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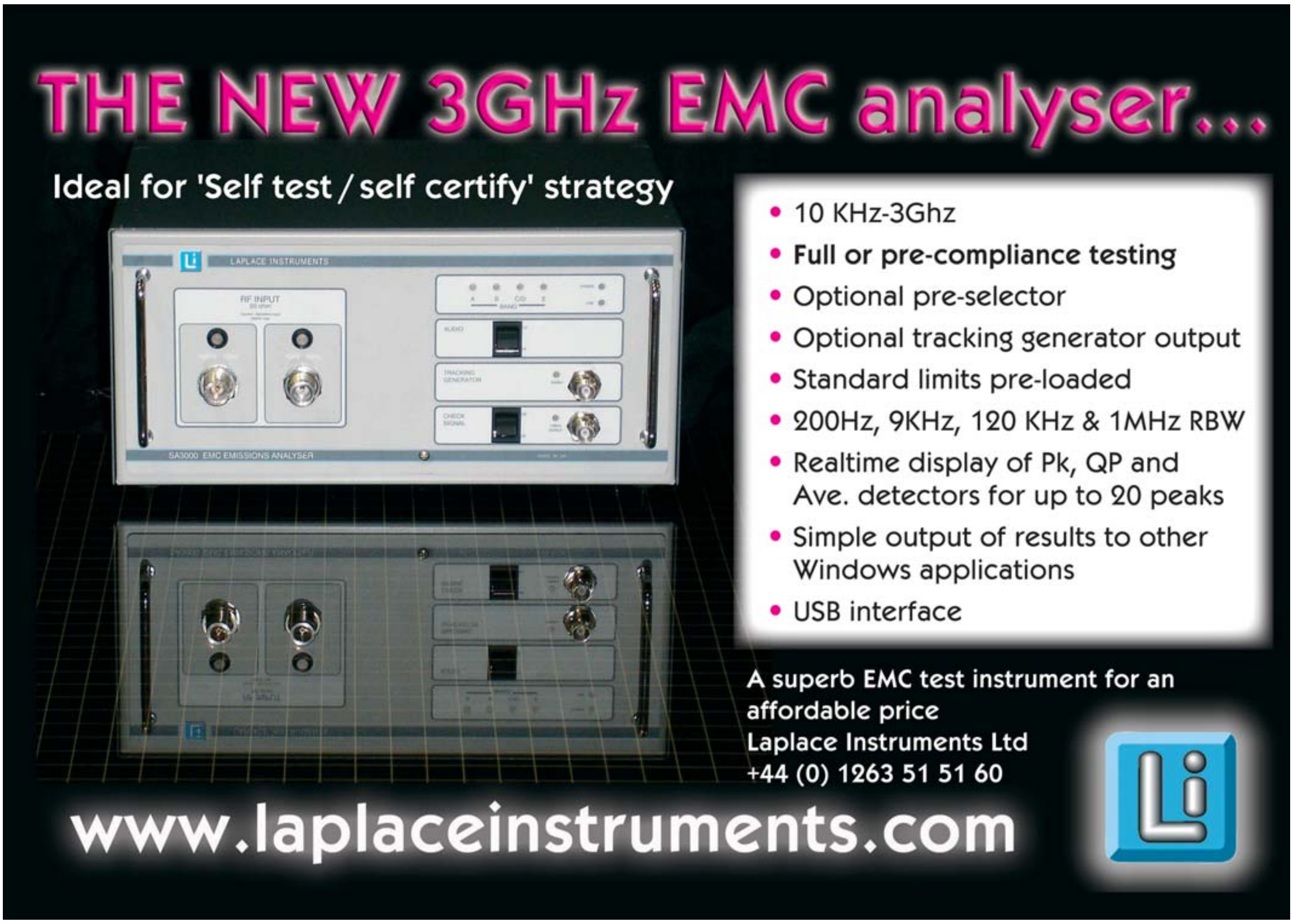
We Want to hear from you!
See Page 5



What's In This Issue

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The EMC Journal

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Front Cover

Hero circle, ETS-Lindgren pages 7 & 18
Circle top, Teseq page 17
Circle middle, Tecan page 18
Circle bottom, Schroff page 18

We want to hear from you!

Content in this Issue... let us have your feedback. Authors spend considerable time writing articles for publication and it is always good to get readers' feedback. So please let us know what you think? It may well be you do not agree with some of the comments made, or you might endorse points of view or have definite views of your own, all comments are welcome. We are always happy to publish responses and points of view.

Common Questions and Misunderstandings about EMI Filters - By Jan Nalborczyk, Technical Director, MPE Limited. Page 19. *(Excellent advice for anyone requiring an EMC Filter, coincides with the publication of the EMC Filter Directory 2009.)*

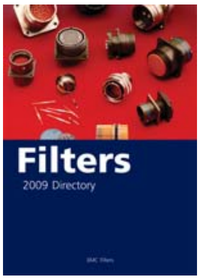
EMC Fundamentals - By Ken Javor, EMC Compliance. Page 21. *(Ken is based in the USA and this excellent article may raise some controversial points of view. Let's have your feedback).*

Why broadband PLT is bad for EMC - By Tim Williams, Elmac Services. Page 25. *(PLT is likely to become ever more controversial and Tim's article gives a comprehensive overview of the situation and how we got to where we are.)*

In addition to these articles there are, of course, the normal contributions of Banana Skins (page 11), John Woodgate's Column (page 13) and Keith Armstrong's interesting rumination on Napoleonic Project Management (page 15).

Interactivity is good for learning and one of the major objectives of The EMC Journal is to provide information from which both beginners and experienced Engineers can benefit. Your feedback can contribute in a major way to this objective.

Please let us have your feedback, email: editor@nutwooduk.co.uk



New

The 2009 edition of the EMC Filter Directory contains comprehensive information on the main manufacturers and suppliers of EMC Filters in the UK. It should prove particularly useful if you are looking for a particular type of filter or want some expert advice.

To get your copy email: pam@nutwooduk.co.uk with your full contact details and we'll pop one in the post. Or register on the website www.theemcjournal.com.

Aircraft Electromagnetic Certification Workshop 2008

The 2008 Aircraft Electromagnetic Certification Workshop (AECW) was held from the 18th to 21st November at QinetiQ's Cody Technology Park in Farnborough. The workshop was well attended with delegates from Sweden, Turkey, Italy, Japan, the Republic of Ireland and the United Kingdom.

The delegates were provided with lectures covering High Intensity Radiated Fields (HIRF), equipment and aircraft level test techniques, good design practice and future challenges. Professor Nigel Carter was joined by other internationally renowned speakers providing their valuable insight into the certification requirements for civil and military aircraft to operate in electromagnetic environments.

Course Director Dr Anthony Wraight, QinetiQ said "This year's AECW was another huge success. The feedback from the delegates was excellent and the interaction during the course was clearly very beneficial to all. We extended the 'Questions and Discussion' sessions this year which provided

a great opportunity for the delegates to gain a greater understanding of the workshop content. The equipment and platform demonstrations were also a great success allowing the delegates to see the methods in practice."

The event was co-sponsored by the Institute of Engineering and Technology, Electromagnetics professional network.

AECW 2009 is scheduled for the 17th to 20th November 2009 at QinetiQ's Cody Technology Park, Farnborough. To register your interest or to book a place, please contact the Course Administrator, Nicky Bevan on 01252 394236 or e-mail nbevan@qinetiq.com.

News and Information

IEEE EMC Society

The UK and Republic of Ireland Chapter of the IEEE EMC Society is pleased to announce that, following its recent AGM, Paul Duxbury is the new Chapter Chairman. Paul has been involved with EMC for 14 years with BSI, IFR (now Aeroflex), Flomerics and now CST, where he is a Senior Sales and Application Engineer. Prior to this, during his degree, he also spent time at the National Physical Laboratory. During this time, he has presented at many conferences and workshops world wide, most recently on the subject of computational electromagnetics, and its use for EMC applications. Paul can be contacted at paul.duxbury@ieee.org.

Paul Duxbury

The chapter is currently in the process of planning a series of events for 2009 and is always interested to hear from potential speakers. If you are interested in presenting at one of our meetings, please contact the Speaker Coordinator, Brian Jones (emc@brianjones.co.uk), Chairman, Paul Duxbury (paul.duxbury@ieee.org), or Events Secretary, Roy Ediss (roy.ediss@ieee.org).

The chapter website is **www.ieee.org.uk/emc.html** and it contains information about upcoming events as well as the presentations from previous chapter meetings and also, the contact details for the committee. The EMC Society has an extensive main website which can be found at **www.ewh.ieee.org/soc/emcs/**

We look forward to welcoming you at one or more of our meetings this year.

...News...Desk...

The Christmas lunch meeting, in addition to interesting presentations, was a true networking session with a superb presentation by Professor Nigel Carter (ex-QinetiQ) entitled "The Confessions of an EMC Engineer".

Paul Duxbury (featured above) was elected the Vice President of the Association. He is also a member of the Executive Committee and replaces Vic Clements whose second 2-year term had expired.

The next meeting will be on 29th April 2009 at the Hotel Russell, Russell Square, London.

If you are interested in joining contact **Alan Warner at aws-emc@talktalk.net**

AR forms AR Europe to better serve Customers throughout European Marketplace

AR, a recognized leader in testing and communications solutions for EMC, wireless and beyond, has announced the formation of AR Europe. The new division has been created to enable the company to better serve the diverse needs of its customers throughout the European marketplace.

AR Europe includes a team of sales associates strategically located throughout Europe and a new web site. The AR Europe website (**www.ar-europe.ie**) provides a direct connection to all AR products, along with an easy-to-use price list, with delivered prices in Euros.

AR Discounts available during introduction period

As a way of introducing the new AR Europe, and to encourage European customers to connect with their AR Europe Sales Associate, the company is offering significant discounts with any on-site demo. Demos can be scheduled by logging on to the web site at **www.ar-europe.ie** and contacting the AR Europe Sales Associate for your area.

For more information, contact AR Europe, National Technology Park, Limerick, Ireland at +353-61-504300 or at **www.ar-europe.ie.**

New Video and Literature provide detailed look at AR Companies

AR, a recognized leader for testing and communications solutions in the worlds of EMC, military, wireless, and beyond, has put together an informative capabilities brochure and a video overview that covers the companies that comprise AR.

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

The new video is available as a free download on the company's web site: www.ar-worldwide.com.

High Quality:
http://www.arww-rfmicro.com/VIDEO/corporate_video_lg.asp
Medium Quality:
http://www.arww-rfmicro.com/video/corporate_video_med.asp
Standard Quality:
http://www.arww-rfmicro.com/video/corporate_video_std.asp

The capabilities brochure is also on the web site (**http://www.arww-rfmicro.com/html/50000.asp?S=1**) Hard copies are available from AR sales associates.

Guide to CE marking Machinery

TÜV Product Service has developed a guide to CE marking machinery, which aims to assist manufacturers in obtaining approvals for their machinery for the European Union. The CE marking of machinery is often a complex affair, typically involving compliance with the EU's EMC, LVD and machinery directives, and sometimes other directives as well. TÜV Product Service's guide includes the typical information required in preparing Technical Construction files and Declarations of Compliance for this type of equipment. This can be found in the Consulting & Training section their website **www.tuvps.co.uk**.

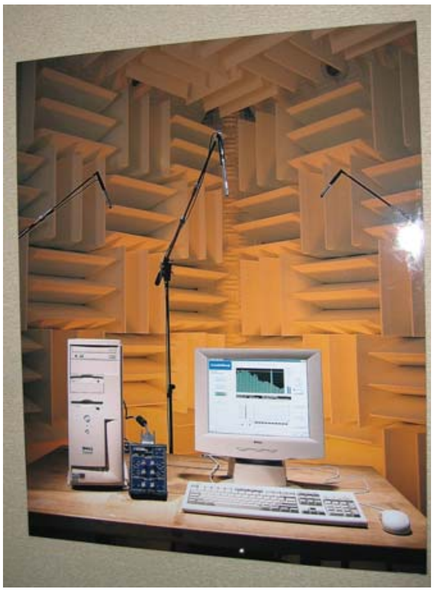
TÜV Product Service can also cover machinery compliance for other parts of the world. This includes the USA, for which TÜV offers field labelling assessments in Europe for companies wishing to export their products to North America. For more information, please contact Ralph Harris (rharris@tuvps.co.uk).

New Acoustic Research Lab Now Open for Business!

ETS-Lindgren have announced the opening of its new Acoustic Research Laboratory featuring state-of-the-art chambers for acoustic test services. With its hemi-anechoic chamber, two reverberation chambers, impedance tubes and supporting acoustic test equipment and software, the laboratory now offers product noise emission testing and structural/architectural acoustic testing. Acoustic field testing services are also available upon request. The laboratory is ISO 17025 accredited under the US Department of Commerce NIST National Voluntary Laboratory Accreditation Program (NVLAP).

Product noise emission testing is commonly performed in the double-walled hemi-anechoic chamber that is designed to measure very low noise emissions from products and devices at 80 Hz and above. Outside chamber dimensions are 8.5 m long x 8.5 m wide x 7 m high. This chamber is ideal for testing sound power and pressure levels as well as small fan noise. Products tested include Information Technology Equipment (ITE) such as laptop computers and associated printers, home appliances, garden equipment - essentially any noise emitting device may be tested in this chamber. Commonly referenced standards for testing in this chamber include ISO 3744, ISO 3745, ISO 7779, ISO 11201, and ECMA 74.

Structural/architectural acoustic testing is performed in the reverberation chambers. With transmission loss testing of wall



samples, windows, doors, automobile panels and the like, customers can determine how much sound energy is transmitted through a product sample at specific frequencies. Sound absorption testing may also be performed in these chambers to determine how much sound energy is absorbed by products. Sound insulation products, fabrics, and wall absorbers for theaters are a few such products tested. The source chamber measures 7.4 m long x 5.9 m wide x 4.8 m high; the receive chamber measures 7.4 m long x 9.2 m wide x 6 m high. ASTM E90, ASTM C423, ASTM E596, and ISO 3741 are the most commonly referenced standards for testing in these chambers.

“We’re very excited about the acoustic testing services we can now offer our customers,” said Douglas Winker, Ph.D., Acoustic Engineer for ETS-Lindgren. “We designed these chambers for the best performance possible and worked closely with our facility personnel to ensure the parent building that houses these chambers enhances their performance. For example, the hemi-anechoic inner chamber sits on a 50 ton isolated concrete slab. The reverberation chambers sit on individual floating concrete slabs.” Dr. Winker added, “With our NVLAP accreditation, customers can be confident that we have a total quality system in place with instrumentation traceable to NIST and experienced technicians who produce accurate measurement data.” For more information on acoustic testing services, visit www.ets-lindgren.com/labservices.

In addition to the Acoustic Research Laboratory test services, ETS-Lindgren also offers its Acoustic Systems brand test chambers www.ets-lindgren.com/acoustics. These acoustic chambers are manufactured by a veteran production team with over 35 years experience controlling sound energy. Acoustic anechoic, predictable field and reverb/transmission loss solutions feature the same level of expertise and quality customers have come to expect from ETS-Lindgren’s EMC, Microwave and Wireless chambers.
www.ets-lindgren.com

Emerson Network Power Connectivity Solutions brings together major forces in the connectivity market

Emerson Network Power Connectivity Solutions, a business of Emerson (NYSE: EMR) the global leader in enabling Business-Critical Continuity™ has strengthened its Connectivity Solutions portfolio by bringing together the Midwest Microwave, Vitelec Electronics, Johnson Components and Stratos Optical brands under one new trading name, Emerson Network Power Connectivity Solutions Ltd.

As part of Emerson Network Power Connectivity Solutions, the combined product lines will deliver cutting-edge RF, microwave and fibre optic interconnect components and assemblies for wireless communications, telephony and data networks, CATV, defence, security systems, healthcare and industrial facilities.

“The unified brand approach marks the beginning of an exciting period of growth and development for the company. It is a significant step forward which will enable us to deliver a comprehensive range of solutions under one brand name, and in the future add to our already extensive product portfolio,” said Peter Walmsley, European Sales & Marketing Director of Emerson Network Power Connectivity Solutions.

Continued use of the original brand names under the Emerson Network Power Connectivity Solutions umbrella will ensure that customers experience a seamless transition.**www.emersonnetworkpower.com**

Farnborough Airshow

Farnborough International Limited have announced the dates of the next three Farnborough International Airshows will be:

2010: 19-25 July 2010
2012: 9-15 July 2012 *This Airshow is one week earlier than previously publicised due to the Olympic games taking place in London.*
2014: 14-20 July 2014

Bahrain International Airshow
Farnborough International are delighted to have partnered with the CAA of the Kingdom of Bahrain to present a dynamic and unique high level trade event, held under Royal patronage. The Airshow will be a global aviation event offering exclusive business-to-business networking opportunities in a five star environment and will be held for three days from 21- 23 January 2010.

For further details and updated information on either Airshow visit:
www.farnborough.com

News and Information

CE Marking Check Service for Manufacturers and Importers

Cranage has launched a new low-cost service for checking the validity of CE markings on imported electrical and electronic consumer products. The service sits between the free initial consultation over the telephone and the Imported Products Testing Service designed to evaluate basic product safety in the key areas of electric shock, mechanical hazard, excessive temperature, and spread of fire. It will be a suitable option for those wishing to have their supplier's self-declaration and supporting documentation thoroughly checked before deciding on whether to accept the information as provided or pursue a more independent approach through an advisor. The service is claimed to minimise the risk of unsafe products entering the market and provide a defence against any claim of negligence by showing that a manufacturer or importer did the best job they could of making sure that products were not only fit for purpose but also safe to use.

For further information go to **www.cranage.co.uk/cetick.htm** or email **info@cranage.co.uk** to arrange for a free consultation.

The IET Seminar Statistical Electromagnetic Methods for Analysing Complex Systems and Structures

National Physical Laboratory (NPL), Teddington, UK:
Thursday, 12 March 2009
www.theiet.org/statistical-EM

Statistical Electromagnetic Methods (SEM) has grown and developed rapidly in recent years, but how can you exploit its practical uses as a business tool?

The Institution of Engineering and Technology invites you to join them on 12 March to find out the answer to this question and many more. You will gain an insight into how SEM works in a variety of applications, as well as demonstrating global behaviour and characteristics of EM fields.

The international programme of key expert speakers includes:

The Use of Unscented Transforms in Reducing the EM Computations for Statistical Analysis
Christos Christopoulos, Nottingham University, UK

Modelling Uncertain Electromagnetic Environments by Canonical Stochastic Fields
Bastiaan Michielssen, ONERA, France

Extracting Independent Samples of Electromagnetic Measurements: The Effective Sample Size Concept and its Estimation
Christophe Lemoine and Philippe Besnier, INSA, France

Computing and Interpreting Statistical Moments in EM Analysis
Martijn van Beurden and Ousmanne Sy, Tu/e Eindhoven, The Netherlands

To find out more and to book your place, visit the web site **www.theiet.org/statistical-EM.** Or phone us on +44 (0) 1438 765 657.

A 'heads-up' on upcoming EMC requirements for installations

EurIng Keith Armstrong, keith.armstrong@cherryclough.com

EMC Journal readers should be well aware by now that the new electromagnetic compatibility (EMC) Directive 2004/108/EC require 'fixed installations' to employ good EMC engineering practices, and document that it was done, from 20th July 2007. However, it seems that almost everyone in Europe is ignoring this law, which they can because the EMC Directive is hardly enforced at all, especially for installations.

So we find that most architects, building and site design consultants, electrical installers, M&E Contractors, and many system integrators and custom control panel builders, are still blissfully ignoring everything to do with EMC engineering.

But there are other standards and regulations that require good EMC engineering practices in fixed installations, which will be very much harder, maybe impossible, to be ignored. Significant difficulties are predicted – the reason for this 'heads up'.

Taking just one example of good modern EMC engineering – meshed earth bonding structures – we find that most of the above hold to the tradition of 'single-point earthing', sometimes called 'star earthing'. Meshed earthing is an example of a good EMC engineering technique, and terminated cable screens at <u>both</u> ends, and also sometimes along their lengths – a big no-no in the hallowed traditions of single-point earthing devotees.

It seems that the tradition of single-point earthing arose as a way of quickly overcoming installation problems caused by poor electronic product design. Way back when electronics still meant vacuum tubes, some designers didn't know that earth potential equalising currents naturally flow in real installations. So they did what gave them the quickest and easiest results on their test benches, by connecting cable shields to their circuits' 0V rails.

If they had known about the problems they were creating for their installers and users, they would have connected cable shields to their chassis, frames or metal enclosures, so that earth potential equalising currents would not flow in sensitive circuits and cause noise. As it happens, connecting cable shields directly to chassis/frame/enclosure/etc., also helps achieve EMC at the lowest cost.

When installers tried to apply these inadequately-designed products in real installations, the earth potential equalising currents flowed in the finite impedances of the circuit's 0V structure and caused noise, usually a mains-related hum or buzz in audio systems, 'hum bars' on a video image.

Of course, installers only have a few hours to install equipment, so they found a quick and dirty technique – removing earth bonds to create single-point bonded earth structures. This practice became sanitised by use over the years, demonising earth potential equalising currents as 'earth loops', 'ground loops', or 'hum loops' – to be avoided at all costs. Of course, this practice ensures that each mains-powered equipment has just the one connection to safety earth, and this lack of redundancy ensures that several people are killed and many more injured each year by electrocution. But hey – the hum's gone!

Because single-point earthing became accepted dogma, many product manufacturers came to believe that their bad cables screen termination practices were just fine, if not mandatory, so bad design tended to drive out the good.

It is only relatively recently, with the introduction of the EMC Directive, that some manufacturers have re-learned that when electronics are designed so that earth potential equalising currents flowing in its cables do not cause noise (a little more work, but quite easy to do) – they will function happily with any kind of earthing structure, and low-cost EMC compliance is most easily achieved.

But how much effort do you think it will take for all architects, building and site design consultants, electrical installers, M&E Contractors, panel builders and system integrators, to learn how to do meshed earthing properly, and turn their back on their decades-old tradition of single-point earthing? And this is just one of many good EMC engineering techniques they will need to learn!

And we mustn't forget that many manufacturers still have to learn to design their electronics correctly as well, especially those who so far have managed to ignore complying with the EMC Directive.

So which are these other standards and regulations, which will be so difficult to ignore?

For starters, the IEE Wiring Regulations, BS7671, will contain EMC requirements, either as an amendment to the 17th Edition, or in the 18th Edition. These new requirements will implement IEC 60364-4-44 clause 444, to harmonise national 'electrical installation codes' across all EU member states.

Buildings, plant and sites in the UK have by law to comply with BS7671 to meet Health & Safety at Work requirements. So when it is up-issued to include EMC requirements, including meshed earth structures where required, they will be mandated in all new electrical installation work. If the electrical inspector finds the new electrical work is not in accordance with the IEE Wiring Regulations and its new EMC requirements, no certificate will be issued and the new installation must remain switched off.

Secondly, all major and public buildings in the UK have to comply with the UK's lightning protection standard in order to get insurance at an affordable premium. But on the 30th August 2008, BS EN 62305 came into force in the UK, and this requires a site's mandatory lightning risk assessment to include the potential for damage to its electronic equipment and systems. Protecting electronic equipment from lightning damage requires a number of good EMC engineering techniques, including earth-bonding cable screens whenever they cross a 'lightning protection zone boundary', effectively creating meshed earthing structures. Almost all commercial, financial, industrial and healthcare premises will thus be required to employ certain good EMC engineering practices in their electrical installations to be able to afford the insurance that allows them to open for business.

I hope this brief 'heads-up' has given some idea of the major changes that will very soon be required for almost all electrical installations, and that it will affect architects, building and site design consultants, electrical installers, M&E Contractors, and many panel builders, system integrators and electronic product manufacturers.

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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.

519 Another example showing that EMI is not a new concern

In the early 1960s NATO decided to start a missile test range in the Aegean sea. Genistron, a Southern Californian EMC testing and filter manufacturing company, was contracted to perform an RF survey of the area. The NATO folks were rightfully concerned about supersonic missiles heading in the wrong direction due to RF interference.

(Extracted from "Chapter Chatter" by Todd Robinson, a column in the IEEE EMC Society's quarterly newsletter, http://www.ewh.ieee.org/soc/emcs/acstrial/newsletters.htm, Issue 219, Fall 2008, page 12.)

520 Headphone magnets interfere with heart implants

Heart patients who have been fitted with pacemakers or defibrillators have been warned against placing the headphones of the MP3 players in their top pockets or draping them over their hearts. According to research presented at the American Heart Association's Scientific Sessions 2008, many headphones contain the magnetic substance neodymium, which could adversely affect the operation of cardiac implants.

Doctors use magnets in a clinical setting to test pacemakers, which treat slow heart rhythms. When exposed to magnets, these devices automatically pace, sending low-energy signals to the heart to make it beat . Defibrillators, which treat slow and dangerously fast heart rhythms, send either low or high-energy signals to the heart, but when near magnets may stop looking for abnormal heart rhythms.

Implanted cardiac devices that react in these ways to magnets outside the clinical setting can be potentially dangerous for patients who rely on their lifesaving technologies. Field strength *(sic)* of 10 gauss at the site of the pacemaker or defibrillator has the potential to interact with the device. The researchers found that some of the headphones had field strengths as high a 200 gauss or more. "Even at those high levels, we did not observe any interactions when the headphones were at least 3cm from the skin's surface."

(Extracted from "Headphones interfere with heart implants", by Kris Sangani, Engineering & Technology, www.theiet.org/engtechmag, 22 Nov – 5 Dec 2008, page 6. This research, combined with the current fashionability of MP3 players, created numerous news items to be published in various media, including: http://www.interferencetechnology.com/lead-news/article/headphones-may-interfere-with-implantable-defibrillators-pacemakers.html?tx_ttnews%5BbackPid%5D=1&cHash=59fcd739b9, www.telegraph.co.uk/health/article3411300.ec. Many people brought it to our attention – thanks to you all! It is a useful reminder that EMC is not simply a radio-frequency issue, it is required down to DC.)

521 Digital TV interference from motorcycles

When I watch digital TV channels from a terrestrial transmitter, I have to endure periodic disruptions during which the audio and video start stuttering. I recently realised that the disturbances occur every time motorbikes – particularly scooters – pass my house. This doesn't happen with cars. How do scooters disrupt my TV?

(This question was posed by a reader in "The last word" column in the New Scientist, www.newscientist.com/lastword, 25 Oct 2008, page 85. Rather than copy the three replies in full, the below is a brief summary of them.)

a) Modern cars use electronic ignition with lossy carbon cables, whereas two-stroke motorcycles and scooters use magneto ignition with metal cables and so emit much higher levels of EMI.

b) Digital TV uses a very high level of coding, making the results of EMI worse than with analogue TV. Sometimes using double or triple-screened aerial cables can help.

c) Until analogue TV transmissions are switched off in the UK in 2012, digital TV is transmitted at low power. After 2012 the situation should improve.

(The third respondent mentioned that watching digital satellite TV he still suffered interference from one particular motorcycle, even though these TV signals are in the GHz range. This item also reminded the editor of staying in a UK hotel in 2008, watching digital TV while a farmer applied a petrol-powered hedge trimmer to his border about 30m away. When the trimmer was revved up to perform a cut, the TV picture would freeze until the farmer let the revs drop to an idle again.

522 New York Blackout caused by harmonics

The last major blackout in New York (NY, USA) was caused by harmonics and resulted in the creation of a series of standards and guidelines designed to guarantee network quality, even in the star-shaped mains distribution networks commonly used in the US (due to the large distances to be bridged.)

(Extracted from: "Beat the harmonics and clean up your power", Panel and System Building, www.psbonthenet.net/enquiries, October 2008, pages 14-17. And to think that President Bill Clinton once wrote to the EU asking them not to list EN 61000-3-2 in the Official Journal under the EMC Directive!)

523 Qantas QF72 plunge

The Singapore to Perth Qantas Airbus A330-300, which had 303 passengers, went into an uncontrolled climb and sharp descent on Tuesday as it neared the West Australia Coast. The scare resulted in injuries to 74 people, with 51 being treated by three Perth hospitals for fractures, lacerations and suspected spinal injuries after being thrown against the roof, walls and cabin furniture. The crew called a mayday and landed at Learmouth airport, where the plane remains.

Chris Zombolas, the Technical Director of EMC Technologies, which tests electro-magnetic fields made by electronic equipment, said the risks of passengers using laptops and other devices in planes was a serious issue. "It is well known in the electrical engineering community that the operation of electronics systems, including air navigation systems, may be adversely affects by electromagnetic interference, " he said. "Could a laptop or mobile phone have caused Qantas QF72 to plunge? The answer is yes," he said.

(Extracted from: "Laptop plane plunge query in Qantas case", Herald Sun, www.news.com.au/heraldsun/story/0,21985,24473201-661,00.html, 10th October 2008. This is another story on which a lot has been published in the media, and many people have sent it in to the Banana Skins column. Possible causes such as laptops and mobile phones have been investigated (although, of course, no-one with any assets to lose would admit to have been using such devices, when asked after the event), as well as the plane's proximity to a 1MW VLF (19.8kHz) submarine communications transmitter at Exmouth, Western Australia – which has been implicated by some in a similar malfunction in a Boeing 777-200 on 1ST August 2005. The latest news at the time of writing is that

Continued on page 12/...

air transport investigators are saying that the incident was caused by a faulty computer component that sent "erratic and erroneous information" to the plane's flight control system. But I don't know at this time if they have actually found a faulty component, or whether they are simply assuming it must be faulty because erratic and erroneous data was received from it, which could of course be due to EMI (see the article: "Absence of proof is not proof of absence" in the EMC Journal, www.theemcjournal.com, September 2008, Page 16.))

524 Cell phone EMI warning

RF signals may affect improperly installed or inadequately shielded electronic systems in motor vehicles such as electronic fuel injection systems, electronic anti-skid (antilock) braking systems, electronic speed control systems, and air bag systems. For more information, check with the manufacturer, or its representative, of your vehicle or any equipment that has been added.
(Taken from the Nokia 6300 Cell Phone User's Guide 2008, kindly sent in by independent forensic engineer Dr Antony Anderson, antony.anderson@onyxnet.co.uk. It is important to understand that similar warnings are, or should be, provided by all cellphone manufacturers for all their models – the RF transmissions from the Nokia 6300 featured above are no worse than other cellphones in their ability to cause interference.)

525 Cellphone causes bus to change gear

NHTSA Identification Number: 06E-100

Date of Notification: 12-29-06

Model or Size Designation: Gear Shift

Identification of Component: Arens AS Tronic

Number of Components Recalled: 2,197

Brief Description of Defect: Mfg. Campaign No. N/A - Electronic Gear Shift. DOM: N/A. Electronic gear shifters, p/nos. 0501 214 599 and 0501 212 979 installed on transit buses. Cell phone placed in proximity of shifter touch pad could cause display to change from "R" (reverse) to "D" (drive) should phone receive call. Radio interference can also cause unintended shift. This will allow vehicle to move in unintended direction, resulting in crash. Correct by providing warning sticker and modifying software to prevent shift.
(Taken from a recall notice issued by the USA's National Highway Traffic Administration Authority (NHTSA), kindly supplied by Clarence Ditlow, Executive Director, Center for Auto Safety, 1825 Connecticut Ave NW, Washington DC 20009, www.autosafety.org, in December 2008.)

526 12 metres of coal is not a good shield

SAFETY ALERT NO. 124, Issued 22/02/2005 by Mines Inspectorate, Safety and Health, Brisbane – Head Office, PO Box 2454 Brisbane QLD 4001, Australia, Phone +61 07 3237 1105 Fax: +61 07 3224 7768

Vision: 'Our Industries Free of Safety and Health Incidents'

Incident With 2 Remote Control Transmitters

MINE TYPE: All Underground Mines

INCIDENT: A twin heading underground roadway was being developed using two mining machines, (continuous miners), both controlled by their operators using hand held remote control transmitters. Each continuous miner remote control operated on a different frequency to prevent interference between the 2 units.

A 10 to 12 metre coal barrier remained between the two development headings, (A&B), when the B heading miner was pulled back to the intersection on dayshift in readiness to recommence driving on afternoon shift.

At the start of afternoon shift the A heading remote control transmitter was mistakenly taken to B heading miner. When the operator tried to start B heading miner, the machine did not commence the pre-start cycle, however the A heading operator witnessed the A heading continuous miner commence its pre-start cycle. The operator alerted the panel deputy, who carried out additional testing and found he could start the miner in A heading from B heading.

EQUIPMENT: Equipment involved consisted of the two continuous miners and their respective hand-held remote control transmitters. The remote control transmitters were painted differently to match their respective continuous miners.

HAZARD: Uncontrolled operation of equipment

CAUSE: There were insufficient controls in place to prevent a remote control transmitter being mistakenly taken to the wrong mining machine, and then used to inadvertently commence the pre-start cycle on another machine in a separate development heading.

COMMENTS: Although the incident could not be repeated consistently, investigation established radio waves could travel through a coal barrier up to 12 metres thick. Therefore the distance separating remote control systems underground cannot be relied upon as the only control measure to prevent interference between units. Beside the signal being able to penetrate the ground for some distance, there is always the possibility of the signal being coupled through cabling, pipework or metal roof supporting structures.

RECOMMENDATIONS: This hazard must be recognised, and the possibility of unintended remote control operation of machinery through use of the wrong transmitter, through the ground or over what at first appears to be long distances, must be considered in the development of a coal mine's safety and health management system, and in the risk management practices and procedures used by metalliferous mines.

Peter Garland, Regional Inspector of Mines – Southern.

Contact: John Kabel, Senior Electrical Inspector of Mines, +61 (07) 3237 1105
(Kindly sent in by Chris Zombolas of EMC Technologies Pty Ltd, www.emctech.com.au, 8th January 2009, http://www.nrm.qld.gov.au/mines/inspectorate/safety_alerts.html. The Banana Skins issue is that the mining industry – at least in Queensland – relies upon shielding by the earth to prevent radio controllers from operating the wrong machinery – yet in this case even 12 metres of (conductive!) coal did not provide sufficient attenuation. Who would have expected that?)

527 German Tornado crashes

Holzkirchen was the location of one of the main transmitting stations for Radio Free Europe. Transmissions started in 1951 and provided the people of Eastern Europe with news from Western Europe. The transmitters had a strength of up to 250 Kilowatts, and in the 1980s caused a Tornado aircraft to crash near Oberlaindern. Transmissions were reduced after the fall of the Communist block and the transmitters were dismantled in 2004.

UK Tornados never suffered from such interference, despite being exactly the same design and build, because pilots were issued with maps showing areas of high field strength from such transmitters, to be avoided during flight.
(From a presentation by Professor Nigel Carter, at the EMCIA meeting, held at the EEF in London on the 17 December 2008. Some of the information above is taken from http://en.wikipedia.org/wiki/Holzkirchen)

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

A mixed bag this time: there haven't been any startling developments in the EMC scene since last time, but there have been developments in other compliance issues.

EMC

Low-frequency conducted emissions

Two very difficult problems exist in this field, which is prone even to impossible problems, such as the proposed, but abandoned, full revision of IEC 61000-3-2. The current delights are concerned with variable-speed drives and air conditioners (some of which include variable-speed drives).

The issue with these drives is that they produce rather large amounts of high-order harmonic currents, and other high-frequency currents, related to the switching frequency. It is easy to show, in theory, that these are very bad news for both supply network equipment and for load equipment. First, the supply network is (or at least assumed to be) inductive at high frequencies (up to 2 kHz in Europe). The 'reference value' (statistically determined according to IEC 60725) inductive reactance at 50 Hz may be taken as 0.25 Ω, so at the 40th harmonic frequency of 2000 Hz, the reactance is 10 ohms. Just 1 A of harmonic current at this frequency thus produces a voltage of 10 V and a voltage distortion of 4.3%. At various places in the supply network, series inductors and shunt capacitors are necessary to reserve network stability, among other things. A 200 µF capacitor has a reactance of 16 Ω at 50 Hz, so passes 14.4 A at 230 V. However, 10 V at 2000 Hz passes 25 A, nearly twice as much, and the dielectric losses are higher at 2 kHz, so the capacitor is heavily stressed. Similarly, higher than normal voltages appear across series inductors, and core losses increase very considerably at high frequencies, even though the applied voltage, and therefore the induction, is lower. Also, the same high-stress considerations apply to capacitors and inductors in load equipment, even though the capacitance values are much lower.

However, that's simplified theory. In practice, these effects seem not to occur to an extent that damage results. One unknown is how far these harmonic current propagate through the system. Low-order harmonics suffer very little attenuation, but the same may not apply at higher frequencies.

The solution has to be a combination of drive design techniques and a justifiable approach to the requirements that must be met. Some progress is being made, notably with the 'C-less' drive technology, but there is a way to go, yet.

There are two issues with air conditioners. First, large equipment needs a large water supply, and most test houses don't have that facility, so there is pressure to allow testing at less than full power. (The option of dispensing with third-party testing isn't open to some smaller manufacturers.) Secondly, standards prepared for the European Energy-using Products Directive specify environmental test conditions, and it would be a big advantage if those conditions could also be used for EMC testing. Unfortunately, they were not developed with that in mind, so may not be suitable. Also, there are 17 different product types that have to be taken into account!

High-frequency emissions and immunity

Work continues in CISPR/I on the new standards CISPR 32 and CISPR 35. As time goes on, more problems seem to surface. A hope was expressed that a CDV for CISPR 32 on emissions could be circulated in 2009, but there have been so many comments on the latest circulation that this is not possible. It is planned to circulate a new committee document (CD) in April 2009. For the immunity standard, the formal time-limit has expired, so a New Work proposal has to be circulated for voting, and a new CD will be circulated at the same time.

What this emphasises is that standards are best improved by *evolution*, not *revolution*. A small Maintenance Team, *with proven editorial skills*, should conduct a pruning and reconstruction operation. It is also very difficult to deal with such a vast and diverse field as 'multimedia equipment ' in one document. Here, there is a very good precedent - IEC 60335, the safety standard for household appliances. This has evolved into a 'general' Part 1, laying down common principles and requirements that are common to the whole product family, and a series of Sections of Part 2, giving specific requirements and variations for individual product types.

I suspect that if that principle had been followed for the immunity standard, progress would have been swifter. It probably isn't quite so advantageous for emissions, because those requirements apply very widely, irrespective of product type, and any variations could be included in the main standard. But not as Annexes, because new users of standards, in particular, assume that there is some essential difference between a requirement in the main text of a standard and one in a normative annex, whereas there is no difference.

Safety of multimedia equipment

The proposed new IEC 62368 is, of course, another *revolution*, suffering from the same problems as the EMC standards. Nearly 500 comments have been submitted on the latest CDV, but it has passed its vote (just, by one vote, and, incredibly, USA submitted 74 comments, but abstained, perhaps due to internal dissent!). The Irish National Committee submitted a plea for a cautious approach, citing the perceived problems with the introduction of any *revolutionary* standard:

- Its practical application and results are unproven
- It will necessitate redesign of hitherto safe equipment
- It will necessitate a major review of design strategy and training of engineers without clear benefits.

It proposes that the new standard should not be published until proven, but that won't, of course work, because no-one will undertake the very costly proving task.

The industry really has got a 'tiger by the tail' with this project, and it is difficult to be optimistic about the outcome.

Continued on page 14/...

Energy-using Products Stand-by Implementing Measure
This was circulated to some BSI committees on 24 December! Thank you, Santa! It is a Commission Regulation, so becomes effective *immediately* and does not require the national implementation process. There are potentially serious interpretation problems with the text, concerning exactly *which* products are within its scope. In the 'Whereas' section, we read:

> The application of this Regulation should be limited to products corresponding to household and office equipment intended for use in the domestic environment, which, for information technology equipment, corresponds to class B equipment as set out in EN 55022:2006.

Note that 'office' - it's NOT only about household equipment with 'stand-by' operating modes. Going into the main text, in Article 1, we find:

> **Subject matter and scope**
> This Regulation establishes ecodesign requirements related to standby and off mode electric power consumption. This Regulation applies to electrical and electronic household and office equipment.

and in Article 2.1, sub-section 1:

> 1. 'electrical and electronic household and office equipment' (hereafter referred to as 'equipment'), means any energy using product which:
>
> (a) is made commercially available as a single functional unit and is intended for the end-user;
>
> (b) falls under the list of energy-using products of Annex I;
>
> (c) is dependent on energy input from the mains power source in order to work as intended; and
>
> (d) is designed for use with a nominal voltage rating of 250 V or below,
> **also when marketed for non-household or non-office use;**

Note the last phrase (my emphasis); it appears that the Regulation applies to any product meeting the four listed criteria 'also when marketed…', i.e. it does not necessarily have to be marketed for household use.

This interpretation would widen the scope of the Regulation to cover practically everything, so a trade association (PLASA) asked DEFRA for advice. Subject to the usual disclaimers about court interpretations ('i.e. you can't know what the law is until you've broken it and are in court!), the response was that '**the Regulation is NOT intended to apply to 'professional products'.** This is reassuring, but what about a sound system, or a CCTV system, in an office building? It's both 'professional' AND 'office equipment'!

Further delights follow in Annex I, where equipment within the scope is listed. Sub-section 3 lists:

> 3. Consumer equipment
> Radio sets
> Television sets
> Videocameras
> Video recorders
> Hi-fi recorders
> Audio amplifiers
> Home theatre systems
> Musical instruments
> And other equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image other than by telecommunications

Note 'Hi-fi recorders' (whatever they are!). Presumably low-fidelity recorders are not included!

You have to laugh, otherwise you'd scream!

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Napoleonic Project Management

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

When I started work as the leader of a design department for a GEC company in the mid 1980's, they sent me on a management training course at their college buried deep in the English countryside near the little village of Dunchurch.

The course included a wide variety of material, and I found most of it very interesting at the time. It was also quite hard work – there were tasks to complete in our own time every night, but luckily the bar was open until the wee small hours (and some learned some more lessons from that, too).

These days I can't remember the details of much that was taught on that course. I claim that this is because I have internalised its good advice and forgotten the stuff that was not so useful, but privately I worry that I might have simply forgotten.

However, one session entitled "Napoleonic project management" has stuck in my mind, and I have found it to be very effective indeed, both as a project manager, and when dealing with senior management.

In preparation for writing this article, I googled 'Napoleonic project management' and found hundreds of references, and all of the links I followed referred to a book with a similar title by Jerry Manas. I don't have a copy of it, and neither do I intend to purchase one, but it is clear that this book covers a much wider range of Napoleonic thought than what I was introduced to at Dunchurch.

Of course, EMC Journal readers, being well-educated and classical sorts, will be very familiar with good old 'Boney' – as Napoleon was derisively called by the British (not his best friends). We know old Boney as the famously successful, supposedly diminutive, French General, although it seems that his claimed lack of stature might just have been another aspect of British propaganda of the time.

According to Wikipedia, 'Boney' later morphed into 'Bogey' and then into 'Bogeyman', the infamous frightener of naughty children in Victorian times. Parents would tell their children that if they were naughty, the bogeyman would cut their throats while they were sleeping, and some artists would enliven children's texts with graphic illustrations of such punishment.

Anyway, what I learned, sitting awestruck at the feet of my trainers 20+ years ago, was the following....

When fighting a battle, Napoleon insisted that if any of his subordinates had a problem that they brought to him for his decision as their General, they had to provide him with not just a statement of the problem, but also *three practical solutions*, with the solution they favoured indicated as such.

Napoleon would generally choose one of the three solutions offered. He said this was because the man on the spot could see the problem much more clearly than he could from his hilltop a mile or more away, from where he had the whole battlefield to look after and of course could be unaware of local details.

Although the man on the spot had the details, he could not know as much as his General about the 'big picture' of the battle, logistics, overall planning, etc. So from time to time old Boney would not choose any of the three options provided, but would modify one of them or come up with a different plan.

Of course, our original Bogeyman had never heard the term "project management". He would probably be insulted to be compared with a project manager in a modern organisation, who generally does not have the authority to send thousands of people into battle. Nevertheless, his clever technique is very relevant in our world.

The project manager is rather like a military General, sitting in an office with PERT and GANTT charts on the wall providing him with an overview of the battle – sorry, project – employing various clever strategies and tactics with the aim of winning the fight against competitors, the clock, or the budget (often all three).

Lower in the management pecking order, are the other people employed on the project. But this does not mean they are lesser beings, even if they are paid less and don't get an office to themselves or a dedicated parking place in the car park.

These people know their stuff, and they know that they know it better than their project manager. It is not unusual for them feel a little miffed that – in a typical organisation – pay grades (and parking spaces) relate to the number of people 'under' you in the management structure, and not on how much the success of the project and hence the very organisation employing you depends on how much your subordinates know, and their expertise in applying that knowledge.

The resulting annoyance of the subordinates means that when they have a problem that needs a decision from their General – I mean project manager – they tend to dump it in his/her in-box and expect it to be solved for them.

Their manager earns so much more money than they do, they argue, and is obviously thought of more highly by their organisation, so obviously they must be the best person to solve the problem in the best way. Let's see them earn their inflated salary, or (more likely) laugh behind their backs and feel superior when they make mistakes that we think we would not have.

All of us who have been working in the real world for more than a couple of years will recognise this situation, and a few more years experience shows us how, at best, it wastes a lot of time – and at worst, it results in non-optimal solutions (sometimes very much so). Neither outcome benefits the employing organisation, or its employees.

The Napoleonic method I have described above – as faithfully as I can be to the memory of my Dunchurch trainers (some of whom have now gone to that great meeting room in the sky, where there are always those little biscuits with the jam in the middle to go with the tea and coffee, and the PowerPoint presentations and discussions are never boring) – cuts right through all this natural human stupidity.

It acknowledges that the people working on some aspect of the project will be the ones who know the best about what they are doing and what they need and how to achieve it. So obviously they should be the ones to suggest three solutions to the problem they have identified, and indicate their personal preference.

(I'm sure I don't need to point out that of course the proposed solutions should be professionally worked-out, and provide at a glance all the data the manager needs to be able to choose, including costs and timescales. A project manager should immediately dismiss less-than-thorough work and insist it is done again, only professionally. (And yes *of course* it's more work, that's part of being successful as a professional. And no whining about needing time with your family, this is war!) Efficient functioning of the project team, to turn investors' money into a lot more money, which pays salaries and overheads such as pleasant working environments and the latest tools, is what it is all about.)

So the myth that the manager higher in the organisation's structure is somehow *better* than people lower in the structure – which some managers have even been known to believe themselves – is exploded. This goes some way to offsetting the annoyance at the differences in pay and car parking spaces.

But of course the project manager *does* have the big picture (on larger projects, they often have nothing else) so *must* be the one to choose which solution to accept, or choose to do things differently.

Everyone is so busy these days that it is almost a foregone conclusion that a manager will simply heave a sigh of relief – choose one of the proposed solutions – and feel very grateful to have such professional personnel on the project. Such emotions can't hurt, at pay review time.

If you are a project manager, I strongly commend this 'Napoleonic' method to you. If instead you are working for a project manager who does not use this method, you will almost certainly find that acting as if they do will work to your advantage, as well as that of the project.

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PRODUCT GALLERY

New TESEQ Multifunction ESD Generator - big things come in small packages

TESEQ, the leading developer and provider of instrumentation and test systems for EMC emission and immunity testing announces the introduction of its new NSG 3040 ESD test generator. The NSG 3040 is small, smart and has a high-contrast 7" touch-screen colour display and rotary control wheel to simplify programming with simple and intuitive operation. With its open modular architecture, the NSG 3040 is the ideal immunity test system for smaller engineering laboratories. The NSG 3040 offers outstanding capabilities to demanding EMC test companies and allow simple integration into production test processes.

The electromagnetic pulses generated from this multipurpose unit are especially tailored for the CE marking requirements of the EU in addition to national and international standards. Like its big brother, the NSG 3060, the NSG 3040 also has a SD memory card where test files can be saved easily and accessed at any time.

NSG 3040 highlights include, modular, expandable architecture, surge voltage to 4.4 kV, EFT/Burst to 4.8 kV/1 MHz, PQT to 16A/260

VAC & DC, easy to operate 7" touch-screen colour display, TA (Test Assistance) for rapid test initiation, test parameters can be changed during test and a broad range of accessories.

The NSG 3040 test system is designed primarily for cable-borne transient interference tests as specified in the European generic standard covering equipment for household, office and light industrial use, and for applications in industrial environments, in accordance with the requirements of the basic standard of IEC/EN 61000-4-4, -5, -11,-29 as well as -8 and -9 are optional.

The most outstanding development in the new TESEQ NSG 3040 is the large 7" touch panel display, featuring superb contrast and colours combined with ergonomically optimised and well designed graphics using pictograms and text. Depending on requirements, test inputs are supported by an integrated keyboard, or by using a thumb wheel with additional keys for sensitivity adjustment. A stylus is not necessary, and ramp functions are programmed quickly and easily. Multi-step test procedures can be created and their sequence or parameter values changed easily. The combination of touch panel and thumb wheel is a perfect combination for simplicity of use in engineering labs.

Paul Dixon, Managing Director of TESEQ comments, "The NSG 3040 is an open architecture, easily modifiable principle test system which provides for customer specific test combinations. With its easily configured coupling devices it is usable as a multi-function generator for comprehensive testing. The innovative design uses modular architecture to provide a versatile system that can be configured for basic testing and expanded to meet the needs of sophisticated test laboratories. Ease of operation, large number of

available test modes and user-friendly technology combine to offer a state of the art test system. A master controller in the NSG 3040 system architecture takes care of all the "real-time" control functions and communicates with all the function modules acting as a slave within the instrument's casing and external devices.

Teseq provides a traceable calibration certificate with each tester and accredited calibration services are also available from TESEQ calibration labs upon request. For further information please call 0845 074 0660, email sales@teseq.com or visit TESEQ's website at www.teseq.com

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Electrically conductive form-in-place gasket product range enhanced to cover widest number of applications

Chomerics Europe, a division of Parker Hannifin, has strengthened its position as the market leader in electrically conductive form-in-place (FIP) gaskets with the addition of new materials to its range. A wide choice of materials is now offered that provide specifications to satisfy a broad range of consumer, industrial, and military / aerospace applications.

Dispensed, electrically conductive FIP gaskets provide the lowest total cost of ownership for small cross-section and complex pattern applications. Chomerics FIP materials can reduce the installed cost of an EMI gasket by up to 60%. The corrosion resistant nature of Chomerics FIP materials provides protection against galvanic activity and may, in many applications, eliminate the need for Ni or Sn

plating and / or secondary environmental gaskets.

Among the new materials are CHOFORM® 1122V, CHOFORM® 5550, and CHOFORM® 5545. All are single component, silicone-based materials that are designed to cure-in-place once applied to customer enclosures or castings.

CHOFORM® 1122V uses a silver / aluminium conductive filler to provide a shielding effectiveness of greater than 65dB (average over 200MHz to 12GHz), and a maximum operating temperature of 130ºC. The material has very high corrosion resistance and a shore A hardness of 50 making it ideal for low-closure force applications.

Low hardness CHOFORM® 5550 uses a nickel / graphite filler to help it also achieve a shielding effectiveness of 65dB. This 43 Shore A material can be dispensed in a unique triangular shaped bead with an extremely high aspect ratio (max height 3mm) to provide a solution where closure forces are extremely low or where there is a degree of unevenness between mating surfaces. Maximum operating temperature is 125ºC.

CHOFORM® 5545 incorporates a tungsten carbide filler and possesses extremely high corrosion resistance to make it the ideal choice for use in the harshest and most demanding environments such as those found in military and aerospace applications. Shielding effectiveness is greater than 65dB and the material can be used in operating temperatures up to 125ºC.

All of Chomerics FIP materials meet UL 94V-0 flammability requirements. A detailed selector guide is provided at www.parker.com/chomerics to assist in the selection of the most appropriate material for a given application.

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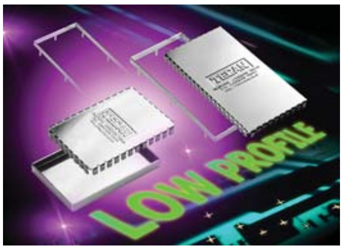
emcia Member

Low-profile surface-mount screening for increasingly compact designs

Aimed at increasing industry demands for smaller and more efficient electronic products and sub systems - low-profile PCB screening cans and enclosures, which can be re-flowed with conventional and surface-mount components, are now available from **Tecan.**



Standard-pitch screening cans, delivering solutions for prototype, development and production needs, are available as single components. The wide range of low-profile and surface-mount components offers a fast and effective means of sourcing radio frequency interference (RFI) screening, at optimum cost. The range encompasses a selection of can sizes, profiles and mounting options, allowing users to select components which assure both maximum RFI performance and compatibility with individual production requirements. Based on standard component pitches, the cans can be supplied with a wide choice of lids, sidewalls, and mountings.

Eight standard configurations include - a 4-sided can with a spring fingered lid, a 4-sided surface-mount fence with a spring-fingered lid, a 4-sided can with a tag-and-slot lid, a 5-sided can formed and spot welded, a 5-sided can formed for surface mount, a 5-sided can supplied flat for self-forming, a total enclosure with a spring-fingered lid, and a 4-sided fence with 2 spring-fingered lids. The standard pitch system utilised covers 20mm x 20mm to 75mm x 125mm. Low-profile cans are available down to 2.5mm high.

The company uses a range of well-established and proven manufacturing techniques, such as photo chemical machining (PCM) and punch/press progression tooling, to provide cans for the most demanding low, medium or high-volume production needs.

Tel: +44 (0)1305 765432
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emcia Member

New shortform brochure provides overview of enclosure products

Electronics packaging specialist **Schroff** has produced a handy new shortform guide to the company's comprehensive range of products and services.

Providing an ideal starting point for anyone involved in specifying electronics enclosures or related technology, the 32-page A4 Product Overview highlights the main technical specifications and key features and benefits of each product.

The brochure encompasses cabinets, cases, subracks, plug-in units, handles, power supplies and backplanes, as well as an extensive range of complete systems for VME, VME64x, CompactPCI and PXI applications.

In addition, there is a detailed section outlining Schroff's co-ordinated service strategy – ServicePLUS - which has been designed to ensure that customers enjoy comprehensive support from the initial configuration to the final assembly of the product.

Illustrated throughout by means of colour photographs, the new Product Overview can be obtained by visiting www.schroff.co.uk and clicking on the 'Catalogue Request' button.

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

New Omnidirectional Antennas for Broadband Spectrum Monitoring

ETS-Lindgren have announced the launch of a new series of omnidirectional biconical antennas, Models 3180, 3181, and 3182, for broadband spectrum monitoring. The omnidirectional radiation pattern means the antenna can receive signals from every direction around its axis. In addition, for Models 3180 and 3182, the elements have been optimized to avoid any splitting of the main radiation beam in the elevation cut.

Models 3180 and 3182 are designed to cover the traditional frequency range of EMC measurements, from 30 MHz – 1 GHz. The antennas also cover all of the VHF and part of the UHF bands, making them ideal for spectrum monitoring of FM, TV and some cellular phones. A flexible mounting system accommodates both the classic EMCO block mount and a rear "stinger" mount. Model 3180 is also ideal for free space NSA (FSNSA) testing of fully anechoic chambers. In addition, its small size allows for amplifier harmonic monitoring when testing per IEC 61000-4-3.

Model 3181 is a "mini-bicon" antenna designed primarily for CISPR-16 chamber characterization over the 500 MHz – 18 GHz frequency range. It may also be used for amplifier harmonic measurements per IEC 61000-4-3, EM field surveillance, spectrum monitoring, and most wireless bands worldwide. With its low weight design, it is ideal for field measurements when connected to a portable spectrum analyzer. Optional weatherproofing is available for long term monitoring outdoors.

Dr. Vince Rodriguez, ETS-Lindgren's Senior Principal Antenna Design Engineer, commented, "This new series of antennas complements our multiple-octave broadband products by adding broadband omnidirectional models to our directional antenna line."

Models 3180, 3181 and 3182 are individually calibrated with actual antenna factors, a signed Certificate of Conformance, and a manual included with every shipment. The antennas are available for immediate delivery with quantity pricing. For more information: www.ets-lindgren.com/3180, www.ets-lindgren.com/3181, and www.ets-lindgren.com/3182.

Tel: +44 (0)1438 730700
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www.ets-lindgren.com

emcia Member

DIN Panel Instrument Cases

Aesthetic, high quality panel mounting instrument cases from Perancea are designed and manufactured to DIN 43700/IEC 61554. This innovative, modular format provides a wealth of cost effective, high quality solutions to instrument housings for panel mounting applications. Features include:

- DIN 43700 & IEC 61554
- 21 panel sizes
- Three rear & four panel styles
- Seven depth options
- IP 42 locking doors
- Integral PCB guides
- UL 94V-1 flame retardant

Front bezels come in three ranges of 48x24mm to 96x72mm, 96mm square and 192x72mm to 288x144mm. A range of panel fixings makes for easy clamping.

Transparent doors are available for instrument case and panel mounting applications. The plastic cases can be RFI screened and a range of options and modules makes for easy customisation to suit specific applications.

Tel: +44 (0)20 8365 2520
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Common Questions and Misunderstandings about EMI Filters

By Jan Nalborczyk, Technical Director, MPE Limited

Introduction

Despite EMC issues now usually being considered at an early stage during the product design process, unexpected problems still occur.

In some cases, a simple approach to EMC and filtering is found to work but more often than not a more in-depth analysis is required to address the relevant EMC design considerations and subsequently identify the EMC solution.

Some of the recurring questions asked of MPE during the filter selection phase of an equipment design are listed below.

Q1. I have bought a 30A filter but only want to use it at 20A. Is it true that the filter will only give its full performance at 30A and will give reduced performance at lower currents?

A1. No! Most filters will give their full quoted performance up to their full rated current. The main exception is for single line filter designs where the magnetic core will progressively saturate and give lower inductance and lower performance as load current increases. A reputable filter manufacturer should allow for this and quote performance figures based on the worst case (full load) condition.

Q2. I want to use a 10A filter at 12A continuously. I think this should be alright as it is only 20% over-rated. Is this correct?

A2. No! The heat dissipation within a filter is proportional to I^2. Therefore a 20% overcurrent will represent 44% excess heat dissipation which is unacceptable. Filters should never be used at above their rated current on a continuous basis.

Q3. Can I use a 240V 50Hz mains filter on 120V 50Hz?

A3. Yes! Filters are normally suitable for operation at any voltage up to their rated voltage provided that their current rating is not exceeded, and the supply frequency is no greater than the rated frequency. It is also normally possible to use a.c. filters on d.c. supplies up to at least the same working voltage. Where filters are fitted with transient suppressors, it should be remembered that the level of transient suppression provided may no longer be optimum for the new working voltage.

Q4. Is it possible to use a 240V 50Hz filter on a 115V 400Hz supply?

A4. Sometimes, especially when the filter capacitance values are low. The main problem is the heating effects of 400Hz supplies on the inductor cores and capacitors within the filter. In the case of the filter capacitors, leakage currents will be about 4 times higher on the 400Hz supply. Capacitor heating by the 400Hz supply can be significant on high performance filters. This can be reduced by using low loss capacitors in the filter design, but careful consideration needs to be given to harmonics on the 400Hz supply which will add to heating effects. The filter current rating may also have to be derated to take account of the additional heating within the inductor cores. The filter manufacturer should always be contacted for advice before proceeding.

Q5. What about filters used on higher frequency supplies and non-sinusoidal supplies?

A5. A check must always be made to ascertain the likely heating effect of a particular supply on any given filter. The heating effect will increase with frequency and will be even more pronounced for non-sinusoidal waveforms because of the high harmonic content. The filter manufacturer should be consulted for advice, as it is unlikely that a standard filter will be suitable, although a special design may well be practical.

Q6. Can I use a power line EMI filter for filtering out mains harmonics?

A6. Generally no! Mains harmonics are most pronounced at the lower frequencies and have a very low source impedance. They will require very large values of capacitance and inductance to filter them out, and a purpose designed harmonic filter is required to do this. A high performance mains EMI filter will reduce some of the higher order harmonics which extend into its stop band, but its impedance is unlikely to be low enough and its capacitance and inductance values will not be high enough to have any great effect on the lower order harmonics.

If a high performance power line filter is placed on a supply known to contain high levels of harmonics, say >5% THD, care must be taken to choose a filter which will not be overheated by the harmonics, in the same way that the harmonics will cause overheating in transformers, cables and other electrical equipment on the same supply. The filter manufacturer must be contacted for advice on this matter.

Q7. I have been told that I don't need to use a filter containing feedthrough capacitors as I do not require any significant suppression performance above 10MHz. Is this true?

A7. Not necessarily! Because of their construction, feedthrough capacitors have lower series resistance and inductance in their connections than two terminal capacitors. They can therefore offer better performance in circumstances where these parameters are important, such as where capacitance values need to be large.

Q8. I have established from pre-compliance testing that I need a filter with an attenuation of 30dB at 50kHz to remove noise peaks. From a catalogue, I have picked a filter which is claimed to have 40dB insertion loss at 50kHz. When connected into circuit, this filter does not work. Why not?

A8. The most likely reason is that the source impedance of the noise is not 50 ohms yet the filter chosen has its insertion loss specified in a 50 ohm system. A filter is needed which will provide the required attenuation in the impedance of the practical system. Alternatively, the filter picked may only provide attenuation in the asymmetric mode whereas the noise could be in the symmetric mode, or vice versa. The application should be discussed in detail with the filter manufacturer who can give guidance on the performance of appropriate filters in systems other than 50 ohms and for both modes of interference.

Q9. Under what circumstances do I need to mount a filter on a bulkhead.

A9. For good filter performance above 10MHz it is advisable to mount the filter through or against a bulkhead to avoid by-pass coupling between incoming and outgoing leads. The effect gets worse as frequency increases so mounting on a bulkhead or, alternatively, using screened leads becomes increasingly important. Many simple filters not containing feedthrough capacitors will have gone into resonance by this frequency anyway, so there would be little benefit to be gained by bulkhead mounting, but for high performance filters employing feedthrough capacitors, a very significant benefit will be obtained at the higher frequencies.

Conclusion

Because of a greater awareness, EMC considerations are taken into account in equipment design to a much greater degree than they used to be.

However, selecting a filter from any catalogue without being aware of its full specification under practical circuit conditions may still not give the expected results. This is usually because the parameters of the circuit to be suppressed are not adequately defined, or not known. Probably the least well understood parameters are the source and load impedance of any interference but there are many other parameters which can cause problems if not taken into account.

A reputable filter manufacturer should always be prepared to give impartial advice on the best choice of filter for a given application. Where a filter manufacturer is able to offer a bespoke design, it is often found that a custom designed filter can offer a more cost effective approach than a standard catalogue item even in cost-conscious commercial environments. This is because, as well as precisely meeting the electrical requirement, it can also offer simplified installation by virtue of its tailored mechanical design.

If you would like MPE to help solve your EMC filtering problems then please contact us on 0151 632 9100 or take advantage of the wide range of technical application notes which are downloadable free of charge from our web site **www.mpe.co.uk**

Examples of standard catalogue filters designed to address specific practical application considerations

1. Catalogue filters for switched mode power supply applications.

These have been designed to incorporate all of the special requirements imposed by SMPS circuits which require filtering. i.e. feedthrough capacitors, suitable for low source impedance, good asymmetric and symmetric performance, bulkhead mounting.

2. Catalogue filters for Military Vehicles

Many items of equipment in military vehicles, such as blower motors or wiper motors, need filtering at frequencies to beyond 1GHz and it is not always practical to fit filters though a bulkhead or mount equipment inside a shielded enclosure. A standard solution is to use a filter with integral screened cables which shield the “dirty “ cables emerging from the equipment to prevent the cables radiating until the noise has been safely removed by the filter.

EMC Fundamentals

By Ken Javor, EMC Compliance,
Huntsville AL, USA

The electrical engineering sub-discipline electromagnetic compatibility is about sixty years old, and in many ways is quite sophisticated relative to its beginnings. The earliest specifications and standards dealt a lot with grounding, bonding, filtering and shielding. Gradually handbooks evolved that discussed circuit design. Today there is extensive high-fidelity modeling of non-rf signals operating at frequencies above the range of the radios protected by the original EMI standards!

Along the way, the sophistication in design techniques seems to have arrived hand-in-hand with a lack of interest in, or indifference to, the motivation behind EMI standards, especially in the world of designing to meet FCC and CE requirements. For many EMC professionals, these requirements and their standards and limits have become an end in themselves, as opposed to the original intent, which was a means to an end.

Now this is meant as a very general statement. There are many engineers working to constantly update and improve the standards. But it seems as if standard setting has become a relatively specialized sub-profession. This little exploration into where we've been and how we got here ends up with a very simple recommendation, aimed at bringing the standard-generating community closer to the user community.

EMI vs. EMC

As noted, the standards have become an end in themselves, as opposed to the original intent, which was a means to an end. The overall intent of applying EMI standards to equipment-level procurements, or as a hurdle to be successfully cleared before marketing a commercial item, is to cost-effectively achieve EMC in the intended installation. It was determined a very long time ago that fixing installed equipment was much more costly and time-consuming than building the proper design into the equipment prior to installation. Installation here can mean on a particular platform or vehicle, or it can mean a home or office or factory, depending on the type of equipment. This relationship between the quantitative EMI standards and the more qualitative demonstration of EMC is captured in the wording that used to appear on every piece of equipment qualified to 47 CFR Part 15 relating to EMI: "This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: 1. This device may not cause harmful interference, and 2. This device must accept any interference received, including interference that may cause undesired operation." Even though the device meets its equipment-level requirement, that is not an ironclad guarantee of compatible operation under all possible scenarios in all possible installations. Guidelines were given that explained who had priority in order to achieve EMC in the field when an EMI problem cropped up.

So we come up with our first important lesson. All the EN 61000-4-X, and EN 55022 and similar renamed CISPR EMI requirements are just that: EMI requirements. They regulate the amount of EMI an equipment can generate, or be susceptible to, in a tightly controlled quantitative manner, for the purpose of providing a good probability that they will neither cause interference, nor suffer interference in the field. EMI standards verified in the EMI test facility promote the achievement of EMC in the field. This is quite clear in the military, aerospace and automotive worlds, where actual EMC tests are performed on the finished installation, which is a collection of equipments that have previously undergone EMI qualification. But the lesson has largely been lost on producers of equipment intended for home, office, and factory installation, because the EMI test is the last bit of qualification the device will ever see.

And it doesn't help that we are constantly bombarded with advertisements by manufacturers of EMI test equipment touting their latest and greatest "EMC receivers" and "EMC test equipment"! One can receive EMI, sure enough – that's why it needs to be controlled. One cannot receive EMC. EMC is achieved when the level of EMI reception is below that causing degradation to your communication link. And "EMC Immunity testing" is an oxymoron. One does not evaluate immunity to EMC, but to EMI. Unfortunately, this is not "just semantics." On the part of many engineers, it represents a misunderstanding concerning what our profession is all about.

Interference with What?

Note that it is the Part 15 digital device (*unintentional* radiator) that must stand down if it causes interference or is interfered with. Interferes with what? And interfered with by what? Today, unfortunately, many EMC engineers would answer, "any other adjacent equipment." But that is not the case. Isn't now, never was. The simple truth that has been lost along the way is that radios and radio broadcasts were the inception of EMI requirements, and are still the prime movers today. Now it is clear that there are add-on type requirements that are not radio-related. EN 61000-4-2, -4, and -5 deal with various sorts of conducted and radiated transients. These standards are all specified in the time domain. And with the possible exception of the showering arc test, which can arise in the field from the use of arc welding equipment nearby, the other requirements protect against certain environments: ESD and lightning. EN 61000-4-3 and -6 impose a certain degree of immunity from radiated fields due to radio broadcasts, and EN 55022 and similar CISPR derivatives protect radio broadcast reception from interference by the qualified item. To some readers, this is an obvious statement, but this argument isn't aimed at them. For the rest, consider the origins of conducted and radiated EMI control.

Conducted emissions are controlled from 150 kHz to 30 MHz, and radiated emissions are controlled from 30 MHz to at least

1 GHz, and as high as 6.5 GHz. The first thing to notice is not the numbers but the units. These are frequency domain requirements. What kinds of equipment operate in the frequency domain? Radios. Where does the 150 kHz low frequency start point originate? The bottom of the AM broadcast band (BCB) in Europe is at 150 kHz. Before the USA harmonized with Europe, the FCC EMI requirements started at 450 kHz. Where did that number originate? In the USA, the bottom of the AM BCB is 530 kHz. The AM band intermediate frequency (IF) is at 455 kHz. Placing the start frequency at 450 kHz protected the USA AM BCB and the IF. There are good reasons for the conducted/radiated break point but they don't bear on the subject at hand, which is the rationale behind the requirements. The end point used to be 1 GHz, but with the advent of various radio services above 1 GHz, the limit has pushed out to 6.5 GHz, and is likely to push out still further as new radio services utilize more of the microwave spectrum.

Next of interest are the measurement bandwidths. Tuning from 150 kHz to 30 MHz, a 9 kHz measurement bandwidth is employed. From 30 – 1000 MHz, a 120 kHz bandwidth is required. In Europe, AM stations are separated by 9 kHz. In the USA, it is 10 kHz. In the FM band signal occupancy is limited to just over 100 kHz, with 200 kHz channel separation. So there is extremely close correlation between the required measurement bandwidth and the spectral occupancy of the BCB. And thus it should be: A basic tenet of communications theory is that maximum signal-to-noise ratio is achieved when the signal and receiver bandwidths are equal. And other bad things can happen when the bandwidth is off. Case in point: dithered clocks whose harmonic spectral occupancy was wider than 120 kHz. These devices significantly reduced measured EMI using a 120 kHz bandwidth, because the harmonic "wandered" in and out of the receiver pass-band. This allowed a marginal outage due to a fixed frequency clock harmonic to meet the limit (because the quasi-peak detector averaged the value of the harmonic that wasn't always in the pass band). But in the television vhf and uhf BCBs, the video bandwidth is 4 MHz, and the dithered clock always stayed in band to that. It has been reported that dithered clocks could cause more interference to television reception (TVI) than the fixed clock harmonic. Oops!

And about that quasi-peak detector? Where did that come from? It is based on the nuisance value of different types of interference to voice communications, and reports back an amplitude whose relationship to the peak of the modulation envelope depends on the duty-cycle of the interference, as long as the on and off times are short relative to the QP detector time constant.
A pretty clear circumstantial case has been made that emissions limits are closely related to radio bands and broadcast parameters. But there is more than simply empirical data available. There is indeed a smoking gun, or a Rosetta stone. A pair, actually.

Where It All Began

There isn't any need, really, to belabor the world of vehicle or platform EMC. Vehicle/platform EMC includes military, aerospace and automotive. People often differentiate between commercial and military EMC, but that is an organizational or economic distinction, not a technical one. The technical distinction between equipment sporting an FCC and/or CE sticker and equipment slated for use on a specific platform / vehicle is very close proximity of culprits and victims (antennas) and the existence of a well-defined ground plane in the vehicle. Both these features are absent in the home/office/factory environment.

MIL-I-6181B, "Interference Limits, Tests and Design Requirements, Aircraft Electrical and Electronic Equipment" was released in 1953 and is the ancestor of all modern platform EMI standards. That in itself is of little interest to this audience, but a report was written documenting the rationale behind the radiated interference portion of the standard. NADC-EL-5515, "Final Report, Evaluation Of Radio Interference Pick-Up Devices And Explanation Of The Methods And Limits Of Specification No. Mil-I-6181B," was published in 1955 and explains antenna selection, antenna separation and the physics behind the choices. And it is all about protecting radios from interference.

Photographic Plate 1: *Re-enactment of NADC-EL-5515 set up that measured the response of an aircraft radio of the period, and used that susceptibility to build a radiated emission limit for MIL-I-6181B in the early 1950s. From left to right: BC-348Q aircraft LW-MW-SW radio, impulse (noise) generator, Stoddart Aircraft Radio Company NM-20 / AN/PRM-1EMI receiver, EMI receiver power supply. (Photo courtesy of EMC Compliance and the Museum of EMC Antiquities).*

In any case, the rationale appendix of MIL-STD-461 explicitly states the purpose of each requirement. Electric field radiated emission control protects antenna-connected receivers from rfi, while the electric field radiated susceptibility requirement protects equipment from the effects of high power radio/radar transmissions. It further states that the two types of requirements have no relationship to each other.

In the commercial world, we have a report written by the Computer and Business Equipment Manufacturer's Association (CBEMA) in 1977, report number ESC5/77/29: "Limits and Methods of Measurement of Electromagnetic Emanations from Electronic Data Processing and Office Equipment." This report explains the rationale behind the conducted and radiated emission requirements later codified into Part 47 of the Code of Federal Regulations, part 15 (now 15J), and also the test methods enshrined in ANSI C63.4. These are the requirements imposed on unintentional emitters of rf energy.

The conducted emission requirement was based on the susceptibility of AM and shortwave radios to noise appearing on their ac mains inputs. Your author was able to verify the Class B 48 dBuV resulting from this work a full twenty years after the original work was done.[1]

The radiated emission limit is based on controlling unintentional emissions to levels below those set for a certain level of reception quality, per EIA standards for broadcast TV and other types of radio reception.

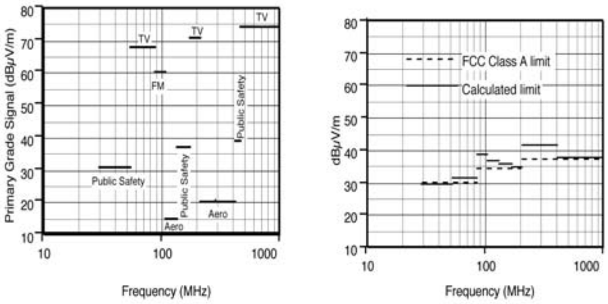


Figure 1: *Comparison of signal level required for primary grade reception (on left) and FCC limits at these frequencies (on right)*[2]

The report also explains the 30 MHz break point frequency between conducted and radiated emission limits and testing.

Someone reading this article in a UK publication is sure to say that US military and FCC regulations and limits have no bearing on CISPR and IEC requirements and standards. *Au contraire*. The very close similarity of ANSI C63.4 and CISPR 22, and very similar limits allowed USA harmonization with EU practices. Had FCC regulations been based on different criteria than CISPR, harmonization would not have been possible.

A Typical Objection

It has been said that while the emission limits described above do indeed have their roots in the protection of radio broadcast reception, that is no longer their sole purpose. There are other types of sensitive equipment requiring protection as well. Medical equipment is often cited as an example.

This is patently false. Two types of control are used to protect medical equipment, and neither is control of unintentional emissions. The first type of control is the levying of EN61000-4-3 and 61000-4-6 on the equipment manufacturer as a suggested technique for verifying proper rf immunity. These two requirements protect against radio frequency fields from 0.15 – 1000 MHz, at levels of either 1, 3, or 10 Volts per meter. These levels are orders of magnitude higher than the emissions limits of EN55022. If medical equipment qualified to EN61000-4-3, and -6 were the most sensitive victims out there, there would be no need whatsoever for EN55022.

That is a specsmanship argument, and should be conclusive, in and of itself. But there is more. Sensitive medical equipment monitors bodily functions, such as EKG and EEG. These signals are indeed minute, but they are time domain and the spectrum of these signals, were we to perform a Fourier transform, would all have fundamentals below audio, with maybe some harmonic structure bleeding over into audio, but surely all the information would be contained below 1 kHz.

Given the time domain nature of medical equipment, and the spectrum of such signals, how is it possible to imagine that frequency domain limits that start at 150 kHz have any bearing on the performance of such measurements? By what mathematical or physical argument do you relate the susceptibility of the time domain sub-audio device to specific microvolt and microvolt per meter levels at 150 kHz and up? Within the realm of engineering, math and physics there can be no answer for this. If there is an answer outside of engineering considerations, then that is why EMC is sometimes referred to as a "black art."

The other protection that medical equipment often receives is restriction of the use of intentional transmitters in their vicinity. Hospitals and medical offices often have restrictions on cell phone use and other rf transmissions.

The entire picture of how emission and immunity/susceptibility requirements fit together within the overall goal of achieving EMC is neatly summarized in a picture.

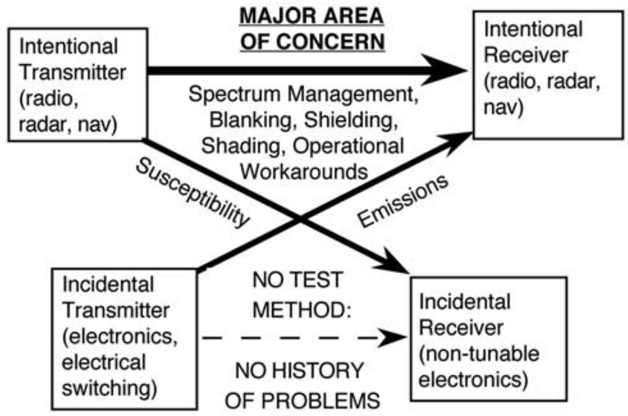


Figure 2: *Use of radiated emission and susceptibility/ immunity requirements to ensure EMC*[3]

The interaction labeled *susceptibility* (control) shows that susceptibility/immunity requirements exist to protect unintentional receiver equipment (ordinary non-antenna-connected electronics) from the effects of high power rf illumination. The interaction labeled *emissions* (control) shows that emission requirements protect antenna-connected receivers from unintentional rf radiators. We do not limit rf transmitter power in order to protect unintentional receptors that may become victims, because the rf transmitter power has been selected to perform a certain job (establish communications or detection at a specified range). Likewise we do not desensitize radio receivers to protect them against rfi; their sensitivity is what is required to complete the communication link with the high power transmitter. The "major area of concern" interaction shows that if transmitters and receivers have to exist side-by-side, then EMC between them must be assured by some kind of physical separation and/or operational control – there is no degree of freedom allowing these two to operate at the same frequency at the same time. This is also likely true if the receiver were to try to operate at a low number harmonic of the transmitter frequency. "Major area of concern" refers to a platform EMC situation with many antenna-connected equipments operating close to one another; not a typical home/ office/factory setting. Finally, the "No Test Method – No History of Problems" non-interaction refers to the fact that non-antenna-connected equipment of roughly similar power levels do not interfere with each other, and therefore no special controls need be put in place. This is an immediate consequence of the most basic diagram showing how EMI occurs. In Figure 3, the path between culprit and victim is always very lossy, and there must be a large disparity between culprit and victim power levels in order to offset that path loss.

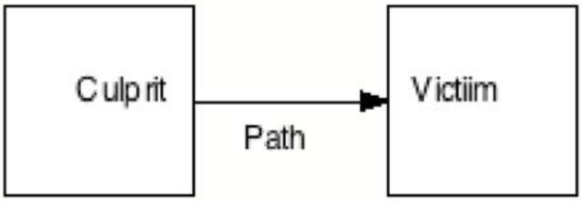
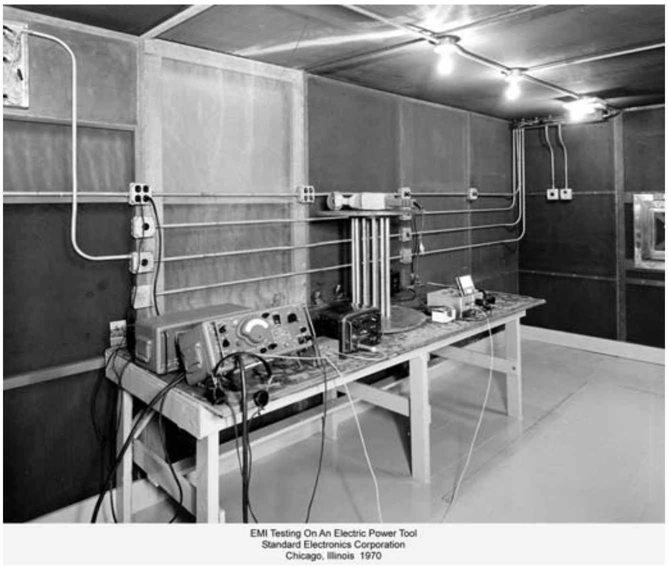


Figure 3: *Interaction between EMI culprit and victim*

Conclusion

A very simple solution exists to the problem of origins identified herein. The solution is for each EMI standard, specification or requirement to have an added informative annex explaining the rationale behind the limit, and the assumptions, calculations, and compromises that went into deriving the limit, as well as similar background for the test methods. This has been standard practice for MIL-STD-461 since 1993.

Another low-tech solution is to do testing the way we used to, back in the day. It's hard to misunderstand that you are making a radio-related measurement when your test equipment is quite obviously a radio itself!



Photographic Plate 2: *Blast from the past - conducted emission testing in 1970. Note headset plugged into EMI receiver – this is a radio! (Photo courtesy of Ed Price)*

Note that the test sample (power tool) is at the top of the circular stand midway down the table, and plugged into LISNs at far end of ground plane. Everything else on the ground plane is test equipment. From left to right there is the EMI receiver power supply behind the Stoddart Aircraft Radio Company NM-22 EMI receiver. Adjacent to the receiver is an Empire Devices SU-105 coaxial switch, and just down from that is a Stoddart Aircraft Radio Company 91263-1 Impulse Generator. Measurements were made by substitution: when manually tuning the receiver located a signal at the LISN port, the level on the meter was recorded by hand on paper and the coax switch then selected the calibrated impulse generator which was adjusted until the receiver meter gave the same response as off the LISN. Then transducer factors if any had to be applied manually on paper (none in the case of a LISN measurement). This all assumes the signal measured in the first place was broadband. Narrowband/broadband discrimination was performed for each signal by the test operator. The handy headset often helped the astute operator make that judgment. It's hard to lose sight of what we are doing when tuning a radio and listening on the headset!

Not too many people will want to return to test methods of yore, so maybe adding that informative annex now seems a more palatable solution!

Footnotes

1 *Investigation Into the Susceptibility of Radio Receivers to Power-Line Conducted Noise*. EMC Compliance, 1998. Technical committee presentation and demonstration at 1998 IEEE EMC Symposium, Denver

2 Data culled from the Computer and Business Equipment Manufacturer's Association (CBEMA) report number ESC5/77/29: "*Limits and Methods of Measurement of Electromagnetic Emanations from Electronic Data Processing and Office Equipment*," published in 1977.

3 *Introduction to the Control of Electromagnetic Interference; A Guide to Understanding, Applying, and Tailoring EMI Limits and Test Methods.* EMC Compliance, 1993.

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Why broadband PLT is bad for EMC

By Tim Williams, Elmac Services

Broadband internet communication is here to stay, but its method of delivery is still controversial. This paper looks at the technology of Power Line Telecommunications (PLT) through the lens of an EMC specialist, and attempts to explain why broadband through PLT is a dangerous and divisive issue.

Abstract

This paper first outlines the technology used in PLT systems, and the political support being offered to the technology, from the point of view of its effect on electromagnetic compatibility (EMC). The radio spectrum needs protection from other interferers, and there is a regime in place to provide this protection. Nevertheless, PLT has several features that mean that it is capable of creating such interference. These features are discussed, and some published field trial results are reviewed. Difficulties in achieving compatibility between the requirements for radio protection and the requirements for operation of the PLT system mean that there is no consensus as yet as to how PLT system components can be made compliant with EMC requirements. It is concluded that there is little prospect of an accommodation between the competing demands, so that if PLT is to become widespread it will be at the expense of the radio environment.

Contents

The technology of PLT

Power Line Telecommunication (or PLC, Power Line Communications, or Broadband over Power Line, BPL, in the US) is a means of transmitting broadband data over the installed base of mains electricity supply cables. It can be used in two ways:

- Access to the home or campus, to deliver the data connection from the service provider;
- Networking within the individual home or larger building, for data interconnection between mains-connected devices.

Although an ETSI document (TS 101 867 [11]) exists to attempt to create co-existence between access and in-home systems, it has been largely ignored and there are several proprietary implementations using some or all of the frequency range between 1.6 and 30MHz. Coding schemes, spectral distribution and signal levels differ between systems and detailed data is not published. For a variety of reasons access systems are not widely implemented in Europe, although they are being actively pursued in other parts of the world.

On the other hand there is an established specification for the HomePlug network system which is in use in the US and elsewhere for in-home networking. The version 1 specification uses OFDM (Orthogonal Frequency-Domain Multiplexing) to modulate the data onto a series of carriers across the frequency range 4.5–21MHz, with notches at certain frequencies to protect the US amateur bands [12]. The delivered bit rate is about 14Mbps. A more recent specification is called HomePlug AV, which is stated to give an information rate of 150 Mbps. In the UK, BT is marketing its BT Vision package, which includes a mechanism similar but not identical to HomePlug for passing broadband data in the range 3–30MHz around the mains wiring.

In round numbers, and bearing in mind that the technology is now sophisticated enough that quoting a fixed level might be misleading, the generally accepted power level for adequate operation of a PLT system is –50 to –40dBm/Hz. Measured in a 9kHz bandwidth, as is standard for interference measurements at these frequencies, this implies a power level of around –10 to 0dBm, which across the differential 100 ohm impedance of the power network is 100–110dBμV (0.1–0.32V). This compares with the allowed levels for conducted emissions in the domestic environment, with which most if not all electronic product designers are familiar, of 60dBμV in a comparable frequency range between each phase and earth – one hundred times lower.

dBs and units

The deciBel (dB) is widely used to describe radio frequency parameters. For power, it is ten times the logarithm of the ratio of two powers:

$$dB = 10 \cdot \log(P1/P2)$$

For voltage or current, it is twenty times the logarithm of the ratio of two voltages:

$$dB = 20 \cdot \log(V1/V2)$$

Thus +20dB means that P1 is 100 times P2, or V1 is 10 times V2; –20dB means that P1 is 0.01 times P2, or V1 is 0.1 times V2; 0dB means that the two quantities are equal.

To express absolute units, the dB is given a suffix: thus 0dBm is 1 mW, +20dBμV is 10μV, and so on.

Electric field strengths are expressed in microvolts per metre (μV/m) or deciBels relative to a microvolt per metre (dBμV/m); magnetic field strengths are expressed in microamps per metre (μA/m) or deciBels relative to a microamp per metre (dBμA/m). Voltage limits are usually expressed as deciBels relative to a microvolt (dBμV).

Notching and power management

One capability which is potentially to PLT's advantage is that it can be programmed, possibly in real-time, to use only certain parts of the spectrum; notches can be applied to protect given frequency ranges, for instance the amateur or broadcast bands. However, the basic requirement is that data is transmitted at a bit-rate that is acceptable to the user (an expectation that is a core aspect of the attractiveness of broadband internet access) and there is a direct trade-off between the bandwidth required for acceptable bit-rate and that which is available to the system after all necessary notches have been applied. In other words, protection of spectrum allocations through notching can only be achieved by a reduction of the operational bit-rate. In the limit, you can't notch out the whole spectrum. So while notching could in theory afford protection to some spectrum users, such as broadcasters or radio amateurs [1], others could still expect to suffer. This issue, as we shall see later, is at the heart of the approach being taken by standards committees.

The technique of notching raises a further question, which is that of intermodulation. When multiple radio frequency signals are applied to a non-linear system – and the mains supply network, with all its connected electronic equipment, will certainly include non-linearities – they "intermodulate" to produce frequencies that were not present in the original spectrum. Thus although the PLT signal itself may be confined to certain parts of the spectrum and avoid others, at the victim receiver the system intermodulation effects may create interference signals within the supposedly protected bands. Although this phenomenon has been accepted as a possibility, there is little or no research into its likelihood or prevalence.
Another technique which can be applied in PLT modems is power management. Widely used in the GSM mobile phone context, it simply means that the system intelligently uses only the minimum power needed over a given part of the spectrum to achieve reliable communication. Thus although a figure can be quoted as above for the power level needed for adequate operation in all kinds of mains environments, in practice this can be adjusted downwards in any given spectrum sub-band depending on the noise level that the modem finds, in real time, in that sub-band.

The European politics of PLT

Because it provides a way to deliver domestic broadband access that is alternative to other providers such as cable and telephone companies, access PLT in particular has been viewed favourably by regulators on the grounds of extending competition. The "strategic goal" of the European Union, known as the "Lisbon Strategy", has been stated [10] to be

> *to become the most competitive and dynamic knowledge-based economy in the world*

and the broadband telecommunications infrastructure with cheap, high-speed Internet access is seen as a cornerstone of this policy. The local loop, or the "last mile" (delivery of the broadband data finally into the home or office) appears as a bottleneck in the process of liberalising the competitive environment for this infrastructure, particularly in breaking the perceived stranglehold of the "incumbents" (pre-existing telecom providers). Hence any technology which promises to unblock this bottleneck is regarded with encouragement by the European authorities. PLT is clearly such a technology.

Meanwhile, some European member states saw the potential RF interference dangers of this technology early [2], and implemented regulations which would allow them to control it if there was any threat of such interference becoming widespread. In Germany, the standard NB30 put down radiated emissions limits in the 1.6–30MHz range. In the UK, the former Radiocommunications Agency standard MPT1570 was also published, though it covered a lower frequency range. Naturally, this put a brake on PLT activity in these countries, since investors were wary of supporting systems which might quickly turn out to be illegal, and it also meant that there were differences in approach across the European Union. (The response of the UK's Federation of Electronic Industries, FEI, to MPT1570 was that it was "unacceptably parochial".)

Because the EMC implications of PLT have been a barrier to its widespread implementation, the European Commission has been, in a manner of speaking, champing at the bit to get this barrier resolved, if not lifted altogether. In 2001 it placed a mandate on the standard bodies ETSI and CENELEC (mandate M/313) to create a standard for the EMC of Telecommunications Networks. This has been addressed by a Joint Working Group of the two bodies but the difficulties involved, particularly that of finding agreement on a set of limits for radiated emissions from the network which would satisfy all participants, have meant that such a standard is a long time coming.

In early 2004 the EC appeared to lose patience with this process, and sent a letter [3] to CENELEC and ETSI which requested them to:

> *Define a technical specification providing test methods and limits for radiated disturbance (and possibly consistent conducted disturbances limits) compatible with state of the art powerline communication infrastructure. This technical specification should be made available by 31/03/2004.*

Such a deadline, considering that the letter was sent in January 2004, was clearly unrealistic, although the Joint Working Group responded quickly by offering a draft Technical Specification [4]. The Commission subsequently issued a Recommendation [5] which included the following uncompromising statement:

> *Member States should* ***remove any unjustified* regulatory obstacles,*** *in particular from utility companies, on the deployment of broadband powerline communications systems and the provision of electronic communications services over such systems. … Until standards to be used for gaining presumption of conformity for powerline communications systems have been harmonised under Directive 89/336/EEC, Member States should* ***consider as compliant with that Directive*** *a powerline communications network which is made up of equipment compliant with the Directive and used for its intended purpose … and which is installed and operated according to good engineering practices… (emphasis added)*

* An early version used the word "remaining"

The text goes on to talk about procedures for "If a system is deemed compliant but is nevertheless creating harmful interference, the competent authorities of the Member States should take special measures according to Article 6 of the EMC Directive, with a view to resolving such interference", but such procedures are bound to be time-consuming, and meanwhile the interference damage is being done. It is, though, interesting that the Commission clearly envisages a separation between "compliance" of a PLT system and its capacity to cause interference.

As it happens, the economics of access PLT systems have meant that the application of the Commission's Recommendation has been somewhat muted. But by comparison, in-home systems have quickly become popular, and it is to these that most attention is now given.

Protection of the radio spectrum

Man-made interference to radio services can come either from intentional radio transmissions, on the same or adjacent channels, or from unintentional sources, typically electrical or electronic equipment, that generates RF energy as a by-product of its operation.

Interference between radio stations

The first of these has been recognised since the early days of radio and has been controlled by international treaty, the Radio Regulations of the International Telecommunication Union. This allows for procedures for detailed planning of radio services throughout the spectrum, both within nation states and internationally. These procedures ensure that each service can establish a "protection ratio", that is the minimum ratio between wanted and interfering signals that ensures satisfactory reception of the wanted signal. Radio services are then planned to provide this ratio with a high probability.

The spectrum planning system results in complex frequency allocation tables, such as the UK's [7]. These show the range of services that have to be provided for; in the HF spectrum these include broadcasting, air, land and sea mobile voice and data communications, and radionavigation. Some of these services are safety-critical. An increasing number of short-range devices using for instance 13.56MHz, such as RFID readers and alarms, are installed in homes and offices. There are also "minority" users such as radio amateurs, radio astronomy, standard frequency and time transmissions and government monitoring stations who are concerned with receiving and analysing very low levels of radio signal. It is hardly surprising that many of these "stakeholders" have expressed grave misgivings about the spread of PLT [8].

One such stakeholder is the Radio Society of Great Britain (RSGB), which represents the UK's radio amateurs. A couple of years ago, the RSGB made a complaint regarding non-compliance of a PLT product that was declared compliant in Germany. Ofcom finally responded in 2008, implying that they would not take enforcement action in the UK. The RSGB's view, expressed in a public letter to Ofcom from its President, is that "this delay, attributed to restructuring, is frankly deplorable, unprofessional and certainly does not reflect well on the neutrality of the administration or the stated Statutory Duty of 'Ensuring the optimal use of the electro-magnetic spectrum'."[9] The evident frustration of radio amateurs at the lack of interest shown in the problem by some authorities is not limited to the UK.

Ofcom took over the duties of the disbanded Radiocommunications Agency at the beginning of 2004. Since their remit also includes "ensuring that a wide range of communications services – including high speed data services – is available throughout the UK", it may be thought that when it comes to enforcing regulations against a form of broadband delivery on behalf of radio users, there is more than a hint of conflict of interest in the air.

The use of the HF spectrum

The slice of spectrum from about 1 to 30MHz (MF and HF) is unique in that it can support long distance communication, and so it is particularly important to broadcasters. Sky-wave propagation in the HF bands enables an international broadcaster to reach a target country without having a transmitter within the target area. This has political consequences, since it means that an audience can be reached without the co-operation of that country's authorities – which cannot be said for other kinds of access, including any kind of internet delivery. The BBC's World Service, for instance, is broadcast on several HF frequencies and is heard by many people in countries that have no free media of their own.

To overcome some of the admitted reception quality issues with conventional AM broadcasting, a new digital service has been launched by a consortium of broadcasters, including the BBC and Deutsche Welle, known as DRM (Digital Radio Mondiale, see www.drm.org). An increase in the local HF noise floor due to PLT, with its continuous, broadband nature, would have the potential to seriously compromise the effectiveness of this service.

As well as broadcasting, aeronautical and marine communications use the HF band for long-distance communication, when the mobile station is out of reach of ground-based VHF stations, which can be a large proportion of their journeys.

Interference from other non-radio equipment

The second type of interference is caused by electrical and electronic equipment unintentionally creating RF noise in the vicinity of the receiver. This phenomenon has again been recognised for many years and a regulatory structure has been set up to deal with it. In Europe this structure is implemented by the EMC Directive (2004/108/EC), whose first essential requirement is that apparatus shall only be placed on the market or taken into service if

> *The electromagnetic disturbance it generates does not exceed a level above which radio and telecommunications equipment or other equipment cannot operate as intended.*

This means among other things that virtually all electrical and electronic equipment, especially that which connects to the mains supply, has to meet limits on the amount of noise it injects into connected cables. These limits are contained in standards which derive from CISPR, the IEC committee responsible for control of radio interference. They have been devised through a process which accounts for the protection ratio required by potential victim receivers, the likelihood of a source being in physical proximity and coupled to these receivers, and the probability of coincidence of operation of the source and the receiver. They apply within Europe through the operation of the EMC Directive to anything that is likely to cause such interference. Designers of mains-connected equipment are by now familiar with these requirements, which constitute an extra but necessary burden on their designs.

PLT's interference capability

Interference from PLT systems stands outside the general regime of interference control. The principal emissions are radiated from the supply wiring, onto which they have been deliberately injected, rather than unintentionally as is the case with other sources such as fluorescent light inverters or computer power supplies. From access-PLT systems, the interference could affect all households being supplied from a substation in a PLT-active zone, whether they are a subscriber or not. In-home systems can interfere with other parties connected to the same electricity supply point or in nearby properties; the electricity supply meter is not designed to attenuate HF signals.

The nature of the interference

Whatever the coding system, the interference signal will stretch across the whole of the spectrum occupied by the modem's output, and will be broadband in nature so that within a given region of spectrum it will be impossible to tune it out. In the quiescent state some systems will create a pulsing type of signal which may or may not be subjectively less annoying than the continuous noise which occurs when the system is actually passing data. Some systems may use low-frequency carriers such that a continuous audible tone is present across the frequency range. Several bodies, notably the BBC and RSGB, have audio recordings of actual PLT interference available on their websites.

One problem with determining the extent of actual interference problems is that non-technical radio users may have no idea that the interference they are experiencing is in fact due to a PLT source, since they will never have heard anything like it before. However the rapidly growing number of BT Vision installations, which appear to create a continuous signal even when not passing data, has already provoked a protest group which can be found via the YouTube website.

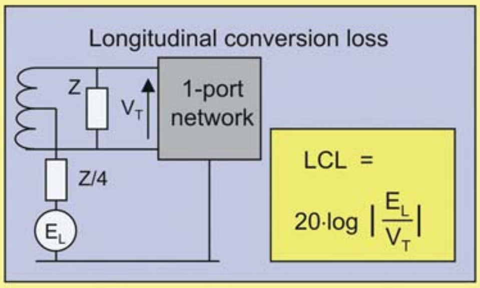
Dependence on quality of wiring

The mains supply wiring both to and within a domestic house was never intended to carry high frequencies. The connection between two points within a home looks like a complicated transmission line with many stubs terminated in unknown and changing impedances. At some frequencies the signal may be transmitted with little loss, but at others the attenuation can be severe, and this characteristic can change with time as users plug various appliances into the mains supply. This means that in order to work at all, the amplitude and frequency coverage of the signal must be enough to ride over any interference already present on the network, and must adapt to time-dependent changes in this interference and the network attenuation. Current-generation PLT systems are designed to do this.

A critical parameter which determines the degree of unintentional radiated emissions that a wired network creates is the "Longitudinal Conversion Loss" (LCL) of the cable. Simply put, this is the ratio between the signal level which appears across the wires, intentionally, due to the desired data transmission, and which to a first order should not radiate; and the signal level in common mode – all wires together – which represents the leakiness of the cable and which contributes the lion's share of the radiation. Data cables which carry broadband signals, of which Ethernet is the most typical example, are very tightly specified for a good LCL, which ensures that the RF leakage from the data signal is kept to a low, known value. This is also true to some extent for telephone cables that are used to feed ADSL and VDSL (phone-connected) broadband into the home.

Longitudinal Conversion Loss

LCL is the ratio of common mode (or "asymmetric") voltage in a network to the differential mode (or "symmetric") voltage that creates it. It is defined in ITU G.117 and measured as shown (the one-port network in this context is the cable, but note the reliance of the measurement on a meaningful ground connection):



It is not true of mains wiring. The most important aspect of cable design which affects LCL is the physical balance of the wire pairs which make up the cable. Each conductor must be tightly coupled to the other in the pair so that the interaction of each with the environment is identical. Then, provided the signal currents on the two wires are perfectly balanced, which can be ensured by suitable design of the terminal equipment, emissions from one wire exactly cancel the emissions from the other. Data cables are tightly twisted in a controlled way to achieve this. The interfaces at either end of the cable must be equally well specified.

Not only is mains wiring not controlled in this way, it is commonly installed in direct contravention of these principles. For instance, the live wire can easily be carried off to a light switch and back again, separating it from its neutral return by several metres. The conductors in the cables that make up the ring main wiring, typically flat twin and earth, are never twisted together. At each junction box in the ring main, there are large, uncontrolled deviations in the wiring configuration of the live-neutral pair. And in the connected appliances (TVs, cookers, computers, washing machines etc) there is every likelihood of unbalanced impedances between live, neutral and earth. None of this matters at the mains frequency of 50Hz, but at PLT frequencies of up to 30MHz it is critical. Even if the wiring is installed (as it should be in the UK) properly in accordance with the IEE Wiring Regulations, these are only meant to ensure electrical safety, and they have nothing to say regarding the high frequency properties. In fact, the UK's protective multiple earth (PME) wiring system is inherently unbalanced at the service entrance by the connection of Neutral and Earth conductors.

The IT emissions standard (CISPR 22 [6], published in Europe as EN 55022) gives a figure of 55dB for low-frequency LCL of Category 3 data cable (rarely used now in new installations) and 65dB for Category 5, degrading by 7dB at 10MHz. By contrast, work under the aegis of the COST 286 programme [14] has suggested a "mains symmetry factor" (comparable to, but not the same as, LCL) of around 7.5dB for same-phase measurements. In other words, mains cable could be up to 58dB or nearly a thousand times worse than the most commonly installed data cable at controlling unwanted radiation.

In fact, because of the inherently unbalanced nature of typical installations, it is arguable whether LCL is a suitable parameter with which to characterise mains wiring networks anyway. It is also the case that the specification of LCL depends on a knowledge of both common-mode and differential-mode impedances, and on a reference connection to an external earth. Since these are generally not available for mains networks, the use of a different measurement such as the mains symmetry factor proposed in the COST 286 paper appears to be a better way forward.

Is PLT the same as other interferers?

PLT supporters base their proposals for a relaxation of the emissions compliance requirements that a PLT system has to meet on those already applied to other devices, such as information technology, lighting, or household appliances. CISPR conducted limits, it is said, have been adequate to protect the HF spectrum so far and therefore any system limits should be no more onerous than levels derived from these. This argument overlooks a number of important points:

- A victim won't be able to get away from PLT interference. When a whole street or a whole building is wired for PLT, it will be pervasive and re-positioning the victim will not work. CISPR limits assume that mitigation by separation from a localised interferer is possible.

- PLT may be always on. CISPR limits incorporate a relaxation which takes into account the probability of non-coincidence in time of source and victim – for instance, no one uses a vacuum cleaner 24 hours a day. For PLT, this factor should be unity.

- EMC engineers know that the vast majority of products which comply with CISPR conducted limits do so with a good margin, often at least 20dB, in the frequency range above 2MHz. Such products are typically only near the limit at one or two frequencies; PLT covers the whole band as a matter of design. If CISPR limits do indeed protect HF reception, this factor should not be overlooked.

In fact, PLT modems seem to be unable to operate anywhere near the mains conducted emissions limits in force in CISPR at the moment.

Radiated or conducted?

It has been said that PLT is not intended to communicate via radiated signals. However, an elegant demonstration reported by Jonathan Stott [1] shows that even so, a PLT in-home system (using US HomePlug devices) does indeed do so. He describes the experiment as follows:

> *A HomePlug network was established. One terminal was a laptop PC using a USB-to-mains-PLT HomePlug device. The latter was plugged into a mains extension lead and thence into the mains wall socket. A set of Christmas-tree lights was also plugged into the same mains extension lead. The PLT network functioned as expected, communicating with a second terminal that was plugged in elsewhere. When the mains extension lead was then unplugged from the wall, so that the laptop PC's HomePlug device was no longer physically connected to the mains, the HomePlug network nevertheless continued to function. It was now functioning in effect as a Wireless LAN, using HF frequency spectrum. The lights acted as an antenna for the first terminal. This is possible since the particular USB-to-mains-PLT device draws its power supply from the USB connection and not from the mains and thus can still inject PLT signals. The mains wiring acted as the antenna for the second terminal. It could also be made to work (at lower capacity) with less obvious 'antennas' than the lights, e.g. by simply holding an exposed pin of the plug of the 'unplugged' HomePlug device.*

This suggests that a more appropriate response would be to regard the PLT system as an intentional radio transmitter and license it appropriately.

Cumulative effects

The foregoing discussion has concentrated on the emissions of PLT as they affect victim receivers in close proximity to the PLT system, generally within or near the subscriber's house. This is not the only threat that concerns radio administrations. If PLT were to be widely implemented within any country, the total radiated power would be sufficient to increase the radio noise floor at distances remote from the source, potentially in other countries. If, say, an entire city was to be wired for PLT, this could form an aggregate transmitter whose RF energy would be reflected from the ionosphere and illuminate a continent. In addition, an aircraft flying over such a city might find that its ability to receive HF signals was curtailed. The UK's Civil Aviation Authority has expressed its concern that "aeronautical services are under threat from cabled telecommunications services." Established HF propagation models exist for this phenomenon and a number of studies have been carried out to try and model the possible outcome.

The concern has focussed on several broadband technologies, including ADSL and VDSL. ERA report 2001-0333 [18] stated:

> *The study has found that the cumulative VDSL space wave emissions from a large city such as Greater London have the potential to increase the established ground level radio noise floor published by the ITU. In addition, considerable risk of interference is presented*

to Aeronautical mobile HF radio services sharing the frequency band.

VDSL uses similar frequencies to PLT, but the radiating efficiency of PLT systems, which use mains cables rather than telecom cables, is that much greater. A different study, York EMC Services AY3525 [17], said:

the only technology that is likely to significantly increase the established radio noise floor due to cumulative skywave propagation is PLT….

The problem with any such study is that for the time being it must remain theoretical, since it's impossible to validate the models used for prediction until there are sufficient installed systems to be statistically acceptable; but by then the roll out will be so advanced that it will be impossible to stop it. And the authors of these studies readily admit that their results are heavily dependent on the initial assumptions that they use, with regard particularly to the degree of market penetration and usage of the systems, and the figures that are assumed for the radiation efficiency of the cabling. For instance, the ERA report estimated that there was a 40dB "window" between the effects of pessimistic and optimistic assumptions for the various parameters. Even so, if the situation is likely to be bad for VDSL, it can only be worse for PLT.

Field trial results

Many field trials have been carried out on various systems in various European countries. Several of these were reported at the EC PLT Workshop in Brussels on 16th October 2003. Some significant points were [13]:

- Finland: from results of three installations, PLC is not compatible with HF radio services if the proposed emission limit is set to 55dBµV/m at 3m; this is about 40dB too high.

- Austria: put forward a proposal for a field strength limit of 14dBµV/m at 10m.

- Germany: initial findings about PLC applications suggest that, despite contrary assurances by the manufacturers, the ceilings in force nationally (NB30) cannot be adhered to.

- Netherlands: believes cumulative effects have been underestimated.

- Switzerland: conclusion from a trial in Fribourg is that PLC emissions exceed the German NB30 limit by up to 24dB near points of data injection and up to 18dB in urban areas.

- Spain: from trials in Madrid, Zaragoza and Sevilla, "There have not been any complaints from telecommunication users which could be caused by the operation of the PLT networks".

UK trial at Crieff

In the UK, Scottish and Southern Energy held trials with a total of three systems, from Main.net, Ascom and DS2, in Crieff in Scotland. The former Radiocommunications Agency, the BBC, and the RSGB were all invited to make measurements on these trials, and all three have put their reports in the public domain, with the exception of the DS2 trial which was held later. The RA measurements were made only outdoors, in roadside locations, over 21st-25th October 2002. The BBC [15] and RSGB [16] reports are more comprehensive, giving details of both indoor and outdoor measurements and an assessment of whether interference due to the PLT systems was actually noticeable. Their visits were concurrent and occurred on 12th-13th November 2002. Both parties concluded that, within the houses, both the Main.net and Ascom systems had the potential to deny the use of the broadcast and amateur bands to the occupants of the subscriber's house, and probably also to neighbours. The systems had different characteristics and used different frequency ranges, so that it might be possible to select PLT frequencies that were sufficiently separated from the desired reception frequencies that these latter would still be useable. But the actual amplitude of interference was substantially greater than any level that would render co-channel interference harmless. The measurements made by the BBC team showed levels that were sometimes in excess of the NB30 limits by 20dB, thus confirming the German and Swiss findings reported above; and the fact that even the NB30 limits are too high to protect broadcasting and amateur radio, as quoted by Austria and Finland, was also confirmed.

Reading all three reports, one is struck more than anything by the manifold difficulties involved in making reliable and repeatable on-site measurements of this type of interference, especially in situations where a baseline cannot be obtained because the PLT operation cannot be fully switched off. This is no surprise to an experienced EMC test engineer, but it does not bode well for a compliance regime which relies entirely on investigation and resolution of interference issues on a case-by-case basis after a PLT system is installed, as is envisaged by the European Commission.

Compliance status of PLT devices

The EC's Recommendation on PLT quoted above refers to a system being "made up of equipment compliant with the Directive". Here is the nub of the question: how can PLT modems be made compliant with the EMC Directive? It is the case that some PLT modems are already on the market in Europe and are CE Marked, which means that their manufacturers believe that they meet the essential requirements of the EMC Directive. But there are no standards specifically for such devices and for now, no such device could actually meet the general standard for RF emissions from IT equipment [6]. This is because the level of RF voltage that is put onto the mains connection is far in excess of the levels which are allowed for conducted emissions from all such products.

If these products can't comply with their applicable standards, how could they be CE marked? Until recently, the only alternative available to their manufacturers was the Technical Construction File (TCF) route, according to Article 10.2 of the first edition EMC Directive. This required the case for compliance to be submitted to a Competent Body, who provided a certificate stating that compliance with the essential requirements was actually achieved without recourse to standards. It is understood that all PLT modems on the EU market in the early days did actually use such a TCF route for their CE marking, implying that there was a Competent Body somewhere in Europe who believed that such a case could be made.

Because of the difficulty in justifying it, both the EC Association of Competent Bodies and the UK EMC Test Laboratories Association drafted guidance urging caution:

> *The basic question for a Competent Body when reviewing this or any other TCF is "Does this equipment meet the essential requirement of the EMC Directive". Given that a PLT requires a good signal to noise ratio to operate it must inherently generate emissions that may be in excess of the current limits allowed in EN 55022 and may therefore cause interference to some receiving equipment. It is the responsibility of the manufacturer to demonstrate in their TCF that the equipment does not generate such emissions and hence does meet the essential requirements. If the CB is not satisfied that the TCF accomplishes this then it should not provide a positive report or test certificate. (EMCTLA [19])*

> *As the topic of PLC is very controversial and developments and activities are on-going at several levels, Competent Bodies when asked to carry out a TCF assessment on a PLC system, should take all the latest developments and activities into account. … Although the situation with regard to these systems is still constantly changing, CBs should keep in mind that the systems must meet the requirements of Article 4 of the EMC Directive. (ECACB [20])*

The sensitivity of both of these documents can be gauged from the fact that neither of them were finally published in this form. Their sub-text was that there was very considerable doubt that any PLT system could meet the essential requirements embodied in Article 4. So any Competent Body which provided a positive report or certificate was, to put it mildly, adopting an exposed position.

The position changed with the adoption of the second edition of the EMC Directive, and the publication of a new guidance note from the ECANB [21]. This advises the use of the emissions measurement and limits according to the draft document CISPR/I/257/CD (see later), along with mitigation measures as proposed in the companion CISPR document (adaptive notching, also discussed later). But CISPR/I has already (within a few months of its circulation) rejected the method of CISPR/I/257/CD. This leaves the unsatisfactory position that EU Notified Bodies are being advised in the ECANB guidance to use an inadequate method for giving a compliance opinion.

The alternative, now available to manufacturers under the second edition EMC Directive, is to perform their own "EMC Assessment" without seeking the opinion of a Notified Body and without fully applying EN 55022. This leaves them open to a greater risk of challenge to their compliance statement; but given the lengthy process and uncertain outcome of such a challenge, some manufacturers might opt for this approach.
The fifth edition of CISPR 22/EN 55022, published in 2006 and harmonised with a date of withdrawal of older editions of 1st October 2009, has caused further upset to PLT manufacturers. This is because it includes a flowchart (Figure C.10) which determines the appropriate method for testing a telecommunication port. If this port is defined as a "mains" type (i.e., a PLT modem) then it insists that the test should be done according to the standard method applied to all types of mains-powered equipment. This has removed any lingering hopes that an alternative procedure that allowed the device to pass, could be applied – unless and until CISPR 22 is amended further.

Opening the floodgates

The EMCTLA guidance quoted above touches on a consequence of PLT which has caused concern to many in the relevant administrations. It must be assumed that the mains supply already carries noise from other apparatus which may approach the limits of EN 55022, even if everything connected is in full compliance with the Directive. For PLT to operate, its signals must be greater than this minimum noise level, and so it must breach these limits, almost by definition. As we have seen, this is indeed so, by several tens of dB. Yet all other mains-connected equipment, such as ITE, medical and household appliances, lighting and so forth – is subject to the standard mains conducted emissions limits.

What is to prevent the manufacturers of such equipment, which after all forms the vast bulk of products placed on the market within the EU, from demanding to know why PLT has received such special treatment? Why, they would want to know, do we have to comply with these limits, at considerable extra cost to our industries, when this technology alone is granted exemption? If PLT can flagrantly flout the limits and still protect the radio spectrum, they would say, so can we. But of course, were they to do that, it would open the floodgates to an uncontrolled escalation of interference on the mains wires. To mix metaphors more bluntly, it would drive a horse and cart through the principles of interference control established over decades.

Nevertheless, this exposes a contradiction at the core of the case for PLT. It can only operate if it is indeed granted special status to apply RF disturbances to the mains lines. It must, in fact, be regarded as a special case in the context of the EMC Directive. It cannot possibly comply with the requirement not to generate an electromagnetic disturbance exceeding "a level allowing radio and telecommunications equipment and other apparatus to operate as intended"; because, since the limits are set to achieve this requirement, it must itself exceed those limits and therefore breach the requirement.

Attempts to write a PLT equipment standard

Mindful of this contradiction, and parallel to other standards activities on PLT, CISPR/I is looking at ways to adapt CISPR 22 to apply in a meaningful way to PLT. The PLT project team has produced a succession of drafts, each of which seems to have provoked more controversy than the last, in defiance of the established method of standards production in which consensus is reached by an iterative process of comment and refinement.

The approach they have taken has been to re-define the mains connection for a PLT modem as "A port connecting to power lines supporting data transfer and telecommunications". It is measured once in the conventional way, with the established limits, with the communications function inactive; and it is then measured again, in a different way, with the communications function active. The second way relies upon treating the live and neutral wires as a balanced pair, and measuring only the common mode signal through a network (not the standard mains LISN – a decision which has itself provoked controversy) which applies a defined degree of longitudinal conversion loss (LCL).

Clearly, the LCL figure is crucial for this approach. The higher the value, the less interference is converted to common mode and so the easier the limits are to meet; or, the higher the level of differential signal that can be transmitted and just stay within the limits. The figure mooted in an early draft (CISPR/I/89/CD) was 30dB across the whole frequency range. But this figure was decidedly optimistic, and it was revised down to 24dB in the later draft, CISPR/I/257/CD [22]. Even this is too high to be acceptable to the majority of CISPR, and 6dB was to be the next proposal, tying in with the 7.5dB mains symmetry factor offered by the COST 286 work. But it appears that there is a practical difficulty in constructing a network that would both create a 6dB LCL and pass the wanted data signal – the standard CISPR mains LISN, used for conducted emissions tests for many years, actually gives an effective 6dB conversion between differential and common mode, since it measures half the differential signal on each line with respect to earth, but it deliberately blocks the wanted signal.

So, having gone around in several circles, the project team is now heading back towards specifying a higher LCL but with a different set of limits. In doing that, as a result of a higher-level decision within CISPR, it will have to verify that any new set of limits it comes up with are adequate to protect the radio spectrum.

Notching to the rescue

Having repeatedly run into the buffers on the question of measurement and limits, the CISPR/I project team has turned its attention to other technical fixes. The one that is causing most interest is adaptive notching. The way this works is described in CISPR/I/258/CD [23] as follows:

> *Adaptive Notching is a new technique in an advanced state of development in industry and in ETSI. It aims to protect in-house short wave broadcast reception and avoids static notching of all broadcast bands at all times, which would result in substantial permanent performance loss. Laboratory and field tests jointly with the EBU have successfully demonstrated this technique. Adaptive Notching is a powerful mitigation technique for PLT devices.*
>
> *Adaptive notching operates autonomously. The modems sense the radio frequency spectrum, detect the broadcast channels received* ***with usable quality*** *at the site and at the time and notch out these channels in the transmitted signal. The loss of throughput of a PLT system due to adaptive notching is very low.* ***Only the few broadcast channels which offer useful indoor reception at a given time are notched.*** *(my emphasis)*

The status of CISPR/I/258/CD is not entirely clear; it seems to be meant as no more than a report, but there is pressure to implement it as a standard requirement, and as said earlier, it is already viewed in this light by the ECANB guidance. This would be an entirely new development in the history of radio spectrum protection. It is clearly intended to address the powerful broadcasting lobby which has been a major stumbling block to the acceptance of PLT within CISPR, and there is every likelihood that if the technique is made mandatory within CISPR 22, it will neuter the objections of this group. What are the implications of this?

Note the emphasis in the above quotation. It is *the PLT modem itself* which judges what broadcast signals are received "with usable quality" and only these frequencies are notched – the rest of the spectrum is blotted out. So what becomes of the specialist user of the HF bands: the short-wave listener, the seeker of interesting but low-level broadcasts, the DX-er, the radio astronomer, and other uses such as long-distance aircraft communications? Such users clearly do not have any influence on the PLT modem to represent their interests. This is possibly the first time that an interference control agency has proposed to cede its authority so comprehensively not just to a third party, and not even to another authority, but to the whim of an autonomous piece of electronics in somebody's home. The phrase "driving a horse and cart through the principles of interference control" has already been used in this article. If CISPR/I actively votes this amendment into being, those principles are clearly being re-invented wholesale.

Aside from the issue of principle, some unanswered questions remain. Firstly, will it work even within its own remit? There appears to be no acknowledgement within CISPR that intermodulation could undo the effect of the notches and "fill in" the holes carefully left in the spectrum for the few privileged broadcast frequencies that are deemed to be usable. Laboratory and field trials will not answer this question – only experience.

Secondly, how would the operation of a modem using adaptive notching be tested and verified? Accurate standardized EMC emissions measurements are notoriously difficult to achieve even assuming a static interference source. How long would it take to develop and validate a new test method for such a device within CISPR, and what would the PLT industry be doing meanwhile?

Third, where does it leave the mainstream of electronic products that are not PLT modems? If an enterprising switchmode power supply designer were to create a power supply that was able to dynamically and adaptively notch its switching frequency emissions (admittedly unlikely with the present state of the art), would it benefit from the same waiver in emissions limits? If not, why not? More importantly, if the principle of uniform emissions limits is breached in this special case, there will surely be many other special cases to follow. CISPR must realise the nature of the Pandora's box it seems intent on opening.

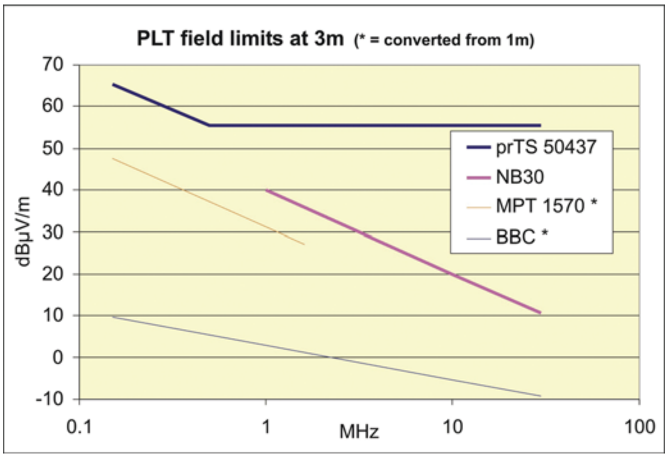
Another mitigation technique that could prove more beneficial is adaptive power management, briefly mentioned at the beginning of this paper. Reducing the power output to the minimum necessary to communicate might, in favourable circumstances, allow a PLT modem to operate at levels compatible with existing limits. But as with notching, this would be at the expense of delivered bit-rate; and it would limit the possible size of installations that the technology could address, since a large distributed system (think of a hotel, for instance) would still need high power levels just to cover the required distance.

Attempts to write a PLT systems standard

Meanwhile, acting in parallel, the CENELEC/ETSI Joint Working Group (JWG) produced in 2004 a draft of its Technical Specification (NB: not a standard) for the measurement of emissions from an operating PLT *network* [4]. This was restricted to limits and methods of measurement for electromagnetic emissions emanating from access powerline communications networks; in other words it didn't apply to in-home networks. Over the frequency range from 0.5 to 30MHz, it applied a limit of 4dBµA/m, which is taken as equivalent to 55.5dBµV/m, at a distance of 3m. As has been observed earlier, some national administrations thought that such a value was about 40dB too high.

In a presentation to the EC's October 2003 workshop on PLC, the chairman of the JWG wryly observed the dilemma that was facing him regarding the question of limits:

1. Radio users and some administrations: Tighten existing limits by 30 dB
2. Telecom suppliers and operators and some administrations: Continue to apply existing limits
3. PLT suppliers and operators: Relax existing limits by 30 dB



Or, as has also been observed, the spectrum users and PLT operators do actually agree on the values. They just disagree on whether they should take a negative or positive polarity.) The TS was never published, and in the end, in 2006 the JWG agreed to stop work on the project. It fell short of returning its Mandate to the European Commission, which would effectively have been an admission that PLT networks were incompatible with radio reception; it carried on work in other areas, in the hope that the networks standard could "resume some time in the future when new technology was in place". Because the EC Mandate was still active, this had the effect of preventing national authorities from introducing national regulations on their own initiative for the conformance of networks. In fact, with the advent of the mitigation methods referred to earlier, work has indeed resumed, but at the time of writing there is still no published specification.

Meanwhile, an Australian radio amateur has developed a prediction program [24] for determining the level of local interference that can be expected from a system which just meets the limits that were suggested in the original TS, at a given distance and frequency.

The graph above shows some of the limits that have been proposed, and demonstrates the wide variation between the values felt to provide protection for radio users (BBC) and the values that might be acceptable to PLT operators (prTS 50437).

Conclusions

A number of broad conclusions follow from the discussion outlined in this paper:

- PLT technology has the capability to create widespread interference, amounting to a denial of use, to users of the HF radio spectrum;
- This interference capability is inherent in the technology, particularly because of its use of standard mains wiring;
- Proposed technical fixes, such as frequency selective and adaptive notches, have limitations and cannot satisfy all users of the HF spectrum;
- Attempts to find a compromise set of system radiated emissions limits which will satisfy both HF users and PLT operators are bound to fail, since there is 50–60dB between them;
- Similarly, attempts to create a product related emissions standard for PLT equipment involve unmanageable technical contortions or a re-definition of what is meant by protection of the radio spectrum;
- Nevertheless, the political imperative behind the expansion of broadband over PLT is sufficiently strong that in some countries it is likely to outweigh any imperative for radio protection.

From the point of view of radio users, PLT is a technology too far.

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