR 16-1-1:2003 [3].

Product standards don't consider the APD measurement function for the moment. But CISPR sub-committee B has decided to investigate the APD measurement function to be applied as an alternative method for compliance testing of microwave ovens in the scope of CISPR 11 [5].

Because peak limits and average limits are already specified in CISPR 11, it is recommended that these limits be used together with an APD limit p_{limit}. Alternatively, the APD data can be used to calculate the linear average value, which can then be compared directly against the average limit. The peak limit is compared against the measured disturbance field strength level $E_{measured}$ at a probability of occurrence over time of 10^{-7}, for example.

4. Measurement Instrumentation

The R&S ESU EMI test receiver (Figure 5) for detecting electromagnetic disturbance is recognized globally as a benchmark for compliance measurements. To serve latest developments in standardization both RMS-Average detector and APD measurement function are available as standard functionality.

Fig. 6: EMI Test Receiver R&S ESU

The R&S ESU divides its 80 dB display range for the disturbance field strength level into 625 subranges and, for every subrange, measures a disturbance field strength level $E_{measured}$ as well as the probability $p_{measured}$ with which this is achieved. This means that both APD measurement methods are applicable. The R&S ESU is fulfilling the requirements of CISPR 16-1-1 as shown in Table 1.

	CISPR 16-1-1 [3]	R&S®ESU
Dynamic range of amplitude	>60 dB	>70 dB
Amplitude accuracy	better than ±2.7 dB	typically <0.2 dB
Maximum measurable time period	≥2 min [1)]	2 min (no dead time)
Minimum measurable probability	10^{-7}	10^{-7}
Amplitude level assignment	at least two amplitude levels with a resolution of 0.25 dB	625 levels with a resolution of 0.128 dB
Sampling rate	≥10 Msample/s for B_{res} = 1 MHz	10.2 Msample/s for B_{res} = 1 MHz, 4.0 Msample/s for B_{res} = 200 Hz, 9 kHz, 120 kHz
Amplitude resolution of APD display	≤0.25 dB	0.128 dB

1) An intermittent measurement is possible if the dead time (during which no values are measured) is less than 1 % of the total measurement time

Table 1
Specification of the APD measurement function and comparison with the R&S ESU EMI test receiver

Using the APD function, the R&S ESU accurately detects impulsive electromagnetic disturbance such as from microwave ovens. This is a particular advantage when performing very time-consuming measurements with high redundancy in type approval and quality acceptance testing.

5. Conclusions

Analogue radio services have been replaced by digital radio services successively in the last decade. This means the established weighting methods need to be reconsidered to serve an adequate protection level for today's dominant digital radio services. It has been shown that the RMS-Average detector and the APD measurement function are applicable for measuring electromagnetic disturbances in the age of digital radio services.

The RMS-Average detector corresponds to the weighting characteristic of digital radio communication systems. It is possible to define one limit to replace AV and Quasi-peak limits. Furthermore, there is no need to change the detector for measurements above 1 GHz and faster measurements are possible when the RMS-Average detector is used instead of the quasi-peak detector for final measurements. For the first time the RMS-Average detector can be applied as alternative to Quasi-peak and average detector for disturbance power, conducted and radiated disturbance measurements on consumer electronic products in the scope of CISPR 13:2009 (5th Ed.).

The APD measurement function is suitable for evaluating the impact of impulsive disturbances on digital radio communication systems. APD measurement is an alternative to the present Peak/AV limits in CISPR 11 with the benefit to evaluate the true average value. It results in an improved detection of pulsed signals as compared to weighting involving the reduction of the video bandwidth. CISPR is investigating the APD measurement function to be applied as an alternative method for compliance testing of microwave ovens.

References

[1] Amendment 1:2005 to CISPR 16-3:2003 (2nd Ed.) Specification for radio disturbance and immunity measuring apparatus and methods – Part 3: CISPR technical reports; *Background material on the definition of the APD measurement function for measuring receivers*

[2] Amendment 2:2006 to CISPR 16-3:2003 (2nd Ed.) Specification for radio disturbance and immunity measuring apparatus and methods – Part 3: CISPR technical reports; *Background material on the definition of the r.m.s.-average weighting detector for measuring receivers*

[3] Amendment 1:2005 to CISPR 16-1-1:2003 (1st Ed.) Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus

[4] Amendment 2:2007 to CISPR 16-1-1:2006 (2nd Ed.) Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus

[5] CISPR 11:2009 (5th Ed.) Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement

[6] CISPR 13:2009 (5th Ed.) Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement

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Environmental Effects of the widespread deployment of high speed Power Line Communication

Cumulative Effects on Signal/Noise ratio for Radio Systems

By Richard Marshall, MA, CEng., FIEE, FIET, FInstP, Richard Marshall Limited

1) Introduction

High speed Power Line Communication (hereinafter "HS-PLC", and elsewhere PLT or BPL) lays claim to a substantially higher allowance for radio interference emission than is permitted for other products, and many papers have been written pointing out the inevitability of serious interference to existing radio services in the High Frequency ("HF") spectrum should HS-PLC be widely deployed. We emphasise "High speed" because low speed PLC in the band below 150KHz poses no such problems. The HF band, covering 3 to 30MHz, is fully used by an overlapping mixture of broadcast transmissions and point-to-point services on land, sea and air. The band offers the special feature of ionospheric reflection that allows very long-distance transmission and reception with simple apparatus. Use of this spectrum becomes a matter for international regulation with strong implications for human rights.

The inevitability of interference can be proved beyond doubt by academic analysis, but demonstration of the problem is by definition difficult until the deployment of HS-PLC reaches such a scale that it is too late to take remedial action. The only direct proof of the cumulative interference phenomenon known to the present author is an anecdotal report that the frequencies used by analogue cordless phones in the 1990's were then clearly recognisable on a marine HF receiver in the North Sea as a series of noise bands of such strength as would hamper use of those frequencies.

The UK's official position on environmental effects of PLC was set out in a submission by the then DTI to an EC workshop [**ref.1**] as *"Many independent studies have been completed, but in the absence of validation, the application of any mathematical model will always be subject to debate, and no firm conclusions are possible on the likely impact of mass deployment of PLC on radio services"*

In the present paper we will briefly review the relevant fundamentals of radio communication. We will discuss some of the "many independent studies" in the light of the present situation, adding one new insight into the accumulation process that suggests a small but not crucial adjustment to some earlier predictions.

In the light of the present situation in the market place we will assess how long it will be before the belated validation sought by the DTI (now BIS) will occur.

Note that this paper does not discuss the issues of close-up interference from a single HS-PLC installation, or of the weaknesses in the problem-reporting process, or of the relation between problem reports and problem size. These are well covered by Williams and Marshall in **refs. 2 and 3**.

Almost all the work discussed below refers to frequencies below 30MHz. There are now proposals to extend PLC to higher frequencies, where, as may be seen from **figure 2**, the existing background noise levels are even lower.

2) Theoretical background

Radio signals always travel from a transmitter to a receiver via a transmitting antenna, an intervening path and a receiving antenna. These three sections may be intentional or unintentional, complex or simple, but the properties of each may be calculated according to the laws of physics as determined a hundred years ago. Very complex cases may be more easily explored experimentally with little risk thanks to this sound theoretical background. The whole process of propagation prediction has been routine since the 1930's.

Briefly, the antennas at each end of the path have directional characteristics and resistive losses that determine their "gain" in any specific direction. In the case of mains power wiring, and over the frequency range 3 to 30MHz used today for PLC, there is some agreement [**Refs. 4, 5, 12, 25**] that the transmission "gain" is actually a "loss" of about 20dB – that is mains wiring radiates about one-hundredth of the differential-mode radio-frequency power that is presented to it and the directional characteristics are on average largely independent of direction.

Propagation may be direct from transmitter to receiver by the so-called "space wave". In this case, if the path is unobstructed (eg. to an aircraft) – then the received power is precisely calculable: It falls as the inverse square of the distance. (To avoid confusion note now that the received *voltage* falls in inverse proportion to the distance, since the *power* is proportional to the *voltage squared*.) The basic inverse square law may alternatively be stated as 20dB fall for a ten-fold increase in distance, and is translated for EMC Standards work to the approximate equivalent of 10dB fall for every trebling of distance.

This rate of fall in the absence of any obstruction is shown by the black dashed line in **figure 1**, which shows the signal strength from a source of 100 mW effective radiated power over distances of 1 to 1,000km. The blue and orange lines in each chart show the more rapid attenuation of "ground wave" signals at 3 and 30MHz respectively when propagated across the English countryside. This chart is based on ITU-R P368-9, but with the transmitter power and field strength voltage scaled down to represent a background noise situation rather than an intended transmission.

For short distances buildings create even greater rates of fall-off; for an analysis of this and some examples of the pitfalls encountered in such calculations see Stott's paper [**ref. 4**]

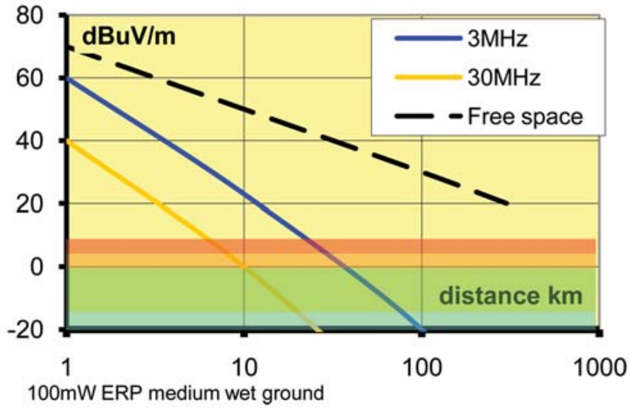

Figure 1 The signal strength of a 100mW source compared with the noise background. The red background corresponds to a "business" environment, the orange to "residential", the green to "Rural" and the blue to "quiet rural" at 10MHz

In **figure 1** the lower background is shaded to show the existing noise levels at 10MHz. Red = business areas, orange = residential, green = rural, blue = quiet rural. Useful signals must be above the relevant noise level, whether it is the existing one denoted by the coloured background or the enhanced one due to reception of the distant interference source as identified by the blue or orange lines. The shaded areas are based on data from ITU-R P372-9. Their edges are only approximate since these levels actually vary slightly with frequency as may be seen from the plot of **figure 2** that shows the ITU data after translation into field strength units. Some people believe that levels have risen since this data was compiled, but **ref. 27**, annex O, slide 6 (page 246) shows four professional plots of measurements in a UK residential area that are about 5dB *below* the ITU data. The orange triangles in **figure 2** show another set of recent measurements in a suburban UK location that also suggest that UK levels are *well below* the ITU figures.

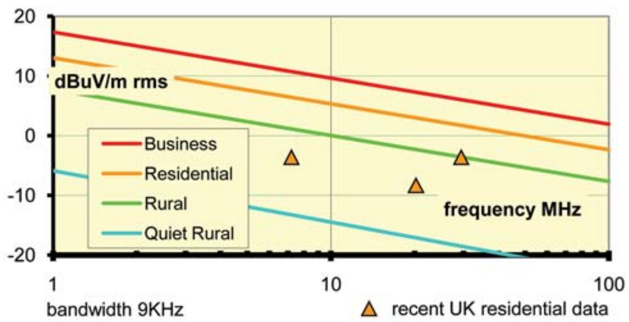

Figure 2 Man-made noise levels in various environments. This data is derived from ITU R372-9 figures for median external noise figure, assuming use of a half-wave dipole and 9kHz bandwidth. Note that above 10MHz galactic noise is some 5dB *above* the man-made "Quiet rural" level shown here.

Sky wave propagation involves one or more reflections from the ionosphere, which is a conducting layer of the upper atmosphere whose characteristics have been well researched since early measurements in 1924. [**ref. 6**]. **Figure 3** shows a section through the earth and the curved conducting layers of the ionosphere above it. The transmitter is shown near the lower left-hand corner. The "ground wave" is also shown hugging the earth's surface. This is a matter of diagrammatic convenience since as already mentioned there is a "space wave" propagating high into the atmosphere that may be received by aircraft.

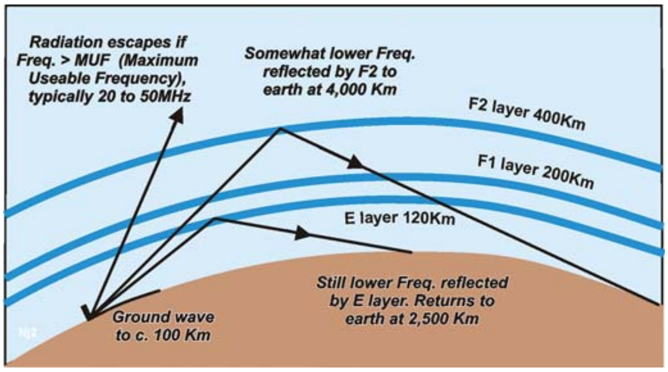

Figure 3 The geometry of radio wave propagation (not to scale)

Ionospheric reflection can be very low-loss, and is responsible for the enormous importance of the 3 to 30MHz "HF" radio frequency band for long-distance communication. Multiple reflections between ionosphere and earth, and continuous curving of radio waves around the planet within ionospheric "ducts" are also possible. With quite limited resources, it is possible under good conditions to send radio signals three times around the world before the signal sinks irretrievably below the noise floor. However, these ionospheric effects change according to the position of the sun and sunspot activity and suffer a good deal of statistical uncertainty.

For a radio transmission to be useful it has to be strong enough to overcome the noise and interference level existing at the receiving location. The required signal to noise ratio depends upon the modulation method. The ITU has recommendations for this too. In summary, the service area of an HF amplitude-modulated broadcast transmitter is defined in ITU-R BS.560-4 as that area of the globe in which the transmitter provides at least a 34dB margin of signal above the local noise level as plotted above in **figure 2**. Below we note that if the local noise level is increased, for example by additional man-made interference, then a larger transmitter power is required to maintain the intelligibility and reliability required for service area status.

3) Broadcaster victim; planet victim

A piecemeal erosion of the service area of broadcast and point-to-point HF radio is inevitable if HS-PLC spreads; it is only a matter of how much and how long it will take. Viewed locally this is the problem that has caused most anxiety, and it is exhaustively set out elsewhere.

However, there is a cumulative effect of local interference that has not received much attention. **Ref. 7,** prepared by Radio Netherlands World-wide, examined the effect of PLC installations near to the listeners to a Dutch broadcast transmitter beaming 500kW at 9.7MHz ESE across Europe and the Middle East. Today such a transmitter would service by a single ionospheric reflection an area covering Eastern Germany, Poland, Lithuania, European Russia, Kazakhstan, Iran, Saudi Arabia, Egypt, Libya and Sardinia. With two ionospheric reflections it would serve the Yemen and Oman. However, the widespread deployment of PLC in these countries that met the then-proposed NB30 limits (which are tighter than those current today) would limit the service area to Slovakia, Hungary, and parts of their immediate neighbours. To restore the original service area the transmitter power output would have to increase to 78 Megawatts! The well-argued calculations assume the use of domestic short wave radios with telescopic aerials only one metre from the nearest mains cable carrying PLC – but that is how it would be.

The economic consequences to broadcasters of a *gradual* increase in HS-PLC usage may be scoped as follows. A recent analysis [**ref. 8**] estimates that the worldwide average daily transmitted broadcast radio power in the HF band amounts to 2,666MWh. Suppose that HS-PLC deployment grows only slowly taking the world as a whole, so that the average background noise rises by 0.5dB per annum. This would equate to a 12% annual interference power increase. To maintain the signal to noise ratio in their service area (and their commercial/political viability) the short wave broadcasters would have to invest in more powerful transmitters to match the growth of interference. Assuming that these additions are of 85% efficiency their power consumption would increase by 2666 x 365 x 0.012 / .85 =137,300 MWh/annum. Each year this would require the installation of a further electrical generation resource equivalent to some 30,000 wind turbines!

What evidence is there that this assumption of 0.5dB/annum worldwide increase of background noise is reasonable? Early estimates were based on *access* PLC. Fortunately this has proved economically unattractive, though present interest on "Smart Metering" may offer a replacement mass market. Recent developments have been of in-home systems, for which there is no shortage of buoyant marketing claims. In the UK, the BT Vision service has installed large numbers of in-home systems and has plans to grow its field population 7 fold **[ref. 28].** This project is discussed later under the heading "Today's worst case spelt out".

4) The mains as an antenna

An early measurement of the antenna gain of an in-house network [**ref. 25**] made measurements of the horizontally polarised field from a two-storey house whose wiring was energised *in common-mode* against ground. The results were;

MHz	3.6	7.05	10.1	14.1
dB loss	26	11	21	19

The 50 ohm source was not matched to the house wiring – but the minimal 11 dB loss figure at 7.05MHz suggests that matching was good at that frequency. If we add 6dB to these numbers to correct for the common-mode energisation then the result is a good match to more recent *differential mode* measurements.

Direct measurements of the sky wave antenna gain of mains networks (both access and in-house) have been conducted in Switzerland [**ref. 5**]. The measurement method used the mains wiring as a *receiving* antenna and compared the received signal from remote broadcast transmitters with that obtained from a reference antenna near to the PLC installation. A sufficient number of transmitters were monitored to allow the determination of the average gain and the polar diagram in elevation across the relevant range of frequencies. A sample of this work is reproduced in **figure 4.** The plotted points are the averages of 66 measurements. The trend line is that deduced by the present author. The figure shows somewhat lower "gain" than has been assumed elsewhere, but it is of course representative of Swiss wiring practice and the wiring was given a balanced 50 ohm termination rather than 100 ohms as has been assumed in some other work. This might have given up to 4dB extra attenuation.

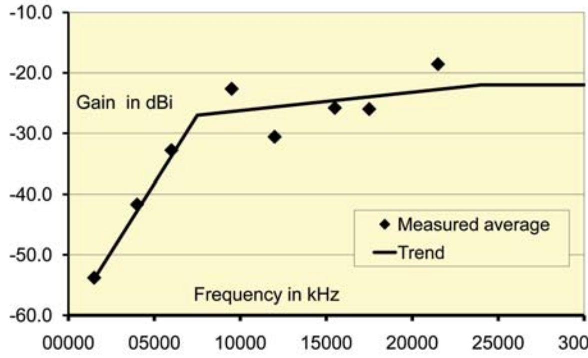

Figure 4 Average sky wave antenna "gain" for indoor sockets.
*Data from **ref.5**. courtesy H Widmer, ASCOM Switzerland; trend line by present author.*

The differential-mode impedance of mains wiring varies, and with it varies the power transfer from HF-PLC modem to that wiring. This variable is generally absorbed into the "antenna gain".

The conversion of differential-mode power into common-mode power that can be radiated has been the subject of bitter debate for the last 15 years since it is a vital part of the arguments about the effect of PLC on *nearby* radio reception. In that context a part of the argument relates to whether the worst-case or the average conversion factor is relevant. However, for the long-distance effects discussed here there can be no dispute: We are concerned with the rms average factor. It must be said that the UK's "protective multiple earthing" power distribution system adds an extra degree of unbalance and so must lead to a greater degree of radiation than most other configurations. However, no measurements of this have ever been published.

All authors have absorbed these variables into the "antenna gain".

The "antenna gain" measurements discussed above appear to be the only credible published sources of data. The considerably reduced gain observed in **figure 4** and in **ref. 25** and **ref. 5** at lower frequencies has important implications and further verification is needed.

The German NB30 specification sensibly transferred responsibility for determining antenna gain onto the PLC system owner by specifying not the culprit launch power but instead the resultant magnetic field strength at 3 metres distance from the installation. However such a specification does lead to regulatory difficulty when the PLC modem and the cable network are in different ownership – and 3 metres is too close to allow meaningful measurement.

5) Prior work and its contemporary relevance

Here we concentrate on the likely magnitude of the cumulative effects of very large numbers of PLC installations at a considerable distance from a victim radio *receiver*. Several studies have been published over the last twelve years – but they have all had to "shoot at a moving target" by making assumptions about the scale of a *future* emission threat. This target was initially "access" PLC. Today it is "In house" PLC. Soon the target may have to encompass "Smart Metering" and wireless power transfer.

The principal source of complaints about "In house" PLC emission in the UK today is the BTVision product. The technical characteristics and field population of this are set out and analysed in "Today's worst Case" later in this paper. First, we will use these present-day figures as a part of the following review of earlier studies to scale their conclusions to the emission level in the UK today.

Exclusion zones and aircraft communications

The victim status of receiver users was analysed in a pioneering contribution [**ref. 4**] to the work of a group meeting under the aegis of the UK's Radiocommunications Agency. In this Stott analysed the requirements for the protection of "sensitive receiving sites". (These might include commercial, marine, aviation, diplomatic, security, and radio astronomy installations. Today the "LOFAR" and "Square Kilometer Array" radio astronomy projects would be prime examples.) Stott's calculations were intended to define the necessary size of an exclusion zone around such a site assuming a uniform distribution of PLT sources across the entire region beyond that zone. Stott analysed the effect of ground wave and sky wave propagation, and introduced the concept of "effective radiated power per square kilometer". The paper set out a method for computing the effects of sky-wave propagation from distant rings of uniformly distributed interferers, noting that interference from such sources "may not always be negligible". He based his conclusion on access PLC, with 3.5 installations/km² across large conurbations, each installation generating a differential-mode power of 500μW in 10KHz bandwidth, and subject to a wiring antenna power gain of x 0.01. These figures correspond to 101 dBμV rms conducted emission per wire and –20dB antenna gain. He calculated that this would equate to an effective isotropic radiated power (EIRP) of 17.5μW per km² and provided a table of exclusion distances that would be required to protect a sensitive site from ground wave interference from such a PLC scenario. It was noted that nothing could protect such sites from distant interference coupled via sky wave.

Whilst it is conceivable that "sensitive sites" might be protected from access PLC whose deployment was in the hands of a single entity such as an electricity supplier, it would be both politically and legally very difficult to exclude consumer electronic devices such as indoor PLC as deployed today from any specific zone.

Aircraft communications were identified as being at particular risk of interference from PLC. The received noise would be largely independent of aircraft height, since the higher the aircraft the more PLC systems would be in view. The paper concluded that a noise field strength of the order of 40 to 43dbμV/m might be expected with the assumed source power density. This is about the same level as would be expected for an active, reliable communications signal and so suggested a significant threat that needed further consideration. A later paper by Stott [**ref. 14**] generalised the mathematics of his earlier note and covered a wider variety of cases – including interference to aircraft from a non-isotropic ground source. There was no change to the basic conclusions.

In comparable terms to Stott's work the most recent figures of EIRP in the UK may be estimated by applying a little arithmetic to the figures in **ref. 3**, where it was noted that there were 300,000 installations of BTVision in the UK. Since 7.51 million of the UK's 60 million population live in greater London, we can estimate that there were 300,000 x 7.51/60 = 37,550 BTVision installations there. The land area is 1,579km², so there were about 37,550/1,579 = 24 installations per square kilometer. Given the recent clarification of the 4μW average *conducted* power delivered by a BTVision modem, the conducted power must be 4 x 24 = 96μW/km². The *radiated* power will be less by the antenna gain; taking Stott's figure of –20dB, that is one-hundredth in power terms, the radiated power density for Greater London was 0.96μW/km². So Greater London's PLC interference emission in March 2009 was about one-twentieth (0.96/17.5) of the basis figure calculated by Stott ten years earlier. In decibel notation it was 12.5dB less.

Stott's reasoning regarding interference to aircraft communications can be scaled in the same way, changing his field strength estimate from 43 to 30.5dBμV. This figure is still well above the ITU "business" noise field as reproduced in our **figure 2** above, and strongly suggests that HF-PLC is already reducing the safety margin of HF aeronautical communication. Recently the work gathered into the annexes of **ref. 18** has confirmed the reality of this threat. This ITU-R Study Group report is a very comprehensive document. Although the main report provides no summary and minimal conclusions there are 128 pages of annexes detailing measurements of excessive emissions from PLT systems world wide. For example Annex 2.6 describes measurements in Germany of the noise level recorded in an aircraft (presumably over an area without existing PLC deployment). Using the known characteristics of a reference PLT installation replicated across the ground at a density of 250 culprits/km², this annex calculates the degree of reduction of PLT transmission level that would be needed to reduce the risk to safety-critical aeronautical radio to an acceptable level. It is concluded that a 50dB reduction is required, and that with today's technology *"Compatibility is not given even when using power management and dynamic notching"*.

Ground wave and sky wave

The work of York University [**refs 10 & 11**] covered HF-PLC and the telephone-line technologies ADSL and VDSL. The following comments relate only to PLC. At the time it was written PLC was seeking to use spectrum "chimneys" from 2.2 to 3.5 and from 4.2 to 5.8MHz. The proposed power within these bands was very high: The authors assumed 100% adoption of access PLC and hence calculated a conducted power density of 3.57mW/km² - about 37 times (+15.7dB) the power density actually reached in greater London by 2009.

The discussion of ground wave effects is based on Stott's paper that we have just discussed. [**ref 4**]. The York paper takes Stott's figure of 14.2 dBμV/m in 10KHz for the field strength at the centre of a 10km radius exclusion zone and uses this as representative of ground-wave effects in the more general case. One could criticise this selection of data on the grounds that a major conurbation is of well over 10km diameter and rarely has sharp edges. It would have been better to quote Stott's figure of 3.25 dBμV/m for a 30km zone and then further correct it downwards for a situation where the culprit area did not completely surround the victim.

Sky wave effects were analysed by assuming a uniform distribution of access PLC systems within each of the 15 major conurbations of the UK together with the Ruhr treated as a single entity. No account was taken of other overseas contributions. The PLC antenna radiation pattern is derived from a street model, but the antenna efficiency is assumed to be –15dB after reference to Stott's earlier work. The received powers were summed and it was concluded that the result would be a more-or-less uniform interference field across the UK of some 7.5dBμV/m. Interestingly, the contribution of the Ruhr to this figure was greater than that of London. From **ref. 5** we can now judge that this estimate of antenna efficiency was about 7dB too high. Since the source power assumption was 15dB above that actually reached in 2009, this work allows an updated prediction of 7.5 – 15 –7 = -14.5dBμV/m for the UK in 2009. It is clear from our **figure 2** that such a level would be difficult to detect – but the task will get easier year by year.

The York paper noted that the sky wave field would be about 7dB lower than the ground-wave field at 10km from "Greater London". We have already cast doubt upon this ground wave figure and so are equally unhappy with the author's conclusion that "Ground wave propagation is the mechanism that is likely to lead to the largest increases in the established noise floor". Stott's statement "When there can be nearby interferers … ground-wave propagation provides the dominant part of the received interference" is much better since it allows the important conclusion that for rural and sensitive sites sky wave interference will certainly establish an inescapable man-made noise floor.

Skywave Studies

A study at the University of Karlsruhe [**ref. 12**] concluded that there would be no cumulative problem if all the PLC sources met the requirements of NB30. However, today's PLC systems do not meet the requirements of NB30. The authors noted that their conclusion differed from that of the York study discussed above, but calculated that their results would have been closely similar to that sky wave analysis had they made the same assumptions for PLC source power.

A Swiss analysis [**ref. 13**] concluded that "the present natural noise levels in electromagnetically quiet areas will not change significantly with … deployment of …(access PLC) if the maximum psd (power spectral density) per cell … is below -40dBm/Hz". This figure was based upon measurements of the magnetic field near to a buried low-voltage distribution network carrying PLT signals at a rather higher level. An antenna model was then chosen to match this magnetic field, and its radiation used as input for a proprietary computer program developed for military HF radio system design purposes. This was then used to compute the disturbance field strength produced by unwanted emissions of PLC users located in distances ranging up to a few thousand kilometres from a victim receiver. The input to this program was based on 0.35 access PLC cells/km² averaged across the whole of Germany, each energised for only one tenth of the time to allow for typical power control and traffic levels. Plots of the resulting field strength covered a variety of ionospheric situations, and it was by inspecting these that it was determined that the source power would have to be reduced to -40dBm/Hz (100nW/Hz) to achieve the desired result. This figure is equivalent to 0dBm in 10KHz bandwidth – the same figure as used for skywave emission in the York study discussed above.

Surprisingly this analysis did not consider the additional world-wide interference that might reach remote areas from countries other than Germany. It was the first to recognise that PLC sources might not be emitting at their maximum level all the time – an important truth. It has been criticised in **ref. 10** for the obscurity of its ionospheric calculation and summation.

The authors specifically excluded *indoor* PLC from their scope, presumably because an indoor power circuit would radiate much more than a buried access cable. If however we ignore this factor we can compare the authors case with BTVision in the UK today as follows:

UK/Germany = (relative % "on" time) x (rel. culprits/km²) x (rel. power in nW/Hz)
=100/10 x 1.24/0.35 x 0.4/100 = 1/7 or –17dB.

However, bearing in mind the issue of increased indoor cable emission, the UK must now be near the limit determined by this Swiss author.

Radio astronomy

A Japanese contribution [**ref.15**] calculated that because of the extreme averaging time applied to space signals a *single* access PLC installation (launching –50dBm/Hz and assuming -20dBi antenna gain) would need to be at least 424 km distant to avoid disturbance to any of the country's four radio astronomy laboratories. These establishments investigate HF emissions from the Sun, Jupiter and other large gaseous planets. The solar studies are essential for the prediction of ionospheric disturbances that may have a serious effect upon communication and power distribution here on earth. The sensitivity of all such measurements in the HF radio band is limited by the laboratory's radio noise environment.

The contribution assumed free space propagation; presumably it was felt that a more sophisticated approach was unnecessary given the revealed magnitude of the problem. The 424km figure underlines the fact that a single PLC system emits an interference power equal to many thousands of CISPR22-conformant products – and has correspondingly greater long-distance effects. This can be seen as an indication of the inevitable international implications of PLC emissions.

The assumed –50dBm/Hz per installation has to be compared with the 2009 UK figure of –64dBm/Hz per installation. Accordingly a group of just 25 installations of BTVision should produce the same calculated trouble distance as has been determined by these authors.

A Military View

Ref. 26 is the final report of a NATO task force that considered the impact of ADSL and PLC upon COMINT - Communications and Intelligence. Its 101 references include the most comprehensive bibliography of PLC. Original work includes consideration of ground reflection (which appears to have a substantial effect upon measurements within 200 yards of the PLC site). A further comment is that measurement of CMRR/LCL at the injection point may not be representative with respect to radiation since impedance mismatches can cause large variations in common-mode current along the line – a factor disputed in PLT standardisation work.

On the basis of the bibliography different assumptions were made for Indoor and access PLC;

	d/m modem power	mains antenna gain	modem duty cycle
Indoor	-50dBm/Hz	-30dBi	30%
Overhead Access	-50dBm/Hz	-15dBi	15%
Buried Access	-50dBm/Hz	-30dBi	15%

Market growth figures from Germany in 2006 suggested that Indoor PLT was the greatest contributor to interference emission. Future emission from this source alone was modelled using the above assumptions and the rather extreme prediction of 0.5 modems per capita – a market presence some 20dB higher than the contemporary situation. Today we can postulate a contribution from "Smart Grid" that would make the NATO prediction a modest one.

The calculation method and an example of the results is set out in the box **"The NATO sky wave analysis".**

It was noted that the ITU-R noise levels were median values and might not be acceptable metrics for NATO purposes. An Absolute Protection Requirement of –15dBμV/m in 9kHz was postulated with the comment that the probability of this being exceeded was large for all the frequencies and receiver locations investigated.

Conclusions included;

* There is a high probability that PLT will cause increased noise levels at sensitive receiver sites given the projected market penetration.
* NATO should seek to support harmonised regulatory limits by working with national and international authorities.

Summary of the above prior work

Each of these documents state that there is, or soon will be, a problem. Each of them has been ignored by the Standards makers and the regulatory authorities. Each of them has been ignored by the designers, manufacturers and marketeers of PLC equipment.

6) Uncertainties in calculations

In the following analysis we expand the path from culprit to victim that was identified earlier. It is necessary to start with the summation process, in which large numbers of unwanted signals arrive at a receiver. We can assume that they are independent of each other, though they may share some subtle characteristics (such as being of reduced power in notched bands). The correct parameter to add is therefore the received *power* from each individual source. This is awkward, because power is rarely measured directly in EMC practice: It is inferred from voltage whilst making assumptions about bandwidth, waveform and time-profile. EMC measuring receivers generally measure average, quasi-peak, or peak voltage. Very recent measurements of the real launch power from a PLC modem on Standby (to be described in section 8)) gave an answer *well above* that which would be calculated from the *average* conducted voltage and only 10dB below that corresponding to the quasi-peak figure.

The NATO Sky Wave analysis

Analysis was restricted to Sky Wave propagation. This was treated thoroughly – not just by picking a few key areas as in the other work reviewed. The authors developed a Cumulative PLT Tool as a front-end for the IONCAP ionospheric propagation tool. For each chosen victim site their CPLT tool accepted data for population per "square" of 0.25° x 0.25° within a grid of latitude and longitude co-ordinates over an appropriate region of the globe. IONCAP was then called for each transmitter "square" and the received powers at the victim were summed by CPLT.

The results for one European site are presented here in figure 6.

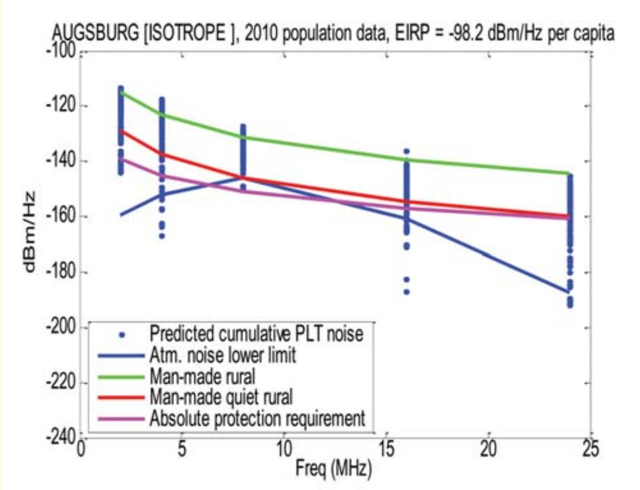

Figure 6 Predicted cumulative PLT noise parameters for example with receiver in Augsburg, compared to established background noise levels.

The original version of this material was published by the Research and Technology Organization, North Atlantic Treaty Organization (RTO/NATO) in Technical Report, RTO-TR-IST-050 - "HF Interference, Procedures and Tools", in June 2007. See ref. [26]

The columns of partially-overlapping blue dots represent the predicted summation of PLC noise at Augsburg by sky-wave *only*, excluding the larger contribution to be expected by ground wave. The source area covered Europe, N Africa, the middle east and part of Russia. Within this area radiated interference power was calculated from an estimated emission *per capita* of –98.2dBm/Hz . This figure was based upon a substantial market penetration of Homeplug devices *only*. Each blue dot represents a particular assumption about reception frequency, time of day and season, sunspot number and geomagnetic activity.

There will be relatively few different designs and protocols for PLC devices, so the statistical benefits of averaging will not remove systematic errors in source power measurement.

The variation of interference power with data rate is also important. In this respect Williams **[ref. 9]** has shown that at least one implementation of the UPA standard is very unsatisfactory. Some of the work described earlier assumed that the effective culprit power would be that specified for the technology. That by Widmer **[ref. 13]** assumed that it would be one-tenth of this. Accordingly we have to be aware of the assumptions made in previous work when transposing their results to present and future situations.

The propagation of radio waves has been well-studied as it is a vital factor for planning radio systems, and most authors have followed the ITU guidelines. Propagation is affected by absorption by the terrain. UK authors **[refs. 4, 10, 11]** assumed "wet ground" (conductivity 10^{-2} S/m) whereas **ref. 12** assumed that Germany was "land" (conductivity 3×10^{-3} S/m). At 3MHz and 100km the latter results in 7dB lower field strength, so the assumption is of some importance.

The ITU data of course assumes deliberate transmission from an antenna intentionally raised above the surrounding terrain. Whilst installations in a tower block will be like this, most PLC will be at or near ground level. In this situation we have to consider the possibility of extra attenuation beyond the "one-hundredth power (-20dB) at ten times distance" theoretical rule.

In **Ref.4** Stott reported measurements in the UK by the electricity distributor Norweb of 25dB, but it is not specified over what distances this figure applied. Recent attempts in the USA to table a figure of 40dB have lead to a comprehensive rebuttal by the ARRL [**ref 16**]. A recent Canadian study [**ref.17**] claims statistical confidence in an 18.2dB figure – but only by extrapolation from measurements at 3m and 10m. Both these figures are questionable because they do not take proper account of "near field" effects. The near field is the region close to an antenna where the amplitude and phase relationship between the electric and magnetic fields is not properly established, and so there is an ebb and flow of energy between the antenna and its surroundings, and simple maths does not apply. For a half-wave dipole the near field ends at a distance from the antenna approximately equal to $\lambda/(2*\pi)$ – that is one sixth of a wavelength or 1.6 metres at 30MHz. However, for complex antennas such as the multiplicity of cables in an indoor mains network, both theory and modelling by the present writer [**ref.19]** has shown that far field conditions are only established at a greater distance where the contributions of the various antenna elements approach the phase relationships that they would have at infinity. This "Rayleigh Distance" is given by $2*D^2/\lambda$ where D is the largest dimension of the antenna aperture, and is equal to 13 metres at 30MHz. So PLC emission measurements at 10 metres or less will be of poor repeatability and give limited indication of the far-field effect. However, for cumulative effects, the averaging will substantially reduce the impact of such errors. The NATO report [r**ef. 26]** provides data and analysis of this near-field problem. It is concluded that a universal model is not possible and that it is best to use the measurement results obtained by the referenced groups. These results depend on frequency and distance and range from 10 to 40 dB per ten times distance.

The NATO authors have also modelled the effect of ground reflections; - a factor ignored by other writers but well known to EMC test engineers.

All cumulative assessments must make assumptions about the culprit population size and usage. EMC Standards do not explicitly consider these factors – but because of cumulative effects such consideration is vitally important for exceptional mass-market products. For access PLC market penetration may yet become 100% if the technology is adopted for smart metering. For in-house population size we are reliant on marketeer's numbers. The various studies reported above assumed 15% to 100% usage. For in-house PLC 100% usage factor is already commonplace because of poor protocol design **[ref. 9].**

Calculation errors relating to the mains as an antenna and to propagation will be minimised by averaging across the large population – but this does open up the possibilities of "hot spots" of more serious trouble such as were encountered following estimates of the average level of radioactive fall-out from the atom bomb tests of the 1950s **[ref. 20].**

All these studies make assumptions about culprit population that are as-yet unfulfilled. If allowance is made for differing assumptions they all agree substantially. However there is no reason for complacency. Whatever population there is, we can safely assume that in the developed world it is growing at 25% pa (15% sales and new product introductions, 10% increasing data throughput) which equates to 1dB/annum increase in cumulative interference. If the calculated figures are a 10dB overstatement this only delays the rise of spectrum pollution by 10 years. For access PLC and for smart metering the ultimate market size is equal to the number of electricity meters!

7) So why has nobody noticed - YET?

The measurement of one noise source in the presence of others is only possible if one can identify some unique non-noise characteristic. For example, man-made noise from business activities is almost completely turned off on Christmas day, so the reduction of background noise then compared with that on a normal business day gives a useful measure of business emission. Again, under certain ionospheric conditions distant sources of noise are absent and so their normal magnitude may be estimated by the effect of their absence.

PLC data transmissions are designed to be noise-like because that maximises the communication efficiency. So far no one has published any method of identification applicable to HF-PLC, other than switching it off – which is hardly possible when cumulative effects of multiple sources are involved. Nevertheless, there are some characteristics that might help identification;-

a) Most PLC systems are notched to minimise interference to amateur radio. Accordingly a comparison of noise measurements inside and outside of each amateur band should help. There appear to be ten notched band edges for HF-PLC that could be measured and the results averaged.

b) Where a single transmission format is predominant, as is currently the situation in the UK, it may be possible to identify some more detailed structure. The UPA specification [**Ref. 21]** specifies sub-carriers spaced at 156.25KHz ±100ppm. In **Ref.22** Bigwood shows an instantaneous spectral plot of some of these sub-carriers. This reveals regions of 10dB lower emission between them. However these regions disappear in a time-averaged plot.

c) A single installation using the UPA protocol may be identified by the 1.3KHz tone demodulated by an am receiver. However, this tone is not locked to mains frequency. It will be of unpredictable phase and so not detectable in a cumulative situation.

Further work is needed to evaluate these methods of source identification.

To plan a demonstration the situation offering the highest PLC/ background ratio must be chosen. One aspect of this choice is the behaviour of the ionosphere at different times of day. At frequencies below a few MHz we may look for a minimum of sky wave interference at about noon, because the "D" layer, which is predominately an absorber, will then be at its thickest. At higher frequencies the maximum useable frequency ("MUF") is the controlling factor and night time may be the best choice for ground-wave measurement.

8) Today's worst case spelt out

Given the complexity of the models used previously and the greater detail that is now available about the culprits it is worthwhile to review what appears to be today's worst-case scenario. This is the rise in HF noise level that might interfere with communications to an aircraft overflying London, England.

In **Ref. 3** it was noted that in March 2009 there were about 300,000 active BTVision installations using Comtrend Power Line Adaptors in the UK, and that from UK population statistics we can expect 300,000 x 7.513/60 = 38,000 of these to be in the greater London area. This equates to 24 installations per km². These modems employ the UPA protocol **[ref. 21]** which results in the very unfortunate feature of emitting as much interference when idle as when carrying data. The protocol designers clearly did not appreciate the EMC responsibilities of the writers of communications software. In **ref. 9** Williams stated that the quasi-peak level in 9KHz bandwidth on each wire of such an adaptor is about 90dBµV. (We may ignore the 0.41dB correction between 9KHz and 10KHz bandwidth.) As discussed in the previous section, the rms voltage is the appropriate parameter for the necessary power summation. This is difficult to determine for PLC because of the high crest factor and wide bandwidth, but two independent tests of Comtrend modems have recently given values of 80±1dBµV rms on standby, and we have one measurement of a 2dB increase in rms voltage when active.

Accordingly we can assume a power output equivalent to 80dBµV on each wire, which translates into a two-wire power of -24dBmW total, or 4µW. For some comparisons it is useful to translate this into 0.4nW/Hz or -64dBm/Hz by subtracting 40dB to correct for the reduced bandwidth. Given the limited database on mains antenna gain we have to accept a typical PLC far-field antenna gain figure of –22dB, (that is a power reduction of 1/158) and limit consideration to the frequency range of 10 to 30MHz because of the uncertain antenna efficiency at lower frequencies. Therefore the *radiated* power *density* across the greater London area is estimated to be 24 x 4 x 1/158 = 0.6µW/km², or –32.3dBm/km².

Echoing the approach used by York **[refs 10, 11]**, it follows that the total radiated power from BTVision installations in Greater London in May 2009 was about 38,000 x 4x10^-6 x 1/ 158 x 10^3 = 0.96mW (0dBmW) measured in *any* 9kHz bandwidth within the adaptor's spectral emission range of 10 to 28MHz excluding the notches. The field strength/distance curves of **figure 1** were plotted for 100mW (20dBmW) radiated transmitter power: With Greater London as the source the plotted lines need to be corrected for today's worst case by lowering by 20dB. **Figure 5** shows the effect of this adjustment. On the ground, the interference drops into the rural noise at about 11km distance even at 3MHz, but in the air, where the dotted line plot of the pure inverse square law applies, there appears to be a 20dB excess of PLA interference above likely other sources.

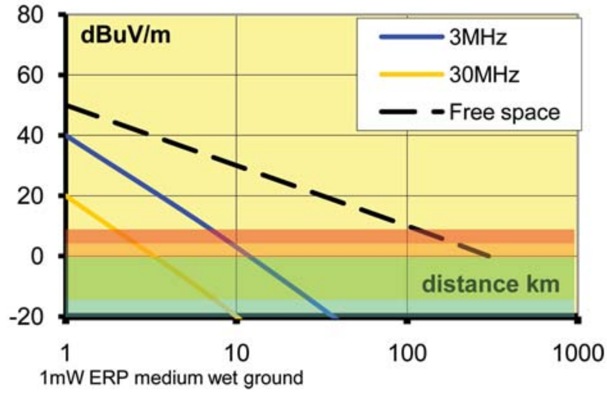

Figure 5 Field strength resulting from a 1mW transmitter. As in Fig 1 the red background corresponds to a "business" environment, the orange to "residential", the green to "Rural" and the blue to "quiet rural"

The 1mW EIRP estimate used to prepare this chart is subject to most of the uncertainties discussed earlier. Maybe these amount to 10 or 15dB in total. Also the spectrum will be filled with much stronger wanted signals that will make measurement problematical at most frequencies, but there is a reasonable chance that a measurement at an elevated site or from an aircraft would be possible today – and it will certainly be possible within the next few years unless something is done to make PLC more environmentally friendly. Note that the ambitions of Marks **[ref. 28]** for BTVision were for 3 million subscribers by 2010. If this ever becomes a reality it will raise their cumulative emission by 10dB.

9) Future Prospects

There is no doubt that HF radio communication at any distance - from wireless mice to intercontinental broadcasting - will suffer directly from the continuing marketing of PLC equipment with today's emission characteristics. Fixed and dynamic notching and power management as currently being discussed would help but not solve the long-distance problem if they were rigorously applied, but such rigor is unlikely given the present regulatory inertia and the steady growth in demand for the transport of data. It is noteworthy that the global demand for data transmission bandwidth continues to grow unabated, according to a leading optical components manufacturer [**ref. 24**].

We have to be concerned also about the example set by these high levels of emission, and the prospect of other products (eg Wireless power transmission) playing catch-up.

If the installed base of these "greedy" technologies continues to grow at 25% per annum, which corresponds to 1dB in engineering terms, then any errors in the calculations made by the experts referenced in this paper only amount to a delay of 5, or at most 10, years before the situation becomes so serious that radio interests have to respond. They have few options.

10) Conclusions and Recommendations

There is strong evidence that the wide deployment of high-speed PLT will seriously impact radio communication. If we allow this to happen we sacrifice a proven long-distance universally accessible technology of considerable commercial and social importance for what can only be described as a short-term gain in convenience for local data networks.

There are several things that could be done to minimise this problem;

First, we must make sure that EMC Standards are preserved from any relaxation that legitimises environmentally unacceptable emission. However, there is little point in doing this without a parallel campaign to increase awareness of the value of these Standards. We need to reverse the trend of the EU to discount Standards, and instead to encourage national governmental and quasi-governmental institutions to support them. It ought to be simple; Standards make people's jobs easier and establish a genuine level playing field.

The key area where awareness is needed is the market place. Today, almost no retail sales literature or product reviews make any mention of EMC specification or performance.

Identification of these noise-like interferers is very difficult. It would be much easier if all such sources were required to embody, and publish, some feature that would be recognisable for both a single source and an aggregation of similar sources. This should be a simple matter for the Standards Committees, but they may claim that it is a regulatory matter and so outside their jurisdiction. In this case, who can make it happen?

The "polluter pays" principle ought to apply to electromagnetic pollution just as it does to atmospheric pollution by CO_2. At present the victim pays in the short-term by inconvenience and in the long-term by the loss of development options and by increased energy cost. "Polluter pays" could be achieved by a tax on all products that do not conform to the internationally adopted EMC Standards.

Of course *local* interference is already being caused by *individual* PLC installations. The case for reduced HS-PLC emission to avoid these problems involves less extrapolation. Let us hope that Standards and Regulations will soon be put in place that will solve both sets of problems. Time is running out.

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Predicting Electromagnetic Radiation behaviour using accurate Simulators

By Dr J P (Tom) Cantle, AR UK Ltd

Abstract

Electromagnetic radiation impinges on all our everyday lives wherever we are or whatever we are doing. We do not seem to be able to exist without being irradiated by TV transmitters, Mobile phones, Radars plus the MRI RF scanners, Radiation ablation treatment and cancer targeting destructive sources.

One rather obvious problem with EM radiation is that we cannot see it, generally cannot feel it and find it difficult to predict where it goes and what it affects. Fortunately these shortcomings have been one of the drivers that gave rise to the modern EMC industry from which we all benefit from today.

The purpose of this article is to present relatively new, easier to use and more accurate solver methods for studying the myriad of complex problems in our world of electromagnetic radiation. The techniques are now sufficiently accurate and user friendly to be used in a wide variety of situations from an accurate predictor of radiation behaviour in free or restricted space to be a useful design tool for components.

Introduction

Historically, methods used to predict or simulate the effects of EM radiation have been difficult to use and employ imperfect analytic type methods to ease the complexity of the problem. A lot of these methods are improved by the use of measured results but this negates one of the benefits of simulating the effects.

If you have to measure it why bother doing a simulation?

We all like measurements as this generates sales for our equipment and services but, in many scenarios, measurements only give a snap shot as to what is happening and are an imperfect, time consuming and an expensive tool to use to get anything like the whole picture.

Techniques for analysis have moved on. It is now possible to know the effects of any Electromagnetic stimulus without the need for extensive testing. The accurate way to predict the absorption, penetration, propagation or the consequences of RF radiation are best evaluated by the solution of the ubiquitous Maxwell's equation. No doubt many will switch off now and cease reading at this point with memories of EM theory at College!!! Fortunately there are new Solver simulators available which take the pain out the problem solving. By adding simplified interfaces they enable any complex problems be modelled accurately and with incredible detail. The results are superior to any of the approximation modelling techniques and this also leads on to the usefulness of the solver to do the fundamental design of such items as antennae, RF circuits, screening, filters etc.

This article describes the basics of these approaches and touches on the use of the software which can be used for a wide variety of applications such as:

- Antenna design
- Filter design
- Circuit effects of propagating waves
- Co site interference effects
- IED jammer effectiveness
- Various medical applications including MRI, SAR effects and testing
- EMC relevant applications
- Screening effects
- Effectiveness of packaging

The list is endless.

This article is based on one of the package available from RemCom[1] but there are others from available from Agilent, AWR etc.

The Techniques Employed

Of course nothing is new in our industry. Maxwell lived and died a long time ago but his equations live on. I remember well spending many DAYS solving the equations for relatively simple structures to design waveguide components. The computer power was limited then so a long-hand solution with many assumptions and error prone simplifications were employed. There followed a first trial model, which was subsequently modified more than once to the finished article. A modern engineer would laugh at the time taken but there was no other real choice. Now with modern cheap computer power the solutions of simple objects are easy and take seconds. More complex problems are more difficult because of the time to set up the physical model but help is now at hand.

The introduction of a more user friendly interface that allows simple meshes or solid objects to be easily defined in electromagnetic terms speeds the process. You simply need knowledge of the sizes and shapes of any object plus the basic conductive, dielectric and magnetic properties to be included. The solver software then breaks the problem down automatically into finite cells in space and then solves Maxwell's equations for EVERY cell at a given point in time. The time is then stepped forward a micro interval and the whole set of equations are solved again. Even for simple structures that would have taken many hours and several assumptions in the past. Now very complex structures and many thousands [kilo thousands] of cells can be solved very quickly at every point in time.

To illustrate the technique further take a simple dielectric sphere. In terms of the computer this will be seen as a series of cells as shown in Figure 1. The computer decides the optimum cell size for the accuracy needed. The user just gives the overall dimensions and dielectric properties.

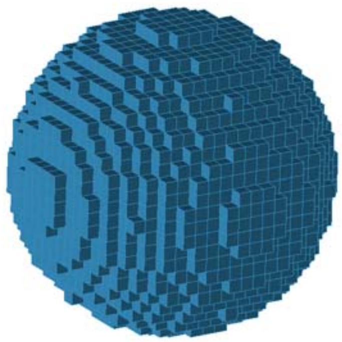

Figure 1. How the computer sees a dielectric sphere

This sphere can be studied in terms of its scattering behaviour, its use as a dielectric lens, its screening, its absorption and general effects on propagation with ease. Adding some other elements and it quickly can give rise to antenna modelling and so on. It is included here just to show the methods used by the computer.

With the capability to define a source of the radiation [which can be wideband or a single frequency] plus the ability to add in points of detection, the results can represent the real world observations with relative ease.

As the simulation moves forward with time the EM radiation will propagate everywhere and anywhere and this can be predicted and shown in graphical form by the software.

The computer complexities do not need to be known by the user. The software is performing a very complex set up from the user's simple model introduction. Much of this analysis is done to ensure the best accuracy and to preserve the stability of the solution. The output from the solver simulator has to be reality and not generated by the method itself.

For a given problem the software is capable of giving Near Zone and Far Zone results. Such things as screening, interference and absorption effects can be easily seen. The results can also show the effects of low or high field signal strength or can be converted to design parameters such as S parameters for use in realising new designs. Even more impressive are the visible charts that a computer can produce. These can show colourfully and quantitatively where the radiation has penetrated, bounced off and generally wound its merry way through life. It may not be able to tell you where the first edition of the longest running serial 'The Archers' has got to in the universe, BUT, it will give answers to questions which were only empirically possible with previous techniques. Incidentally the Archers was first broadcast shortly after World War 2 as a propaganda event by the British Government to promote farming. I have visions of some alien life form sat in a deck chair in another universe about 50 light years away listening to the very first episodes ever transmitted!!!

Some Application Examples for the software

To demonstrate using the software we could use many examples. A simple one to investigate is the effects of screening[2]. A simple box with a slot to show the leakage effects is used here. The box is 22 x 14 x 30 cm with a slot of 12 x 0.1 cm located 0.2 cm above the lower inside surface of the conducting box. The slotted wall of the box is 0.05 cm thick.

In this example the computer splits the problem up in to 21,000 cells. In other words the software solves accurately the full Maxwell's equation 21000 times per iteration. It runs the iteration until a solution is achieved. For the details as to how to define the box and slot and set up the simulation I refer you to the references. The prediction results compared to the actual measurements[3] are shown in Figure 2.

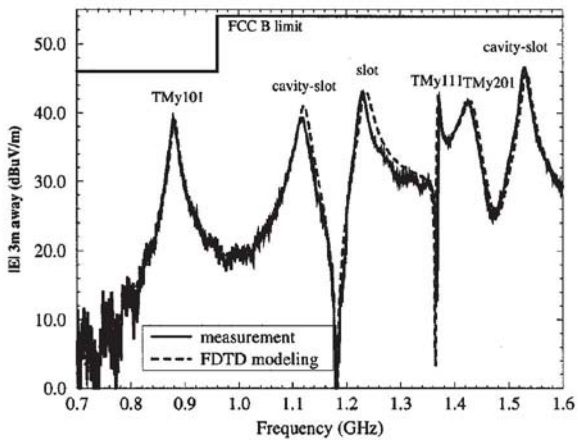

Figure 2 Comparison of the measured performance and EM simulation for a simple slot in a screened box

Of course this is a relatively simple structure which can be easily verified by measurement[3]. The beauty of the prediction method is that it enables the user to make a quick change to any of the parameters. It also allows the far field results to be viewed at any distance away and at any orientation. Many other variations can be made, the effect of which can be viewed almost immediately.

A more real world example is the design of a broad band sleeve monopole antenna. (BBSM). If there is any further interest I will include this in a future article.

If anyone has any comments on the above (good and bad) I will be pleased to hear them. If the reprints of any of the references are required I would be more than happy to supply them.

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The Physical Basis of EMC — Part 3

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Contents

5 Coupling of EM energy (continued from Part 2 [17])

5.5 Differential Mode (DM) and Common Mode (CM)

Differential Mode (DM) is where the send and return conductors carry opposing voltages or currents. Wanted (intentionally created) signals and power are always DM, sometimes called 'transverse' because their voltages appear between the send and the return conductors.

But unbalanced 'stray' coupling converts some of the DM signal or power into Common Mode (CM) currents and voltages, which we call "noise" because they are unwanted.

Part 2 of [1] described how conductors in cables attempt to balance their strays, for example by using twisted-pairs, or contain them – for example by using shielding. [12] describes similar techniques for traces on printed circuit boards (PCBs). But nothing is ever perfect, so there is always a difference between the stray currents and voltages caused by the route taken by the send conductor, and the strays caused by the route taken by its return conductor, resulting in CM noise.

These accidental, unintentional, but nevertheless real and always present CM currents and voltages also have 'stray' couplings into victim circuits. This is called DM to CM conversion, and is a feature of all electronic hardware, active and passive.

CM is sometimes called 'longitudinal', when it appears along the length of a cable. The longer the cable, the more CM is created from the DM signals it carries. DM to CM conversion in cables is generally specified by cable manufacturers as Longitudinal Conversion Loss (LCL) – in dB/metre. It varies with frequency (generally becoming worse as frequency increases) so is specified at certain spot frequencies, or as a graph of dB/metre versus frequency.

LCL is not merely a concern for generating EMI (or picking up EMI from EM fields in the air, since DM-CM conversion works either way around, giving a reciprocal CM-DM conversion). Energy that is lost to the DM signal by conversion into CM noise causes distortion of the signal (see Section 4.1 and 4.2 of [17], and limits the distance the signal can be carried before it becomes unusable. For example, one of the main differences between the various categories of Ethernet cables (e.g. Cat 5, 5e, 6, 6a, 7, 7a etc.) is their LCL at high frequencies.

Figure 30 shows an example of DM (wanted) signals causing CM (unwanted) noises, for a 'floating' load. It doesn't matter if the electronic unit shown in the figure is floating or connected to the chassis or earth, or if the load is floating or bonded to chassis or earth, radio-frequency (RF) energy flows quite happily through quite small values of stray capacitance (see

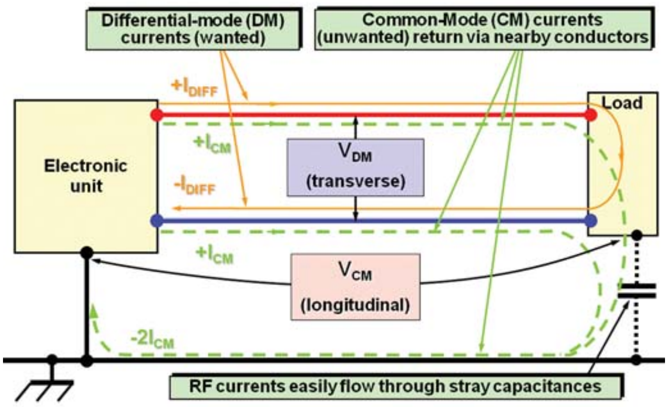


Figure 30 The loops enclosed by DM wanted signals/power and by unwanted CM

Remember – the four types of 'stray' coupling are: Common-impedance; E-field; H-field, and EM-field, (see Sections 5.1 to 5.4 in Part 2 [17]) and they all couple stray CM current and voltage noises just as well as they couple stray DM currents and voltages.

Figure 31 shows an example of CM H-field coupling, between a pair of send/return conductors, and some local conductor (e.g. a metal structure in a wall, floor or ceiling).

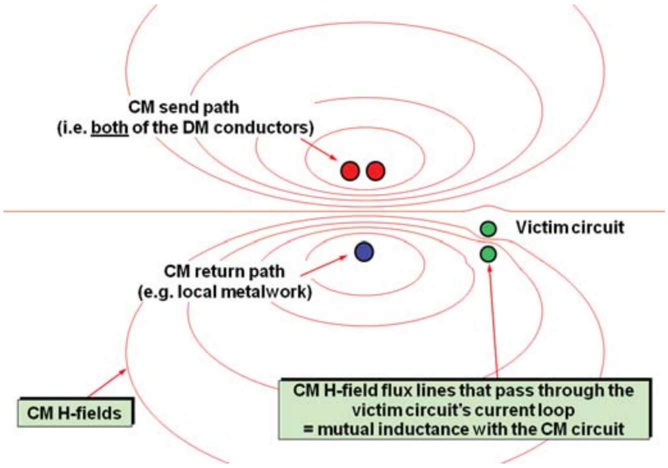


Figure 31 Example of H-field CM coupling

Figure 32 shows an example of a cause of CM. Stray capacitances (E-field couplings) from a logic signal cause stray (CM) currents to flow in all nearby conductors, in this case a metal water pipe.

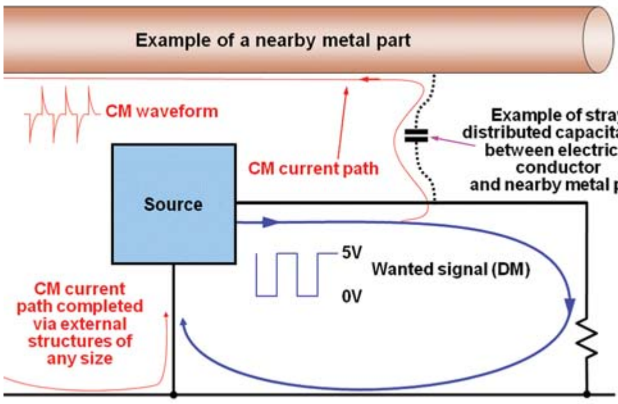


Figure 32 Example of stray capacitance coupling causing CM currents

The best way to reduce the generation of (and susceptibility to) CM, is to use "balanced" or "differential" communications, as shown by Figure 33. These use symmetrical constructions (including PCB layout) and signals/power that are the inverse of each other, to help ensure that stray couplings cancel themselves out as far as practicable.

"Balanced audio" has been in use for many decades, to reduce the power frequency hum noise that intrudes into microphone and other audio signals when long cables are used. This hum is caused by stray powerline currents flowing in the common impedance of the earth/ground structure, creating significant levels of voltage differences and/or currents at the powerline frequency between different parts of the structure.

The CM to DM conversion ratio (called the Common Mode Rejection Ratio, CMRR) of balanced audio circuits can be as good as -100dB at 50Hz, but maintaining such high levels of balance up to (say) 10kHz is very difficult, and above 100kHz it is virtually impossible.

In recent years, LVDS (low-voltage differential signalling) has become a popular technique to reduce emissions (and improve immunity) for high-speed data transfer. If the balance can be maintained to a high-enough frequency, it can avoid the need for costly shielded cables.

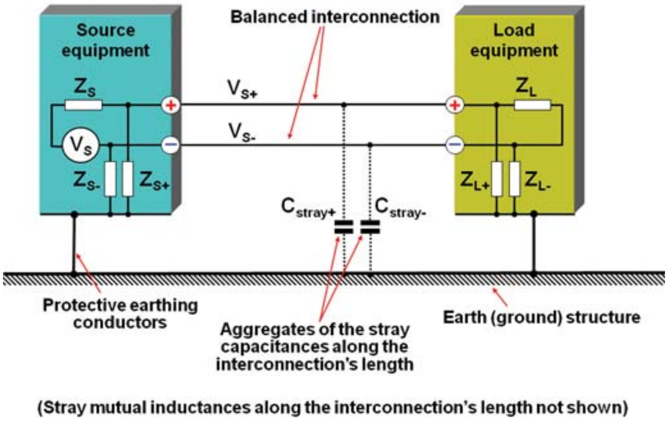


Figure 33 Using balanced interconnections to reduce DM-CM (and CM-DM) conversion

But nothing is ever perfect in the real world, so despite our best efforts, even when we design taking tolerances, soldering shocks, temperature coefficients and ageing into account, we still find that (referring to Figure 33) $Z_{S-} \neq Z_{S+}$, $Z_{L-} \neq Z_{L+}$, $C_{stray-} \neq C_{stray+}$, and also the differential signals are never *exactly* balanced in phase or amplitude, so $V_{S+} \neq V_{S-}$.

The inevitable result is that CM currents and voltages will still arise even when using balanced interconnection techniques, although they can be reduced very significantly compared with using single-ended signalling.

Single-ended interconnections can be made to behave as balanced/differential interconnections very easily at RF, by using CM chokes. Over their effective frequency range, they act as non-isolating "baluns" (balanced to unbalanced converters), and I've solved many EMC problems by adding CM chokes, either soldered onto the PCB or clipped around a whole cable or cable bundle.

Because CM voltages tend to appear across large areas, and CM currents tend to flow in very large loops, CM can cause much higher emissions than a DM signal of the same amplitude and frequency. In fact, the accidental conversion of DM into CM is often the main cause of excessive emissions from 1 – 1,000MHz.

The corresponding conversion of CM signals in the environment (e.g. due to radio frequency fields being picked-up by conductors acting as accidental antennas) into DM noise in electronic circuits is the main cause of poor immunity 1 – 1,000MHz.

From page 460 in Appendix D of [13], we learn that a small wire loop or monopole ("small" means <<λ/4) will emit the following worst-case E field strengths at 10m over a ground plane (the typical CISPR radiated emissions test method) of:

For DM currents: $E = 26.3 \cdot 10^{-16}(f^2 \cdot A \cdot I)$ Volts/metre

For CM currents: $E = 1.26.10^{-7}(f \cdot L \cdot I)$ Volts/metre

— where f is the frequency in Hz, A is the loop area in m^2, L is the monopole length in metres, and I is the DM or CM current in Amps. See Section 4.5 of [17] for other simplified formulas for common conductor structures.

A few sums using typical values will soon reveal that because of the huge attenuation factor of 10^{-16} in the DM formula, at frequencies below 1GHz it is more common for radiated emissions to be caused by CM currents, even though they may be measured in µA, than typical DM (signal, power) currents measured in mA.

In fact, a handy guide is that just 5µA of CM current on just one cable connected to a product can be enough to cause failure to comply with the CISPR 22 (= EN 55022) Class B limits at frequencies around 100MHz, and 15µA can be enough to fail Class A.

This means that we can very quickly and easily get a good idea of whether our product will pass emissions tests, purely by clipping a (calibrated) RF current monitoring probe over each cable in turn, and measuring its CM noise on a spectrum analyser. And we can do this at our usual development bench, we don't need a screened room or open area test site, as Figure 34 shows.

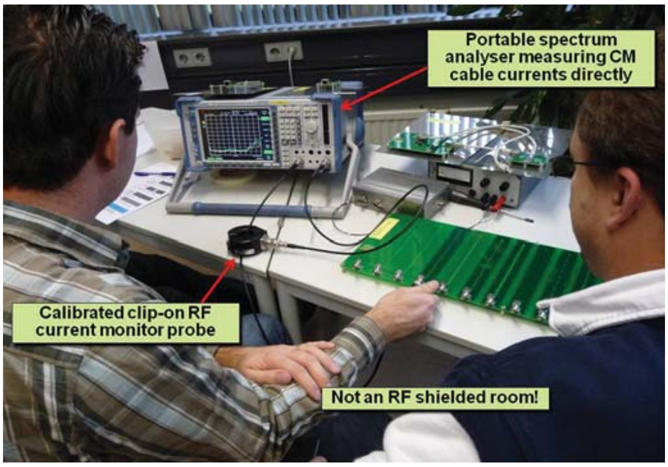


Figure 34 Quickly checking CM noise emissions without an EMC test chamber or site

Of course, nothing is guaranteed in real-life, and sometimes emissions problems are caused by DM signals rather than CM noise. I have had to reduce excessive radiated emissions using DM suppression techniques, when CM techniques did not work.

As the tested frequencies rise to 1GHz and above, the f^2 term in the DM equation above means that it becomes easy for DM signal currents to exceed the emissions caused by CM noise currents, even when their currents are similar.

So much experience has been gained below 1GHz, over the last few decades, and written-up in textbooks and articles like this, that there is a real danger that people will assume they can solve all emissions problems above 1GHz by using CM noise suppression techniques – when what they may need to address instead is the emissions from the DM (wanted, signal or power) currents. You have been warned!

5.6 Controlling CM return currents

For the reasons discussed above, controlling the paths taken by each CM return current, relative to its send current's path, is very important indeed in EMC design.

Firstly, we reduce the generation of CM by:

- Reducing the RF impedance in shared conductors
- Providing DM send/return paths in close proximity for both signals and power (e.g. twisted-pair conductors)
- Using balanced/differential signalling techniques, or at least CM chokes

Secondly: we reduce the effect of the resulting CM voltages and currents by:

- Where practical, providing a path for CM current to return in very close proximity to each CM send path (i.e. each DM circuit)
- Electrically bonding all 'floating' circuits to the CM return current path, designing the bond to have the lowest practical impedance at the frequencies concerned

Remember, one of the key issues in EMC design is that currents always take the path that uses the least energy, which is also the path that emits the least E or H-fields. So by providing a CM return path close to its send path, and helping ensure that most of the CM current takes this path by low-impedance bonding, we cause the least CM stray coupling.

Mobile and portable equipment cannot take advantage of the techniques listed under "Secondly" above. But on the other hand, they are not often connected to large numbers of long cables and so their CM generation is more limited than permanently installed equipment that often can control the CM return path, e.g. using cable trays (see [18]).

5.7 RF "Grounding"

Safety earthing (grounding) does not help EMC at RF. I haven't mentioned safety earthing/grounding yet in this series of articles, because the terms "earthing" and "grounding" are so widely abused that it is best to use them only for electrical safety issues, and not for circuit design or EMC.

I've seen many projects suffer huge delays, because the different teams working on different parts of the equipment took different views on what was their RF Reference (that they simply called earth or ground, hence the confusion) and so had huge "internal EMC" problems (see Section 8).

But anyway, wired connections to the protective (safety) earth/ground have little effect at frequencies above 100kHz, because...

- They have far too much inductance (e.g. a 2 metre length has 188Ω at 30MHz, when a good "RF Ground" needs <<1Ω)
- Like all other conductors, they behave as accidental antennas (e.g. a 2 metre length makes a perfect antenna at a variety of frequencies at or above 75MHz; green insulation striped with yellow has no magical anti-antenna effects!)

So what must we use for our RF Ground and how should we connect to it?

The only effective RF Ground is what we should learn to call an "**RF Reference**", and it provides a low impedance, <<1Ω (preferably <10mΩ, with no lower limit), over the range of frequencies that need to be controlled to achieve EMC.

An RF Reference is a highly-conductive area (i.e. metal) that is as large as possible. It could be a 0V plane in a PCB, a chassis or frame, an enclosure, even (for frequencies below 100MHz) a grid of cross-connected metal structures in a room or a building. The larger the area of the RF Reference, the better it is, with no upper limit on size.

Also – to be able to be used effectively – the RF Reference must be very close to the item that is to be "RF grounded": <<λ/10 at the highest frequency of concern (equivalent to <<30/f_{max} when surrounded by vacuum or air. f_{max} in MHz gives spacing in metres; GHz gives millimetres).

Much closer spacing is better: <<λ/100 at the highest frequency of concern (equivalent to <<3/f_{max} when surrounded by vacuum or air).

RF grounding to an RF Reference Plane is more correctly (and less ambiguously) called "**RF Bonding**". Direct metal-to-metal connections give the best RF bonds (i.e. the lowest impedances at up to f_{max}).

Where two conductive parts are to be joined that are not just a circuit connection, for example a metal filter body to the RF Reference, there should be 'RF Bonds' at multiple points equally spaced <<λ/10 apart along the perimeter of the seam or joint (equivalent to <<30/f_{max} when surrounded by vacuum or air). A single-point connection cannot work, the RF energy will just flow through the stray capacitance or stray mutual inductance instead, and will resonate at certain frequencies causing accidental antenna behaviour of the part.

Ideally, instead of multiple RF bonds – seam-weld, seam-solder, or apply a continuous conductive gasket all around the perimeter of the joint.

Some mystique surrounds the use of metal braid straps, especially if they have a length/width ratio of no more than 5. They so obviously have a very low resistance that it might appear that they must make a good bond at any frequency – but I'm afraid this is not so. As mentioned in Part 1 [8], everything that has physical existence in this universe has inductance and capacitance, so at RF can have considerable *impedance* even if its *resistance* is negligible.

In fact, the use of braid straps with a length/width ratio of 5 appears to come from a practical recommendation in a very early military "EMC good installation practices" concerning short-wave communications, with frequencies below 50MHz. These days we have to deal with frequencies that are at least 20 times higher, where braid straps have too much inductance.

I have seen the results of a test conducted in the 1980s that showed that a metal cabinet, RF bonded to the deck of a ship with a single 9.5 inch long braid strap, had lower emissions up to about 10MHz then higher emissions above 20MHz, when compared with no connection to the deck at all.

Around 20MHz, the stray capacitance of the cabinet was resonating with the series inductance of the strap, making the cabinet into a more efficient accidental antenna than without the strap.

However, a number of wide braid straps <150mm long equally-spaced <<λ/10 apart around the perimeter of a metal cabinet might have been effective at RF bonding it to the metal deckplate and reducing its emissions up to about 100MHz.

5.8 Metal planes bring many EMC benefits

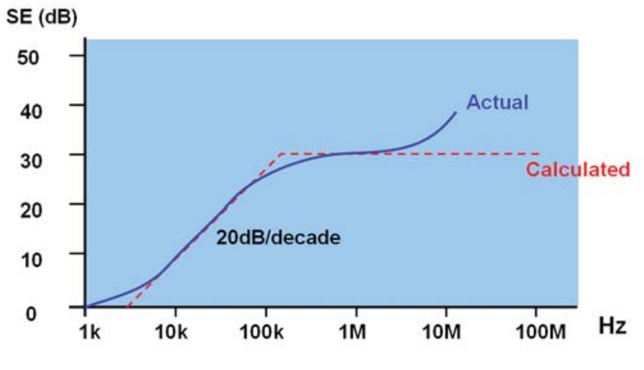
Planes have very much lower RF impedance than conductors such as wires, cables or PCB traces, so when used in a shared circuit they cause very much lower common-impedance coupling (see Section 5 of [17]).

Figures 3 and 4 in [19] show that replacing a 300m long 4mm wide copper PCB trace by 300mm-spaced connections to a copper PCB plane, reduces the impedance at 50Hz from 35mΩ to 0.8mΩ, an improvement of about 43 times, or 33dB lower noise levels due to common-impedance coupling. This is entirely due to the plane having a much lower *resistance* than the trace (at 50Hz, the inductive component of the impedance is negligible).

At frequencies above a few kHz, the inductive component of a conductor's impedance starts to dominate its resistance, and the difference between the trace and plane will be much greater than it is at DC. The higher the frequency, the greater the improvement, for instance, at 160MHz (and taking skin effect into account) the 300mm-spaced plane connections provide an impedance that is about 70dB less than the 300mm long 4mm wide trace (a 3,000-fold improvement).

For a source or victim circuit that is closer than λ/10 at the highest frequency of concern (equivalent to $30/f_{max}$ in vacuum or air), electromagnetic waves that hit a highly-conductive plane are partially cancelled out by their anti-phase reflections from the plane.

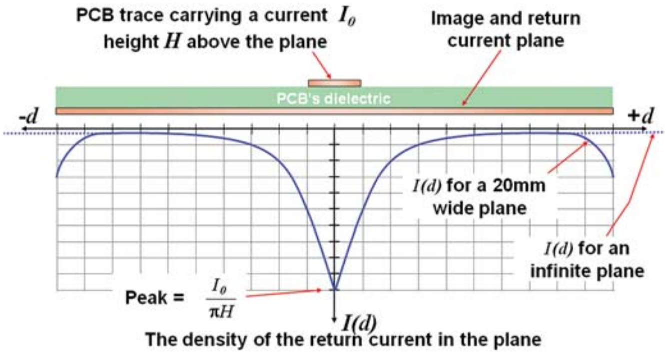
So, when a source or victim circuit is very close to a large area of metal plane this 'image plane' effect reduces its coupling with E, H and EM fields in its environment, as if it was being shielded to some degree. Figure 35 shows the shielding effect (SE, in dB) of a copper PCB plane, using the example of a 120mm long trace spaced 1mm above a 150mm square plane that is carrying its return current.



From: Swainson, IEE International EMC Symposium, 1990

Figure 35 Shielding effectiveness of a plane under a PCB trace

The image plane effect for a nearby circuit results in its return current travelling mostly underneath the conductor and following its route very closely, for frequencies above 100kHz. No matter how the conductor wriggles, as long as it stays close to the plane its return current in the plane follows it very closely indeed. Figure 36 gives the example of the return current density in a PCB plane, for a trace routed above it (shown end-on, in cross-section).



$$I(d) = \frac{I_0}{\pi H\{1+(D/H)^2\}}$$ for a long straight trace over an infinite plane

Figure 36 Return current density in a plane under a PCB trace

As we learned earlier (Section 5 of [17]), having send and return current paths close together generates the most compact fields and so couples the least E, H and EM fields into victim circuits (such as an antenna in a test laboratory). When using a plane near to a conductor, we automatically get the most compact fields and least stray coupling. This is another way of explaining why a nearby plane provides shielding effectiveness.

So, metal planes are a powerful tool for EMC, and they are used in some ICs and most PCBs. Large systems sometimes use meshes instead, but unlike sheet metal they are only effective up to a frequency related to the reciprocal of their mesh size (smaller mesh size – effective to higher frequencies).

In fact, their highest effective frequency can be crudely calculated as $f_{MAX} = 100/D$ (f_{MAX} in MHz, D in metres, where D is the diagonal size of the mesh's elements – the largest dimension of the mesh). So, for example, a 1m diagonal mesh would provide some control of RF emissions and immunity up to 100MHz. At 100MHz the mesh will not be *terribly* effective, it will be much better at 10MHz, but at least it will be very much better than the traditional "single-point earthing/grounding" method, which simply cannot control emissions or immunity whatsoever above a few kHz.

6 An overview of emissions

Real-world EMC is often very complex indeed, because of the eight modes of EM coupling (4 each for DM and CM) and the ever-increasing complexity of modern devices, circuits and systems. When bogged down with complexity whilst trying to deal with emissions, it often helps to get a perspective, and overview, by realising that the situation is usually very simple – all electronics can be thought of as many tens of thousands (maybe millions) of noise sources, connected to thousands of accidental antennas.

The noise sources are the transistors, either in integrated circuits (ICs) or power transistors. The accidental antennas are all the conductors, e.g. IC leadframes, PCB traces, wires and cables, metal boxes, etc., all of which have resonant frequencies that depend on their length, exact build conditions, terminations, routing, gaps and slots, and proximity to other conductors and materials.

There are many enjoyable aspects to EMC, and one of them is determining the "accidental antenna behaviour" of components, conductors, packages, boxes, assemblies, installations, etc. For example, a heatsink might have its first resonance at the GPS L1 frequency (1.6GHz), and respond to the 16th harmonic of a 50MHz clock – radiating so much noise at that frequency that a nearby GPS antenna cannot "see" any satellites.

An example I had recently in an installation, that used a number of variable-speed motor drives for pumping gasses and liquids. The noises the drives created (harmonics of their power switching frequency) could be found all over the installation, particularly at frequencies around 1MHz, where they were easily 20dB worse than at other frequencies and interfering with measurements. The installation's metal structure was circular with a diameter of about 150 metres, giving it a strong self-resonance at around 1MHz in all directions, which was selectively amplifying the noise from the drives around that frequency.

We often estimate the accidental antenna effects from simple dimensions, but Doug Smith [20] describes a very useful method of finding the resonant frequencies of anything, using a spectrum analyser with tracking generator and applying a pair of current probes to the object in question.

7 Immunity issues

7.1 Issues not covered so far

All of the previous discussions are equally valid for emissions and immunity, because they are all concerned with how conductors interact with the propagation of the E, H and EM fields that that we generally call electrical signals and power. Because of the principle of reciprocity, those discussions are equally valid when we want to control RF emissions, and/or RF immunity.

Now we have to discuss some additional topics, which are generally only of concern for immunity.

7.2 Non-linearity, demodulation, and baseband noise

In a linear material the output is linearly proportional to the input, but all semiconductors are non-linear (as are some oxidised electrical connections) so they tend to rectify AC waveforms. Rectification results in a DC signal plus harmonics, just like a mains AC rectifier.

In a radio receiver this rectification characteristic is combined with a low-pass filter to obtain the modulation signal that is carried by the transmitted radio wave, and is called demodulation or detection. In this case, the DC signal output by the rectifier fluctuates in accordance with the modulation, and is called the "baseband".

One result of this is that all transistors will demodulate radio signals that are allowed to get into their terminals, acting just like radio receivers with accidentally-tuned antennas.

Figure 37 shows the example of a 'slow' opamp rectifying (demodulating) the 1kHz modulation of a radio frequency immunity test, at frequencies up to 1,000MHz, before I modified it to make it pass the test. It is taken from an actual product test that I did in the early 90s. The product was an analogue signal converter in an unshielded plastic box for DIN-rail mounting in industrial cabinets. Inside, it was little more than a quad opamp, type LM324, on a small PCB. It had three cables connected to it: 24Vdc supply, input and output, all of different lengths.

As the tested frequency increased, I saw the classical signs of rectification – the product's output error showed sharp peaks at frequencies that could easily be correlated with the resonant lengths of the cables connected to it (see Figure 7 in Part 1 of this series [8]). So far, so humdrum, but at frequencies above 400MHz I was surprised to see the error increasing linearly with frequency – and still rising at 1GHz, where the test stopped.

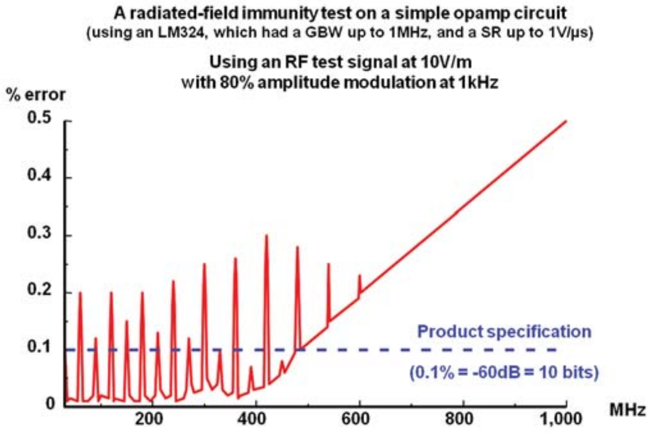


Figure 37 Demodulation in a "slow" opamp

It is very common to hear designers of audio and low-frequency instrumentation say that because they are using "very slow" opamps, they will not respond to an RF immunity test. They use this as an excuse for not bothering to protect their designs against RF interference, and also for not testing them for it. In the early 90s the LM324's main claim to fame was that it was the cheapest quad opamp available, and with a slew rate of up to 1V/μs and a GBW (gain-bandwidth product) of up to 1MHz, it was definitely a "slow" opamp!

And yet, in the test reported in Figure 37, it demodulates at 1000 MHz about twice as effectively as it does at 500MHz. The datasheet figures for an opamp are for its *linear* behaviour, not for its non-linear responses, and it is these that we see causing the error to rise considerably over the specification, in Figure 37.

Even a cheap, low-performance opamp like the LM324, used very tiny transistors that had correspondingly low values of collector-base and base-emitter capacitance. So when hundreds of MHz were applied to their terminals (courtesy of the accidental antennas that we call DC, input and output cables, and PCB traces) there was too little capacitance to prevent the non-linear semiconductor junctions from being exposed to the RF, which they promptly demodulated, producing an error in the opamp's output.

Figure 37 shows us that no opamp is ever "too slow to see RF", and all analogue (and digital) circuit designs are susceptible to RF interference, whatever the application. An on-chip capacitor is used for dominant-pole compensation inside the opamp's IC, but as far as RF is concerned that it just a nice low impedance for coupling RF noise inside the device.

It is tempting to think that it is just an IC's input pins that are susceptible to demodulating RF, but in fact all the pins are much the same in this regard, as Figure 38 indicates. The output impedance of feedback amplifiers may be designed to be 0.1Ω or less, but this is only for the bandwidth for which there is at least 60dB of excess open-loop gain above the closed-loop gain requirement.

At frequencies beyond a few 10s of MHz, when opamp open-loop gain is 0dB or less, the output impedance is typically around 100Ω and makes a good impedance match for the CM impedance of typical cables. So at such frequencies the RF noise picked up by the cables acting as accidental antennae pours straight into feedback amplifier outputs, to get demodulated in whatever silicon junctions it can find inside the IC.

And the power supply rejection ratio of opamps might be specified as 120dB, but that is measured at 60Hz (the US mains power frequency) and typically falls at 20dB/decade to below 0dB at or above 1MHz. Some types of analogue ICs have no power supply rejection at all, at any frequency, as I found in the early 80s when working with some of the first switched-capacitor filter chips.

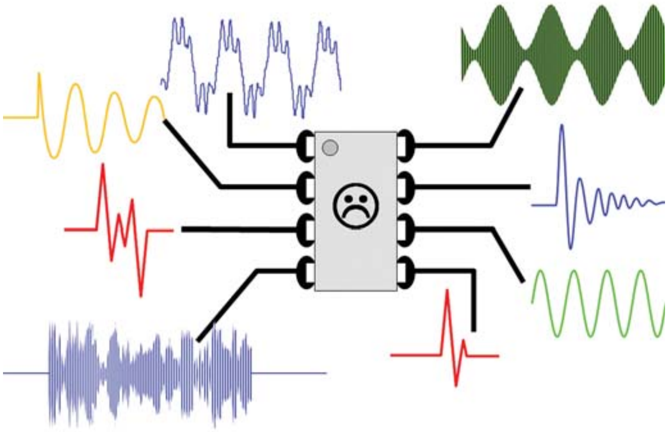


Figure 38 All IC pins are susceptible to RF demodulation

Interference is a bigger problem for well-designed analogue circuits than for digital, because a well-designed digital circuit has a "noise margin" – the peak noise level in the circuit (created by its own digital activities) is less than the threshold at which the devices make decisions about whether the signal is a 1 or a 0. External EMI that adds to the noise in the circuit has to be larger than the noise margin, before a false logic decision is made.

It is a similar issue with Analogue to Digital converters – they resolve their input signals to 1 least-significant-bit (LSB), and so must have an internal or background noise level that is half an LSB or less. But even an 8-bit A/D converter has an LSB that is much smaller than the noise margin of a well-designed digital circuit, so we can say that analogue circuits are always more susceptible than well-designed digital circuits.

Whether devices are analogue or digital, once RF gets inside their package, it can couple through stray capacitances to any/all of the semiconductors inside the device, be rectified by them, then amplified by others. The result of a rectification is a shift in the DC operating point, the DC bias, of a transistor. Modulation of the level of the RF results in modulation of the DC bias point of the transistor, hence what we call baseband noise (or, in a radio receiver, demodulation or detection).

Figure 39 shows the effect of an amplitude-modulated RF broadcast transmission being coupled into an opamp by some means – the opamp's output noise being the demodulated radio signal. Increasingly, radio transmitters are changing to use digital modulation techniques instead, and in typical cellphones the digital data is sent as several bursts a second, each burst containing packets of data at the rate of 217Hz. This is demodulated in opamps in our car radios, landline telephone handsets, etc. as the familiar "blippety-blip" sound we get when making or receiving a call on a cellphone that is too close to the car radio or landline.

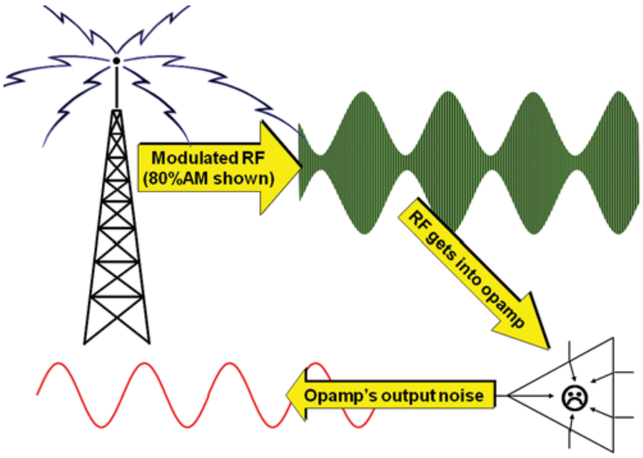


Figure 39 Example of RF demodulation of a radio broadcast

All sparks create noise at radio frequencies – sparks in switch and relay contacts, thermostats, commutators in DC motors, the sliding contacts used by electric trains, etc. This noise is effectively randomly-modulated RF, although it can have strong components at the frequency of the AC mains power line and its harmonics. When it couples with opamps the result of a switching operation is a burst of random noise, that might sound like a "pop", "fizz" or "splat". In the case of a DC commutator – the noise is a whine that varies as the speed of the motor varies. Figure 40 sketches this situation.

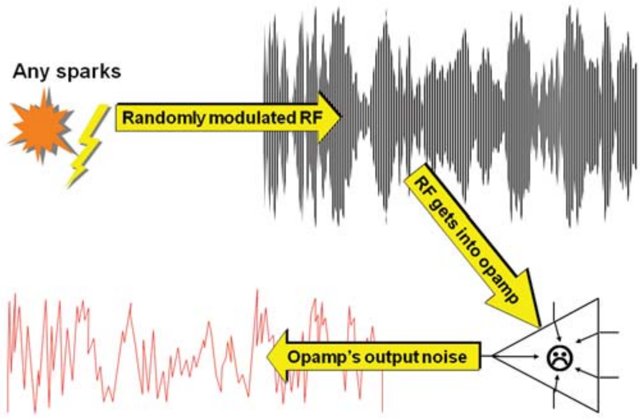


Figure 40 Example of RF demodulation of random RF noise

If the RF signal level is high enough, the DC bias points of the transistors can be moved more than just a few millivolts, altering the way that the semiconductor affects the wanted signal that is passing through it. If the DC bias is moved too far by the RF noise demodulation, the wanted signal might become severely distorted, or even not be amplified at all. This happens in just the same way for digital transistors as analogue ones, but has different consequences for digital circuits.

Once an analogue signal is corrupted by EMI there's no way back (without sophisticated digital processing that "knows" what the signal is supposed to look like). The amplitudes of digital signals are supposed to be always either maximum (1) or zero (0) so RF demodulation doesn't affect them, but of course a sufficiently high level of noise can create a signal that is not full-scale, but nevertheless is enough to cross the logic threshold cause a "bit flip" – turning what should have been a 1 into an erroneous 0 (or what should have been a 0 into an erroneous 1).

Software consists of instructions and the data on which the instructions operate, with both instructions and data stored in memory and accessed when required. Obviously, "bit-flips" can corrupt data to varying degrees, a bit-flip in the LSB being of little importance – but very important indeed if it occurs in the most significant bit, the MSB. So data on the desired speed of a machine might be corrupted to turn the speed up or down by a little more than was actually required, or by a more significant amount, even up to making it stop dead or race away at full speed in forward or reverse.

If a bit-flip occurs in an instruction, it will be corrupted, resulting in a nonsense instruction that could do nothing (perhaps making the software process "hang") or do something very unexpected (but always undesirable). It might, for example, cause the wrong memory location to be accessed, fetching the wrong instruction or data, again with undesirable and possibly calamitous results if anything powerful is being controlled.

Software techniques are available to help correct bit-flips caused by EMI, but are never complete solutions on their own because sufficiently long burst of RF noise or continuous interference can cause critical data or instructions to be delayed by too long, and could possibly even cause the rate of either to fall to zero. Hardware design techniques are still required for EMC.

Another problem for digital circuits is that the rectification of RF noise within the semiconductors causes their logic threshold to vary, and this causes timing jitter on the edges of the digital signals and clocks. When the timing jitter exceeds a certain margin, the digital process will perform other than expected. This is not an error in the data or an instruction, it is an error in the basic operation, and it is very hard to predict what might happen.

Analogue circuits tend to "fail gracefully" when interfered with – higher levels of EM disturbances cause higher levels of signal degradation. This makes it relatively easy to estimate the reliability of a design when exposed to real-life EM disturbances.

But the problem with testing digital circuits for RF immunity is that they might pass the test at a given test level with no degradation in performance, but a very slight increase in the level it experiences in real-life could result in a total failure to operate, or some extreme misbehaviour.

York University have proposed a way of determining how close a digital circuit is to failing, by measuring the emissions from its intermodulation (see 7.3) with the RF frequency it is exposed to, [21]. This can help provide more confidence in the reliability of operation in real-life.

7.3 Demodulation, intermodulation, and the creation of new frequencies

Rectification creates even and odd-numbered harmonics, which were mentioned in the previous section but then ignored. However, where two or more RF signals are simultaneously present in a non-linear device, new frequencies are created from their sums and differences, and from the sums and differences of their harmonics. One of the signals might be the one the circuit is meant to be processing, the wanted signal, whilst the other might be noise, or both frequencies might be noise.

Figure 41 shows the first few "intermodulation products" with two frequencies, one (f_1) at 400MHz and the other (f_2) at 500MHz in this example.

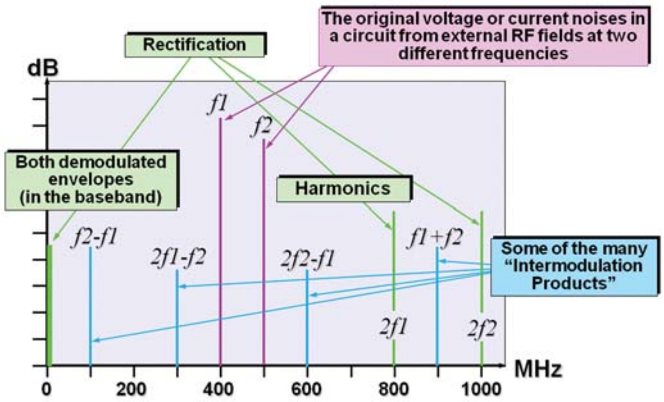


Figure 41 Example of the intermodulation of two frequencies in a semiconductor

Firstly we notice that the baseband noise, caused by rectification, is the sum of the modulation envelopes of the two RF signals. If f_1 was pure unmodulated carrier wave and f_2 was transmitting, say, music, the baseband noise would be a DC offset plus the music. If f_1 was transmitting speech and f_2 music, the baseband noise would be a smaller DC offset plus the speech and music mixed together.

Secondly, we see the second harmonics of both f_1 and f_2, at 800MHz and 1000MHz respectively, the scale of the figure not allowing their 3rd, 4th, 5th, etc., harmonics to be shown.

Thirdly, Figure 41 shows us that we have what are called the "first-order intermodulation (IM) products". There are two of them, at the sum and difference of the two frequencies: $f_1 - f_1$ = 100MHz and $f_1 + f_1$ = 900MHz.

Finally, we see the "second-order IM products", between each of the 2nd harmonics and all of the other frequencies. There are five of them, at $2f_1 - f_2$ = 300MHz and $2f_2 - f_1$ = 600MHz (with $2f_1 + f_2$ = 1300MHz, $2f_2 + f_1$ = 1400MHz and $2f_1 + 2f_2$ = 1800MHz being off the scale).

The figure does not show the 3rd-order IM products, between each of the 3rd harmonics and all of the other frequencies (nine of them, at $3f_1 - 2f_2$; $3f_1 - f_2$; $3f_2 - 2f_1$; $3f_2 - f_1$; $3f_1 + 2f_2$; $3f_1 + f_2$; $3f_2 + 2f_1$; $3f_2 + f_1$ and $3f_2 + 3f_1$), or the 4th, 5th 6th, etc. orders of IM products.

And the above is just with two original frequencies. It starts to become really complicated when there are three or more frequencies present in a semiconductor at the same time. Various IM calculators are available (for a price), such as the one from www.telecomengineering.com/software-download1.htm.

As the order of the harmonics and IM products increases, their levels decrease, so, on a graph like Figure 41, the end result looks like an increased noise floor over much of the frequency range

Figure 42 shows how the three mechanisms by which EMI causes immunity problems: direct interference, demodulation (rectification), and intermodulation, typically cause problems for electronic circuits. Section 9 will go into the practical results of this in more detail.

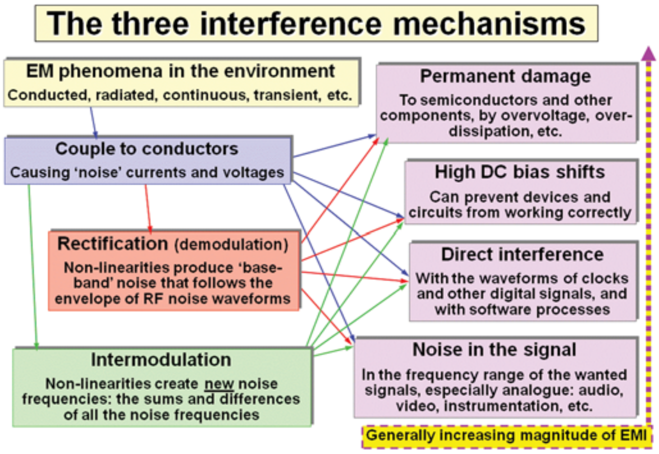


Figure 42 Overview of the three ways in which EMI can interfere

Now we can discuss an example of how the new frequencies created within a circuit by demodulation and intermodulation, can cause immunity problems in real-life operation.

Conventional RF immunity testing applies a single frequency, with modulation, over the range 150kHz to 1GHz and discovers that the product is too susceptible over the range 50 to 200MHz. It would not be unusual to find that they are 20 to 30dB too susceptible.

Being good EMC engineers, we fit shielding and filtering that is effective over the 50 – 200MHz range, and the equipment now passes the test. We pat ourselves on the back and fondly imagine that because our product passes the continuous RF immunity test at levels well above those that it will experience in real-life operation, it will be totally immune and not suffer failures due to that type of EMI. But we would be wrong.

It is quite common to hear people saying that because their products pass some set of EMC immunity tests, maybe in expensive anechoic test chambers, even at levels that are much higher than they will be exposed to on real life, their products are *therefore totally immune to all EMI*. But they are wrong too.

When we added shielding and filtering to our product to pass the test, we didn't try to make it effective over the frequency ranges below 50MHz and above 200MHz. There was no point, and anyway it would have taken longer and increased the cost of the BOM (bill of materials) by more than was necessary, since all we were interested in was passing the test.

But the real-life electromagnetic environment does not consist of just one radio frequency at a time. Simultaneous radio frequencies can and do exist, indeed they are more typical than just one frequency. For example, if you can receive FM radio channels, you are subjected to several radio frequencies (the different channels) at once. Of course, they do not generally have very high levels, but fields in the range 1V/m – 10V/m at each transmitted frequency are not untypical on public roads near to a broadcast radio or TV transmitter in a city.

Near a clinic, hospital, factory or beauty parlour where they are using RF energy to heat human tissues, plastic or metal; dry glue or paint, depilate or remove warts from human skin, there can be many frequencies present at quite high levels at the same time. And then there is the plethora of mobile transmitters we have now, including CB radio, cellphones at (in Europe) 900MHz, 1800MHz and 2100MHz, and Wi-Fi and Bluetooth both hopping rapidly around over a great many frequencies with the 2.5GHz "ISM band".

Frequencies outside the band we filtered and shielded can enter our product and intermodulate in its semiconductor junctions, creating new frequencies in the very susceptible range 50 - 200MHz, and causing interference. Since the new frequencies are generated *inside the very circuits that we protected* with our shielding and filtering, our efforts at protecting our product from 50 to 200MHz are made ineffective.

Intermodulation cannot be created by testing at a single frequency at *any* RF power level, so passing such simple tests creates a false impression of the likely reliability of any electronics or software.

Of course, these "simple" single frequency RF immunity tests take long enough to do, for example covering the specified frequency range in 0.1% frequency steps and "dwelling" at each frequency step for three or four seconds to have time to determine if the product is being interfered with, takes about an hour. But then there is horizontal and vertical polarisation to consider, plus at least one other antenna position (usually three more), so a full test will take between a half and one day. If we were to test with two frequencies in order to simulate intermodulation that might occur in real life, we would probably want to vary f_1 over the range in 0.1% steps as before, and at each step in f_1 vary f_2 over the entire frequency range in 0.1% steps, dwelling 3 or 4 seconds at each f_2 step.

The test time would then be 1,000 times longer than for a single frequency test, at between 500 and 1,000 days.

The solution to this problem of making electronics fit for the real world, especially important for safety-critical applications, is not to rely solely on immunity testing. The IET's 2008 guide to EMC for Functional Safety [22] describes how to do this, and also provides 26 pages of design techniques that can be used. It can also be used to improve the reliability of electronics used in high-reliability and mission-critical systems, and legal metrology.

And while we are on the subject of EMC immunity testing, [23] describes many reasons why the automobile industry's

EMC test programmes cannot ensure the achievement of tolerable levels of safety, intermodulation being just one of them. In case readers who work in other industries (e.g. medical, rail, aerospace, military, machinery, robotics, etc.) are feeling superior at this point, I should point out that exactly the same arguments apply to their standardised EMC immunity test programmes, see [24].

[25] describes some of the many reasons, not just intermodulation, why simply increasing the immunity test level cannot provide additional confidence in the reliability of the tested electronics, and hence the safety of the applications they are controlling.

I find it very interesting that most EMC test engineers and test lab managers worldwide believe that applying the regular immunity tests at ever-increasing levels is all that needs to be done for safety, and that higher test levels correlate directly with increased "safety margins". When I sat down to write [25] it only took me about half an hour to find several very simple and obvious reasons why this assumption *could not possibly be true*.

But this article is supposed to be about the physical basis of EMC, not the impossibility of ever doing enough immunity testing to ensure high reliability – so let's get back on track.

7.4 Overview of immunity

When bogged down with complexity whilst trying to deal with immunity, it often helps to get a perspective, and overview, by realising that the situation is usually very simple – all electronics can be thought of as many tens of thousands (maybe millions) of "accidental demodulators" (i.e. rectifiers) and "accidental superheterodynes" (i.e. intermodulators). These are every silicon junction in every diode and every transistor, whether hidden inside analogue or digital ICs, or power devices.

These accidental radio tuners are connected to thousands of accidental antennas – all of their PCB traces, wires and cables, and coupled to other accidental antennas created by nearby metal structures (e.g. gaps and slots in metal boxes).

These accidental antennas all have resonant frequencies that depend on their length, build conditions, terminations, routing, and proximity to other conductors and materials.

Another cause of accidental superheterodyne behaviour is instability in feedback amplifiers, when just a single RF noise frequency can result in a number of new frequencies as it intermodulates with an amplifier that happens to be self-oscillating at a particular time.

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Part 3) Filtering and suppressing transients, Sept and Nov 2006, and Jan 2007
Part 4) Shielding (screening), March, May and July 2007
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