
# IMMUNITY TESTING BELOW 150 kHz:
# THE UNIVERSAL SOLUTION – NSG 4060 GENERATOR

New requirements for EMC immunity testing in the lower frequency range can now be tested with a complete test generator solution. A large number of current product standards such as EN 61326-3-1, IEC 61850-3, IEC 60255-26, IEC 60533 and IEC 60945 are supported on the basis of the standards IEC 61000-4-16 and IEC 61000-4-19. The key to the test solution is a generator with a unique operator interface and intuitive menu design, with output signal and impedance determined by the coupling device selected. Time-saving analysis options to monitor the testing are available through comprehensive interfaces.

**NSG 4060 Highlights:**

- **Signal generator with built-in-amplifier for the 15 Hz to 150 kHz frequency range**
- **NSG 4060-1 extension unit for IEC / EN 61000-4-16, to cover DC and short-term testing up to 330 V**
- **IEC / EN 61000-4-19 voltage testing with CDND M316-2 and current testing with CT 419-5**
- **5.7″ colour display with intuitive user interface**
- **Comprehensive interfaces for test monitoring**
- **Client-specific test reporting via auto-report funktion**

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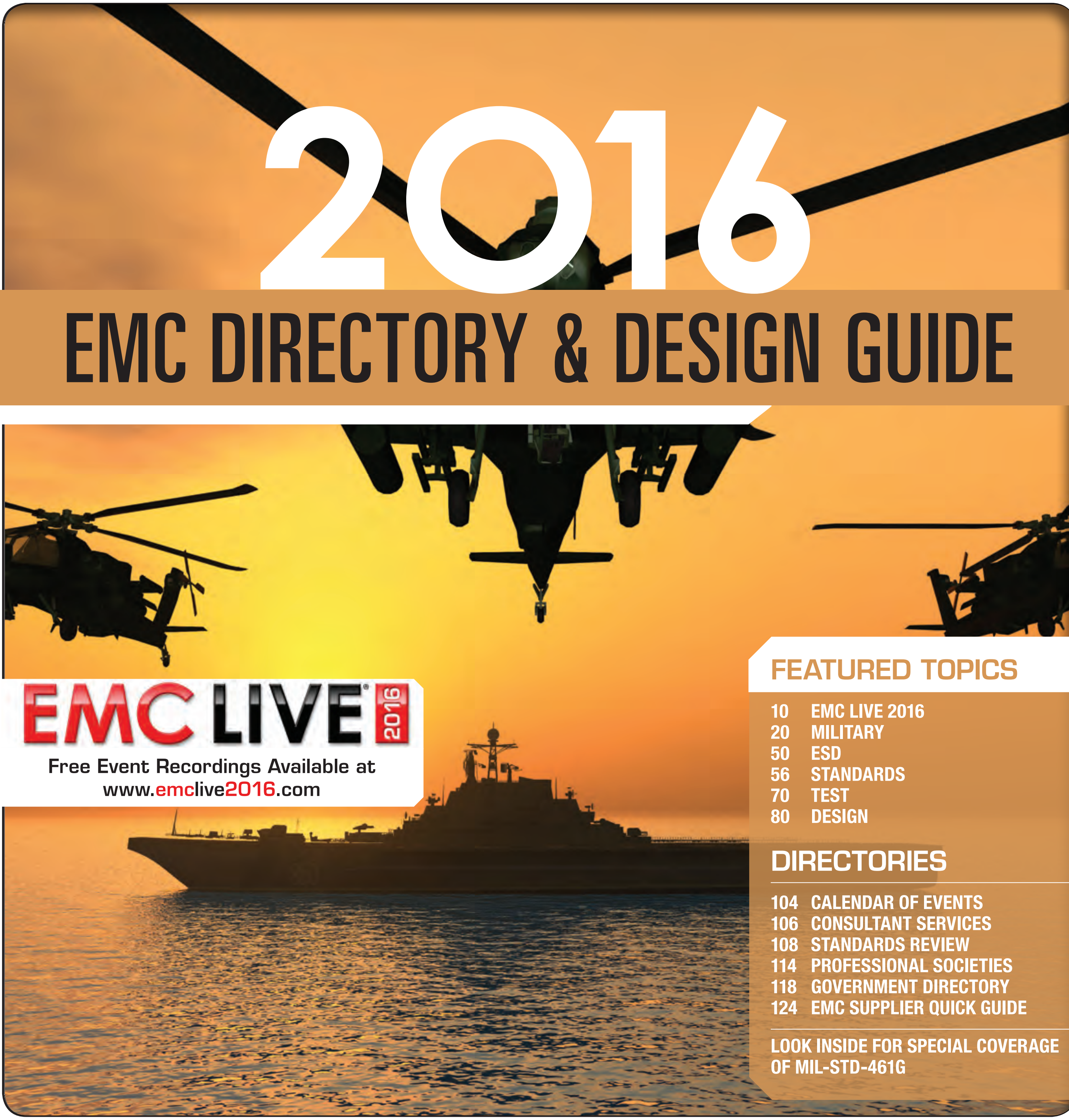
# interference technology

THE INTERNATIONAL JOURNAL OF ELECTROMAGNETIC COMPATIBILITY™



# 2016 EMC DIRECTORY & DESIGN GUIDE

EMC LIVE 2016

Free Event Recordings Available at www.emclive2016.com

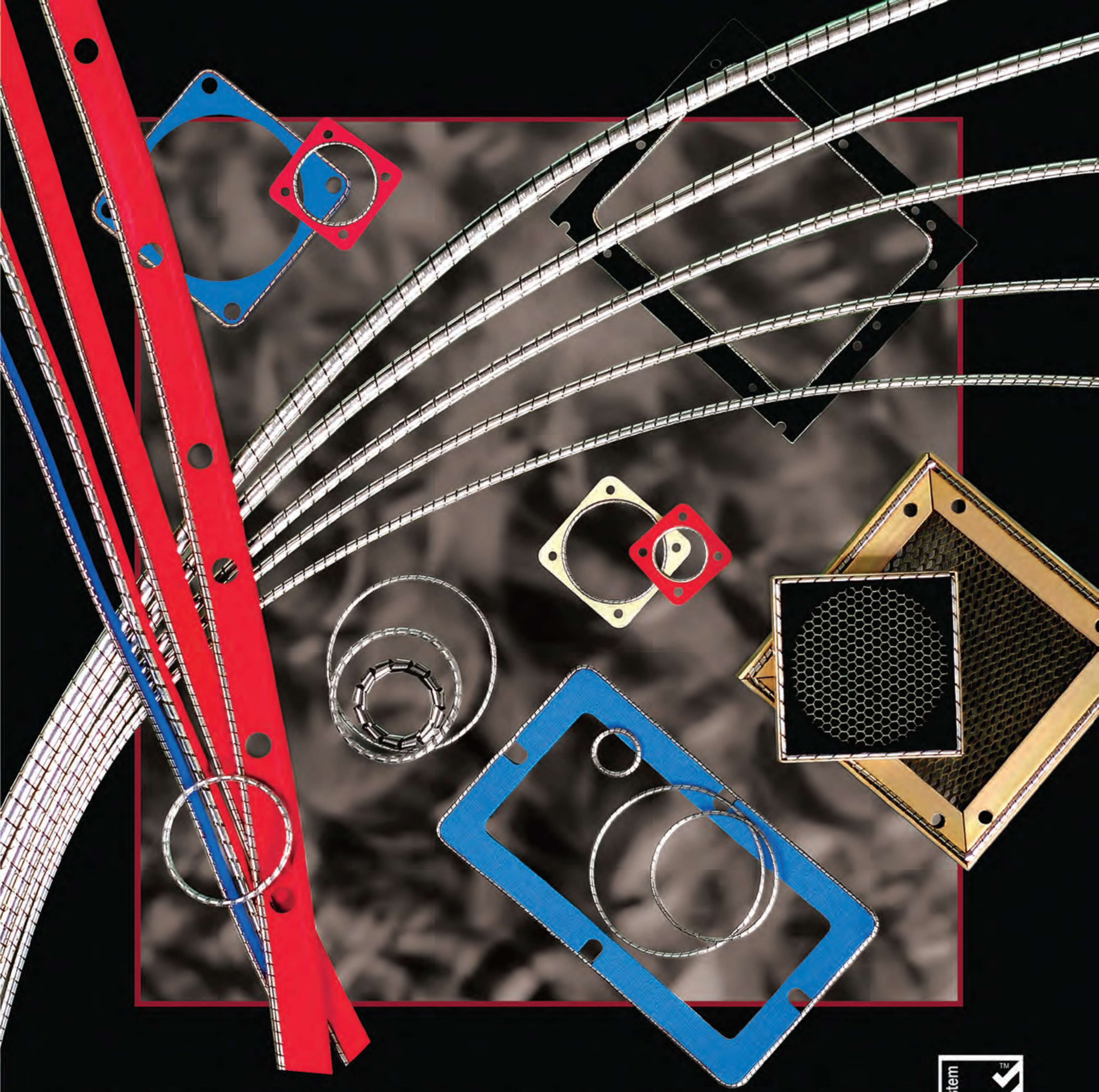
## FEATURED TOPICS



## DIRECTORIES



LOOK INSIDE FOR SPECIAL COVERAGE OF MIL-STD-461G



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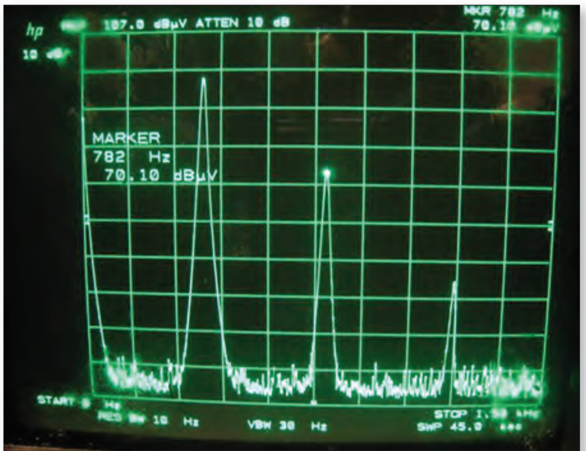
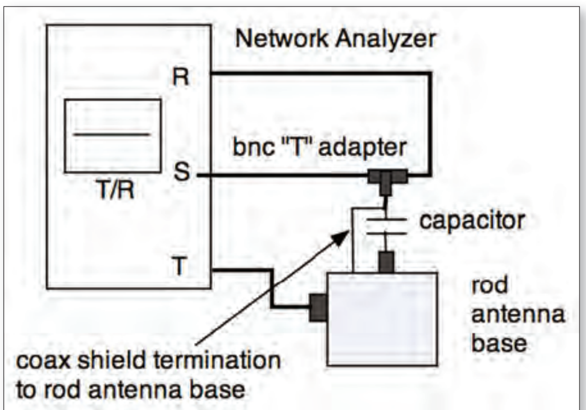



FEATURE - P.26

800 Hz ripple riding on a 400 Hz ac power bus, measured in the frequency domain. The PRD has a -66 dB transducer factor, so 66 dB has to be added to measured values to get to values on the power bus. (From ***MIL-STD-461G: The Compleat Review*** by Ken Javor)

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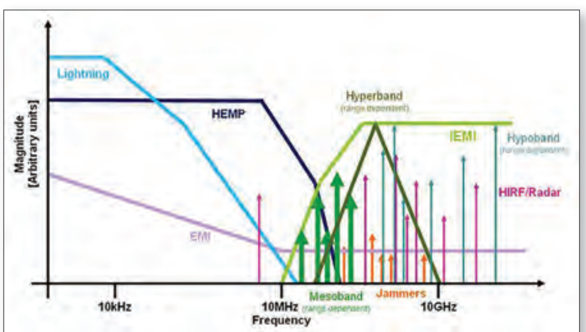
41" rod antenna base transducer factor measurement. (From ***Why Is There AIR (in MIL-STD-461G)?*** by Ken Javor)




P.44

Frequency and comparable magnitudes of the various EM threats. (From ***The IEMI Threat and a Practical Response*** by William Turner)


Our expertise takes you to the top.
EMC solutions from Rohde & Schwarz.
We provide everything you need for development, precompliance and compliance measurements to ensure successful EMC certification.
Exceptionally fast EMI test receivers
Efficient diagnostic tools for detecting EMI
EMC software packages for interactive and fully automatic measurements
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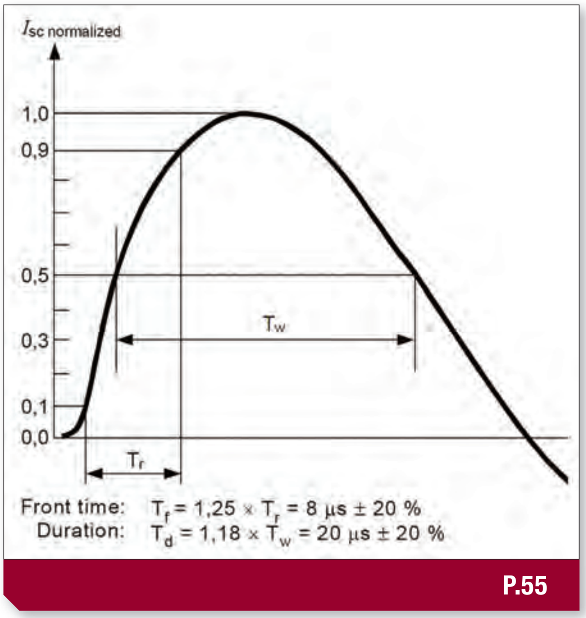


Waveform definition in 3rd edition (Td). (From ***What's new: IEC 61000-4-5 Second Edition vs. Third Edition*** by Jeff Gray)


Troubleshooting kit with most of the major components shown. The spectrum analyzer is the Thurlby Thandar model PSA6005 and tunes from 10 MHz to 6 GHz. Everything fits inside a Pelican 1514 roller transit case. The contents are described in Part 1 and Part 2 of this article. (From ***Assembling A Low Cost EMI Troubleshooting Kit – Part 1 (Radiated Emissions)*** by Kenneth Wyatt)

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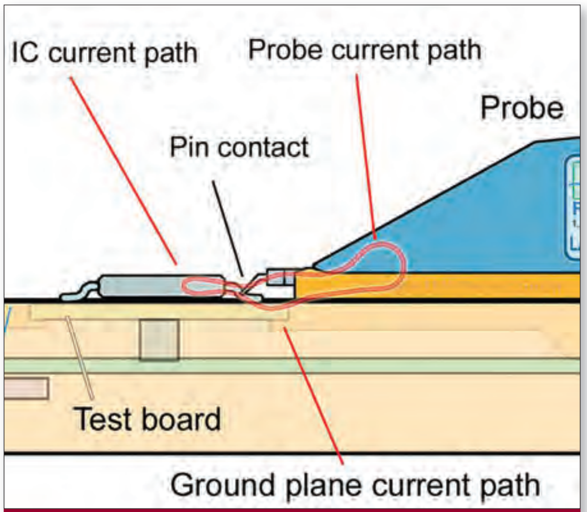


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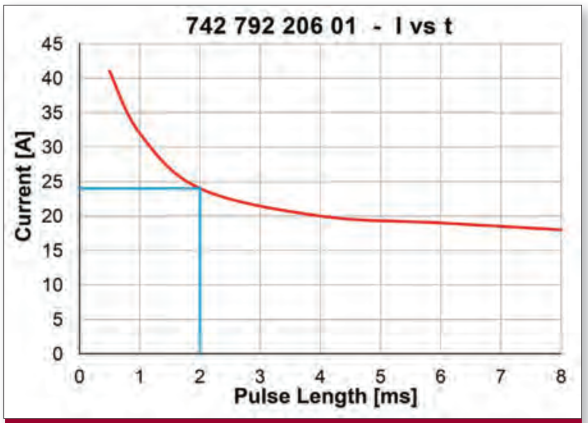
Measurement system for pin current and pin voltage. (From ***Is EMC prepared to handle the challenges of the Internet of Things?*** by Gunter Langer)




P.97

Specified peak current load capability. (From ***Multilayer SMD Ferrites Optimized for Peak Current Loads*** by Markus Holzbrecher)



***InterferenceTechnology—The EMC Directory & Design Guide***, ***The EMC Symposium Guide***, and ***The EMC Test & Design Guide*** are distributed annually at no charge to qualified engineers and managers who are engaged in the application, selection, design, test, specification or procurement of electronic components, systems, materials, equipment, facilities or related fabrication services. To be placed on the subscriber list, complete the subscription qualification card or subscribe online at **InterferenceTechnology.com**.

GUEST EDITORIAL

# From the Editor

**I WANTED TO** introduce myself as the new Senior Technical Editor for Interference Technology. I spent the early part of my career in the aerospace industry as a design engineer and the last 20+ years as an EMC engineer, test center manager, and EMC lead for Hewlett-Packard and later the spin-off, Agilent Technologies. In 2008, I "retired myself" early and started a consulting business helping other companies with their EMC compliance issues, as well as provide training in EMC, troubleshooting, and pre-compliance testing. I'll be continuing as a consultant while providing editorial direction.

I started subscribing to Interference Technology in 1972, just a year after Robert Goldblum started the publication. I was still attending college at the time, but was always impressed with the technical content of what was then called Interference Technology Engineers Master (ITEM). This was also well before I had any inkling I'd spend most of my career in EMC. Now here I am honored to be editing the same publication!

Interference Technology has always had great technical content for the EMC professional and my vision is to continue that, as well as publish basic information on product design and pre-compliance measurement techniques for those product designers that may not have had a formal education in electromagnetic compatibility. If you're interested in contributing technical articles to Interference Technology, check out the Editorial Contributions link at the bottom of our web site and feel free to drop me an email with your proposal.

I see a number of trends in technology that I believe will keep us EMC engineers and product designers busy for years to come. Some of the new technology includes vehicle wireless and vehicle-to-vehicle systems, continued advances in healthcare instruments and mobile health systems, smart home, mobile payments with use of bio-security, and advanced interconnectivity of military and space systems through mmWave technology.

Some of these technical advances will be highlighted in our upcoming EMC Live 2016 Event, April 26 through 28, as a series of exciting webinar presentations from a variety of industry leaders. We'll have two keynote speakers this year to kick off the webinar presentations. On April 26, Dr. Dev Palmer of DARPA will be discussing developments in mmWave technology that are enhancing security and connectivity of military communications and control. On April 27, John McCloskey, chief EMC engineer at Goddard Space Flight Center, will be discussing the upcoming James Webb Space Telescope and the EMC testing challenges that were involved.

One way Interference Technology will help readers keep up with trending technologies is our new series of downloadable digital mini guides on various technologies and how they relate to EMC. The first one was the 2016 Real-Time Spectrum Analyzer Mini Guide, which discusses how this technology has revolutionized the way we look at wireless and digital signals. It also offers a powerful EMI troubleshooting tool for intermittent interference issues. This new guide is available as a link from our home page.

Later in 2016, we'll be publishing guides on Military EMC, Shielding, Automotive EMC, and Wireless Interference. Please register for our weekly newsletters so you'll be informed when these new mini guides become available.

With all the wireless technology infrastructure being developed for our homes, vehicles, and health systems, and military/aerospace, we EMC engineers, compliance engineers, and product designers will have our collective hands full.

It's been said we live in exciting times. Amen to that!

*Cheers, Ken Wyatt, kwyatt@interferencetechnology.com*

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THE INTERNATIONAL JOURNAL OF ELECTROMAGNETIC COMPATIBILITY

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# EMC LIVE® 2016

## Free Recordings Available at www.emclive2016.com

EMC Live 2016 was a huge success, and we hope you had the opportunity to join us. If not, the recordings of the events listed in the technical program below are freely available at www.emclive2016.com. This unique 3-day online event featured live webinar presentations and practical solutions to electromagnetic interference (EMI) challenges. Various electromagnetic compatibility (EMC) topics including shielding, grounding, filtering, standards, pre-compliance and testing were covered.

# Technical Program

## TUESDAY, APRIL 26

### KEYNOTE WEBINAR

***Breakthrough Military Applications of mmWave Technology***

**10:00 a.m. – 10:45 a.m. (EDT)**

#### OVERVIEW

The worldwide availability and proliferation of inexpensive, high-power commercial amplifiers and sources have made the electromagnetic spectrum crowded and contested in the RF and microwave regions. The wealth of technical advantages offered by operating at higher frequencies, most notably the wide bandwidths available, are pushing both commercial and DoD systems into the millimeter wave (mmWave) region and beyond. However, operation at these higher frequencies poses significant challenges as the available power from electronic devices decreases as operating frequency increases. The decreasing available device power is compounded by increasing atmospheric attenuation in the mmWave region of the spectrum. The DARPA mission is to create breakthrough technologies for national security. In pursuit of this mission, DARPA programs have created innovative new mmWave solid-state and vacuum electronic amplifiers with unprecedented bandwidth and power, and have demonstrated their utility in relevant communication and sensing applications. This talk will review some of these breakthrough programs and describe the path forward for mmWave technologies and applications.

#### SPEAKER

**Dr. Dev Palmer** is a program manager at the Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office, responsible for a portfolio of research projects focused on creating the innovations in communications and sensing that will drive the next generation of DoD systems. He is a fellow of the Institute of Electrical and Electronics Engineers (IEEE) and a member-at-large of the U.S. National Committee of the International Union of Radio Science (USNC-URSI). His success in guiding research and technology transition has led to his selection for the Army Research Laboratory Award for Program Management in 2010, the Army Superior Civilian Service Medal in 2011, and the Secretary of Defense Award for Excellence in 2013.

Presented by:

DARPA

### WEBINAR

***Visualize, Localize and Troubleshoot EMI Signals with Real-time Spectral Analysis***

**11:00 a.m. – 11:45 a.m. (EDT)**

#### OVERVIEW

Troubleshooting and localizing intermittent signals or multiple layers of broadband and narrowband signals can be frustrating even for the most seasoned RF engineer. In this webinar we will learn about the capabilities of different types of spectral analysis and demonstrate how real-time can literally make previously-hidden signals leap into plain view.

Watch Recordings at
www.emclive2016.com

### SPEAKER

**Lee Hill**, Founding Partner of Silent Solutions LLC, is an industry expert in electromagnetic compatibility and provides EMC troubleshooting services, design reviews, and training to a wide variety of industries nationally and around the world. Lee also teaches graduate-level classes in EMC at Worcester Polytechnic Institute (WPI), University of Oxford (England), and for the IEEE EMC Society's annual Global University and EMC Fundamentals program. He earned his MSEE in electromagnetics from the Missouri University of Science and Technology EMC Laboratory.

Presented by Platinum Sponsor:

ROHDE&SCHWARZ

## PRODUCT DEMO

### *Rohde & Schwarz Presents: New Product Introduction! The Best EMI Receiver to Date*

**11:50 a.m. – 12:05 p.m. (EDT)**

### OVERVIEW

With a long history of developing world class and industry leading EMI Receivers, the R&S® ESW is no exception. Superior noise floor, dynamic range, speed with time domain scan, a real-time mode with persistence display for EMI diagnostics and an intuitive graphical user interface. And these are only some of the features why this instrument will speed up and help to better your EMI measurements.

This demonstration will walk you through the steps of creating customer limit lines, setting up and executing a scan with and without time domain scan, interactively analyzing the peaks, and then analyzing the emissions with real-time mode persistency display and spectrogram. Join us and find out what all that hype is about!

### PRESENTER

**Bill Wangard** is the EMI receiver and radio monitoring product manager at Rohde & Schwarz. He has 20+ years of RF and Receiver experience at Motorola and Rohde & Schwarz. Bill authored numerous patents at Motorola.

Presented by Platinum Sponsor:

ROHDE&SCHWARZ

## WEBINAR

### *Streamline EMC Compliance Testing with Pre-scan Analysis Tools*

**12:15 p.m. – 1:00 p.m. (EDT)**

### OVERVIEW

Measurement accuracy is a critical requirement for EMC Compliance testing. This webcast will discuss tools that can be used to overcome frequency and amplitude measurement errors related to measuring emissions over broad frequency ranges. It opens with a discussion of the measurement errors associated with making pre-scan measurements used to identify suspect emissions prior to final measurements. These errors are caused by characteristics of both the emissions and the measuring receivers. It then discusses in detail two powerful tools that help EMC professionals improve the accuracy and quality of their final compliance measurements.

### SPEAKER

**Mark Terrien** has over 20 years of product development experience with Hewlett Packard and Keysight (formerly Agilent) Technologies, with a focus on EMC receivers, spectrum analyzers and microwave test equipment. He holds an MBA from Golden Gate University in San Francisco and an MSEE in electromagnetic wave theory from the University of Wisconsin-Madison.

Presented by Silver Sponsor:

KEYSIGHT TECHNOLOGIES

## PRODUCT DEMO

### *EMSCAN Presents: Diagnose and Debug PCB-Level EMC/EMI Problems in Seconds on Your Desktop*

**1:05 pm – 1:20 pm EDT**

### OVERVIEW

Do you want to pass EMC compliance tests quickly? Are you looking for fast and economical ways to design systems that generate the lowest possible EMI? Are you tired of spending time and money to find the components that may act as an antenna that can radiate electromagnetic energy? Do you want to avoid large loops of signal and corresponding ground-return lines? How can you ensure that high-frequency currents do not leave the PCB? Sign up to learn how you can find, characterize, and address unintended radiators or RF leakage to pass compliance testing at an anechoic chamber during any new PCB development process.

**PRESENTER**

**Ruska Patton** is responsible for the evolution of EMSCAN's real-time near-field measurement solutions. He has a comprehensive understanding of general EMC, EMI and RF design and troubleshooting, with excellent skills in related software applications and programming. Mr. Patton holds both a B.Sc. and M.Sc. in electrical engineering from the University of Saskatchewan. During his time at University, he was recognized with numerous IEEE awards and a distinguished research scholarship.

Presented by:

## WEBINAR

### *Automated EMC Testing to Make Your Job Easier*

**1:30 p.m. – 2:15 p.m. (EDT)**

**OVERVIEW**

In recent years, there has been a shift in the process of performing electromagnetic interference (EMI) and electromagnetic compatibility (EMC) testing from a manual approach to a software-driven, automated approach. Generally speaking, this automation has provided numerous benefits to both those responsible for performing testing, as well as for those whose product is under test. This discussion will provide an overview of traditional testing methods and the pros and cons of implementing automation and control software. We will discuss considerations for software selection, and offer predictions on the future direction of EMC test software.

**SPEAKER**

**Flynn Lawrence** is an applications engineer for AR RF/Microwave Instrumentation. At AR, Flynn is actively engaged in new application and product development and testing, worldwide sales and customer support, as well as hardware demonstrations and training. Prior to joining AR, Flynn was an EMC Systems and Test engineer, working in requirements maintenance, test planning and test execution on military space components and systems.

Presented by Gold Sponsor:

## PRODUCT DEMO

### *Siglent Presents: SSA3000X Spectrum Analyzer - Small, Lightweight & User-friendly*

**2:20 pm – 2:35 pm EDT**

**OVERIEW**

Siglent's SSA3000X family of spectrum analyzers offers a frequency range of 9 KHz to 2.1 GHz / 3.2 GHz. With their light weight, small size, and friendly user interface, the SSA3000s present a bright, easy-to-read display, powerful and reliable automatic measurements, and plenty of impressive features. With its available EMI option, the SSA3000X utilizes a Quasi-Peak detection circuit and the standard EMI filters used in the IF section. When used with its free EasySpectrum software, the user is guided through the Pre-Compliance steps of error corrections, setting testing limits, pre-scan / peak searches, final testing, and report generation.

The 350S1G6 is the culmination of years of research and development of hybrid circuit designs utilizing the latest materials, devices and process improvements. The result is an amplifier with greater power density and lower production costs than previously possible.

**PRESENTER**

**Steve Barfield** has been involved with electronic test and measurement instrumentation since starting his career at Hewlett Packard in 1978, where he started as a Field Engineer in both Dallas and Houston. Since that time he has worked with distributors for Agilent, Tektronix, Fluke, Keithley, and many others – as well as serving as the first sales manager for Rigol in North America.

Presented by:

## WEBINAR

### *EMI Pre-Compliance Testing Reduces Time to Market and Saves Money*

**2:45 p.m. – 3:30 p.m. (EDT)**

**OVERVIEW**

The ability to determine success likelihood prior to expensive compliance testing can significantly reduce product development cycle times, and reduce rework costs associated with compliance failures. Access to an affordable pre-compliance test package allows the development team to complete testing of radiated emissions and conducted emissions, as well as immunity testing, during sub-assembly development and prior to full compliance verification. Cost effective Spectrum Analyzers, RF Signal Generators and compliance software enable design teams to find EMC problems sooner and ensure compliance test success.

Watch Recordings at
www.emclive2016.com

**SPEAKER**

**Jason Chonko** is an applications engineer at Rigol Technologies with a focus on EMC and EMI applications. For over 12 years, he has been helping engineers get the most out of their gear. Jason has a B.S. in physics from Kent State University in Kent, OH.

Presented by:

## PRODUCT DEMO

### *Keysight Presents: Keysight Technologies Platform for Emission Security Testing*

**3:35 p.m. - 3:50 p.m. (EDT)**

**OVERVIEW**

This webinar will discuss the feature set of Keysight's Emissions Security System, including wider-available bandwidth and the ability to monitor, record, and automate. The conventional approach to RF emission testing uses manual, analog comparison techniques, which are time consuming and error-prone. The new emissions analyzer software from EMSEC Solutions Inc. (ESI) addresses these issues by using digital signal processing (DSP) techniques to automate the test procedures. We'll discuss the new B-Series Spectrum Analyzers used in the System, and the abilities to record I&Q for post processing. We'll discuss the system as a whole using screenshots of the software, and explain upcoming enhancements. Engineers involved in EMC radiated emissions testing for security requirements should attend.

**PRESENTER**

**Luke Quesnel** is a Solution Partner Account Manager at Keysight Technologies. Luke has been working with EMSEC Solutions to provide security emissions solutions to clients worldwide. He has been involved in the EMC test community for over 15 years.

Presented by:

## WEBINAR

### *Indirect lightning test: The new MIL-STD-461G CS117 vs. DO-160G Section 22*

**4:00 p.m. – 4:45 p.m. (EDT)**

**OVERVIEW**

General presentations on MIL-STD-461G were already available long before its official release, and will probably become even more popular in the coming years. This webinar introduces a precise analytical comparison of test requirements from MIL-STD-461G CS117 and DO-160G Section 22, as the former has been developed based on experience and know-how related to the latter. How similar or different the two standards are is to be decided by EMC Live 2016 attendees after the webinar. EMC PARTNER AG is the leading manufacturer of test equipment for indirect lightning testing, with more than 15 years of experience in the field.

**SPEAKER**

**Adrian Matoi**, currently engaged in market development and strategic sales at EMC PARTNER AG in Laufen Switzerland, holds a PhD in EMC. He has gained extensive experience working with test equipment manufacturers in the European EMC market and spent time gaining practical experience in an EMC test laboratory. Publications to his name on specific EMC topics ranging from evaluation of disturbances in automotive communication systems to research on EMF distribution in the environment are complemented in the past few years by a series of technical webinars, seminars and trainings on indirect lightning testing.

Presented by:

FREE EDUCATIONAL MATERIAL

Recordings of the EMC Live 2016 Events are Freely Available at:

**www.emclive2016.com**

## WEDNESDAY, APRIL 27

## KEYNOTE WEBINAR

### *EMC Test Challenges for NASA's James Webb Space Telescope*

**10:00 a.m. – 10:45 a.m. (EDT)**

#### OVERVIEW

The James Webb Space Telescope (JWST) will be the premier observatory of the next decade, serving thousands of astronomers worldwide. It will study every phase in the history of our universe, ranging from the first luminous glows after the Big Bang, to the formation of solar systems capable of supporting life on planets like Earth, to the evolution of our own Solar System. The science payload of JWST is the Integrated Science Instrument Module (ISIM), which consists of four instruments. This presentation describes the challenges associated with the electromagnetic compatibility (EMC) tests performed on the ISIM at NASA's Goddard Space Flight Center (GSFC) in August 2015. By its very nature of being an integrated payload, it could be treated as neither a unit level test nor an integrated spacecraft/observatory test. The presenters will describe non-standard test criteria along with non-standard test methods that had to be developed in order to evaluate the tests. The presentation includes results that demonstrate all test criteria were met in less than the time allocated.

#### SPEAKER

**John McCloskey** is the Chief EMC Engineer at NASA Goddard Space Flight Center in Greenbelt, MD, where he has worked since May 1988, after earning his B.S. in electrical engineering from Penn State University. For much of his first decade at NASA, he worked as a design engineer and contributed to such flight projects as the CIRS instrument aboard the Cassini spacecraft, which is orbiting Saturn. Around the beginning of his second decade, he took an opportunity to move into electrical systems engineering, contributing to such projects as EOS Aqua and the James Webb Space Telescope (JWST).

Presented by:

NASA

## WEBINAR

### *EMC Amplifiers – Going Beyond the Basics to Ensure Successful Immunity Tests*

**11:00 a.m. – 11:45 a.m. (EDT)**

#### OVERVIEW

Broadband amplifiers are used to generate the high field strengths required by EMC radiated immunity testing standards. Although output power and frequency range are the two most important specifications used in selecting an EMC amplifier, the overall performance of an amplifier is often strongly affected by additional internal and external factors. This webinar focuses on the basics and intricacies of immunity testing, a technical overview of EMC amplifiers as well as a practical discussion of how amplifier class, compression points, VSWR, foldback, and other attributes impact amplifier performance in real-world scenarios.

#### SPEAKER

**Paul Denisowski** is an application engineer at Rohde & Schwarz, where he specializes in solutions for EMC and radio frequency interference issues. He has over 20 years of both lab and field experience in test and measurement and has authored numerous whitepapers and webinars on a wide variety of interference-related topics. Paul holds a master's degree in electrical engineering from North Carolina State University and was also a visiting lecturer at the Tokyo Institute of Technology.

Presented by Platinum Sponsor:

ROHDE&SCHWARZ

## PRODUCT DEMO

### *Quell Presents: A Simple Production Solution: EESeal® Silicone Rubber Inserts for Connectors*

**11:50 am – 12:05 pm EDT**

#### OVERVIEW

EESeal® Silicone Rubber Inserts for connectors are an easy production solution compared to bulky adapters, filtered connectors, and other traditional EMI/ESD solutions. The EESeal® is made of resilient silicone rubber that is quick and easy to install in seconds by using just your finger tip and the mating connector. The EESeals® can even be installed in the field for retrofits. The patented construction allows them to survive extreme environmental abuse and EESeals® can be used for EMI filtering, ESD protection, grounding, adding pull-up resistors and more. Applications include: military, aerospace, medical, transportation, industrial and more. EESeals® typically can save you 20-50%. Free custom samples are available in as little as 24 hours and production in as little a 2-4 weeks.

#### PRESENTER

**Scott Lindberg** is the Director of Sales and Marketing at Quell Corporation, Albuquerque, NM. Scott has been in electronics industry for over 30 years and previously worked in the semiconductor industry as vice president of sales & marketing operations for Microsemi Corporation. Throughout his career he has served on many boards and committees and occupied most of the executive committee positions for the Electronics Representative Association (ERA). He became a Certified Professional Manufacturer's Representative (CPMR) early in the program and then became a member and officer for the Board of Governors, which has oversight of the program. He also was a member of the executive committee of the Manufacturer's Representative Educational Research Foundation (MRERF). Lindberg received a B.A. degree in business administration from the University of New Mexico.

**Watch Recordings at www.emclive2016.com**

Presented by:

## WEBINAR

### *RF Shield Enclosure Design Concepts for Electrical Engineers*

**12:15 p.m. – 1:00 p.m. (EDT)**

**OVERVIEW**

Many times electrical engineers are tasked by sheer necessity with designing mechanical sheet-metal parts when they need to specify a shielding enclosure. Some off-the-shelf shielding solutions are available in the marketplace. However, they are frequently not useful, especially when the board is already designed and manufactured or size or other performance constraints do not allow for the use of a one-size-fits-all shield. In most cases, a custom shield can be produced more quickly and for less money than an off-the-shelf product can be obtained. This webinar will cover RF shield design considerations, sheet-metal design rules for RF shield cans, and a discussion of how metal bends in full-thickness and half-etched bend line configurations.

**SPEAKER**

**Jamie Howton** grew up in England and was trained as a draughtsman back when they still used pencils and spelled it like that; he was a Sea Cadet and emigrated to the USA at the age of 16 with a sum total of $66. Jamie has worked in the photo-etching industry (and at Fotofab in one capacity or another) since 1987. He was hired to design phototools and within two weeks was the tooling department supervisor. Jamie was repeatedly promoted despite his best attempts to find work elsewhere, and once that reality had set-in, he dropped out of college (Columbia College, Chicago – Fiction Writing Program) to lead Fotofab's growth from a founder-run job shop to a professionally managed, world leader in rapid delivery of precision metal parts. Jamie has worked in and managed every operational position at Fotofab; he understands sheet metal part manufacturing and the photo-etching process intimately. In 2000, Jamie Howton and Dan Brumlik led a management buy-out of Fotofabrication Corporation from its founders. Jamie ran the company as president until 2011, when he moved into the Chief Technical Officer role. Since 2000, the partnership group has grown to four partners and four manufacturing companies under our management – all manufacturing is conducted solely in the U.S.A. We are dedicated to helping grow U.S.-based manufacturing – so our grandchildren have some place to work. Jamie and Fotofab were featured in season 14 episode 32 of "Modern Marvels – Acid," which first aired on the History Channel in 1993.

Presented by:

## PRODUCT DEMO

### *AR RF/Microwave Presents: An Industry-First 350-Watts Solid State Amplifier from 0.7 to 6 GHz*

**1:05 p.m. – 1:20 p.m. (EDT)**

**OVERVIEW**

Amplifier Research has recently developed a new solid state, single band power amplifier that outperforms the competition in both output power and bandwidth. Intended as an alternative to TWTA (traveling wave tube amplifier), the 350S1G6 provides wideband high linear output power over a single frequency band of 0.7 to 6 GHz. While the competition only offers this bandwidth in a dual band configuration, the continuous single band operation of the 350S1G6 provides for simplicity of operation. Typical saturated output power above 400 Watts and P1dB above 300 Watts are achievable. In addition to the impressive output power, the 350S1G6 offers low harmonic distortion and high output load mismatch tolerance.

The 350S1G6 is the culmination of years of research and development of hybrid circuit designs utilizing the latest materials, devices and process improvements. The result is an amplifier with greater power density and lower production costs than previously possible.

**PRESENTER**

**Anthony Peroni** graduated from The Pennsylvania State University in 1991 with a B.S. and M.S. degree in electrical engineering. For the past 25 years he has been involved in RF and microwave hardware design for both the consumer and defense electronics industry. He has extensive experience in all phases of discrete circuit, hybrid and MMIC design. Prior to joining AR in 2011, he was employed at Spectrum Microwave, M/A-COM, and Motorola.

Presented by Gold Sponsor:

## WEBINAR

### *Very-Near-Field Scanning Solutions for Diagnosing EMC Compliance Problems at the PCB Level*

**1:30 p.m. – 2:15 p.m. (EDT)**

**OVERVIEW**

When a device fails compliance testing in the EMC chamber, the best way to diagnose the problem is using the very-near-field. The array-based scanning technique developed by EMSCAN can display these very-near-field emissions in real-time to aid in problem-solving. The correlation of emissions to components on the PCB identifies the root causes and hints at potential solutions. Using this technique, a designer can get an "emissions map" of a PCB or product in "real-time" and identify EMI and EMC problems early in the design-cycle, thus saving time and cost. This technique can also visualize the source of emissions that caused systems to fail compliance testing and provide the insight required to fix the problem quickly. This presentation will include a discussion of the array-based very-near-field technique as well as examples of real boards tested of the EMSCAN EMxpert system.

### SPEAKER

**Ruska Patton** is responsible for the evolution of EMSCAN's real-time near-field measurement solutions. He has a comprehensive understanding of general EMC, EMI and RF design and troubleshooting, with excellent skills in related software applications and programming. Mr. Patton holds both a B.Sc. and M.Sc. in electrical engineering from the University of Saskatchewan. During his time at university, he was recognized with numerous IEEE awards and a distinguished research scholarship.

Presented by:

## PRODUCT DEMO

### *Rigol Technologies Presents: New Solutions for Affordable Pre-Compliance Testing*

**2:20 pm – 2:35 pm EDT**

### OVERVIEW

Today RIGOL is demonstrating our approach to EMC pre-compliance testing. Our webinar on Tuesday will describe techniques and strategies for eliminating expensive late stage compliance challenges that affect your time to market. This demonstration program will utilize our spectrum analyzers, signal sources, software, and common accessories to complete radiated and immunity tests. Come see how the RIGOL portfolio can help you solve your pre-compliance challenges at an unprecedented price point.

### PRESENTER

**Chris Armstrong** is the Director of Product Marketing & SW Applications at Rigol Technologies North America. Armstrong brings more than 15 years of experience in test & measurement from sensitive measurement applications to multipurpose benchtop testing to integrating complete systems that control instrumentation across a number of interfaces. Chris has obtained a Bachelor of Science in computer science & engineering from the University of Toledo and an MBA from Case Western Reserve University.

Presented by:

## WEBINAR

### *Problems in EMC Test Set-ups… and How to Fix Them*

**4:00 p.m. – 4:45 p.m. (EDT)**

### OVERVIEW

Fixing faults in EMC test set-ups, especially those in test chambers, can tie test-staff down for an inordinate amount of time. So start saving time and money by finding out how to identify and fix them.

### SPEAKER

**Tom Mullineaux** is a technical content creator and RF Engineer, and has been in the EMC industry for 20 years, both as a supplier to the industry and as a hands-on program manager, achieving EMC compliance for new products. Mullineaux received his degree in electrical and electronic engineering from Portsmouth University, England, and is a prolific writer of EMC related articles, with all articles having a strong slant toward the engineering basics behind the tests. He has given many IEEE society presentations, most looking at the physics behind today's commercial, automotive and MIL-STD tests.

Presented by:

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## THURSDAY, APRIL 28

## WEBINAR

### *Electromagnetic Emissions: Measurement Without an Anechoic Chamber*

**10:00 a.m. – 10:45 a.m. (EDT)**

#### OVERVIEW

Imagine your production-ready electronic device has just failed an EMC radiated emissions test. That requires time-consuming troubleshooting. Wouldn't it have been better to discover and solve this problem much earlier, during the initial design cycle?

In this webinar, we will discuss the relationships between integrated circuits, PCB design and system-level radiated emissions. The use of a shielding tent, sized to fit on your desk, will save the engineer development time and effort. Real-life radiated emissions issues will be explained, analyzed and solved. The analysis and discussion of a real-life example will provide attendees with a better understanding of troubleshooting and solving practical EMC emissions problems.

#### SPEAKER

After finishing high school, **Sven König, Dipl.-Ing. (BA)** studied electrical engineering. During his studies, he gained practical experience in EMC/EMI by developing electronic devices. Once he completed his degree, his gained more professional experience in different, small enterprises. In 2007, Sven joined the team of Langer EMV-Technik GmbH as development engineer. Langer EMV-Technik GmbH is an electro technical company that is active in the field of electromagnetic compatibility-related research, and the development and production of measurement tools. Sven is involved in the development of new measurement tools, practical troubleshooting of electronic devices, EMC/ESD tests on IC´s, as well as teaching the effects of EMC and ESD in Langer EMV-Technik seminars and on competent customer care.

Presented by:

LANGER
EMV-Technik

## WEBINAR

### *Emissions Simulation for Power Electronics Printed Circuit Boards*

**11:00 a.m. – 11:45 a.m. (EDT)**

#### OVERVIEW

The conducted and radiated emission of a switched-mode power-supply continues to be a challenge for both the designer and the engineers implementing these devices into their systems, especially with the trend toward smaller form factor and faster switching speeds. 3D EM simulation can be an extremely helpful tool for investigating, debugging and solving the common EMI issues that are encountered with these devices. In this webinar, we will look at a few examples of how 3D field-circuit coupled workflows make such simulations not only possible, but practical and accurate. Specifically, we'll consider the conducted emission of a motor control and a DC-DC converter for automotive applications, as well as the radiated emission of a DC-DC converter and the potential coupling to automotive AM/FM antennas.

#### SPEAKER

**Patrick DeRoy** completed B.S. (2011) and M.S. (2012) degrees in electrical engineering from the University of Massachusetts Amherst. His master's work focused on cable shielding and transfer impedance modeling using CST STUDIO SUITE and validating simulation results with measurements. He is application engineer at CST of America, where he supports customer modeling of EMC problems, including ESD, radiated emissions and BCI. He is also interested in the simulation of PCBs and mitigation of EMI for such structures.

Presented by:

CST

## PRODUCT DEMO

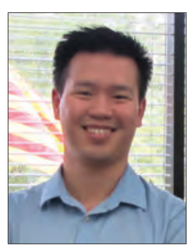
### *Bal Seal Engineering Presents: Complex Problem, Simple Solution — Achieving lower transfer impedance and more effective EMI shielding with springs.*

**11:50 am – 12:05 pm EDT**

#### OVERVIEW

The highly conductive properties and unique design of canted coil springs enable them to provide superior shielding, particularly in high-frequency, small-package applications. In addition, they can mechanically fasten with precisely controllable insertion and removal forces, thereby reducing system complexity and weight.

#### PRESENTER



**David Wang** is a senior project engineer at Bal Seal Engineering. He has several patents pending related to canted coil spring technology. He received his bachelor of science degree in electrical engineering and MBA from the University of California, Irvine. He has previously worked in the semiconductor, automotive, and consumer electronics industries.

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Presented by:

BAL SEAL ENGINEERING, INC.

## WEBINAR

### *An Insider's View on the Changes to MIL-STD-461G*

**12:15 p.m. – 1:00 p.m. (EDT)**

**OVERVIEW**

MIL-STD-461G was released to the public in December 2015 with sweeping changes to the EMC test standard. This webinar is more than a simple laundry list arrived at by performing a side-by-side "F" vs. "G" comparison. Instead, it is an insider account of into the issues with which the Tri-Service Working Group (TSWG) was grappling, and the thought processes behind the changes, as well as, the changes themselves. It also lists some of the issues brought to the table that were not incorporated in MIL-STD-461G, and why.

**SPEAKER**

**Ken Javor** has worked in the EMC industry for thirty years. He is a consultant to government and industry, runs a pre-compliance EMI test facility, and curates the Museum of EMC Antiquities, a collection of radios and instruments that were important in the development of the discipline, as well as a library of important documentation. Mr. Javor is an industry representative to the Tri-Service Working Groups, which that write MIL-STD-464 and MIL-STD-461. He has published numerous papers and is the author of a handbook on EMI requirements and test methods.

Presented by Platinum Sponsor:

ROHDE&SCHWARZ

## PRODUCT DEMO

### *AVI3000 covers latest requirements for indirect lightning testing*

**1:05 pm – 1:20 pm EDT**

**OVERVIEW**

Already well established as a supplier of equipment to test indirect lighting effects, EMC PARTNER introduces the AVI3000, an innovative test system for DO-160 section 22 and the new requirements of MIL-STD-461 CS117. AVI3000 offers full compliance up to level 3 for Pin Injection and Cable Bundle tests, including single stroke, multiple stroke and multiple burst. An EMC PARTNER representative, active member of the SAE AE2 committee, explains why AVI3000 is the best solution to test indirect lighting effects, according to latest standard requirements.

**PRESENTER**

**Nicholas Wright**, international sales manager for EMC PARTNER AG in Laufen Switzerland, graduated from Worcester College. Extensive experience in the defense industry provided a good foundation for a later transition to the EMC world. After 20 years in EMC, as development engineer and product line manager, he became active in standardization of indirect lightning as member of the SAE AE2 committee with responsibility for DO-160 Section 22.

Presented by:

EMC - PARTNER

## WEBINAR

### *Are you compliant? The new European EMC Directive (2014/30/EU) deadline was April 20*

**1:30 p.m. – 2:15 p.m. (EDT)**

**OVERVIEW**

The New EMC Directive is applicable from April 20, 2016 and 2004/108/EC is repealed. This webinar will review the requirements of the new directive, which is applicable to a wide variety of products including information technology equipment, test and measurement equipment, consumer electronics and industrial controls. This review will include equipment contained within the scope of the directive, the essential requirements of the directive, as well as routes to compliance and the necessary technical documentation that the manufacturer must establish and maintain.

**SPEAKER**

As Retlif's Director of Engineering, **Richard Reitz** is responsible for the technical oversight of all testing operations. Retlif's three testing facilities (New York, New Hampshire, and Pennsylvania) provide independent EMC and Environmental Simulation testing services to a broad range of manufacturers.

Richard holds a B.T. in electrical engineering technology and a B.S. in electrical engineering technology from the State University of New York, College of Technology at Farmingdale.

Richard is a Senior Member of the IEEE EMC Society and a member of the executive committee of the Philadelphia Chapter of the EMC Society. He has been a member of the National Cooperation for Laboratory Accreditation (NACLA) Board of Directors since 2001 and is the immediate past President. An iNARTE Certified EMC Accredited Test Laboratory Engineer, he also has served on the ACIL Board of Directors, the Conformity Assessment Section, its EMC Subcommittee, and the United States Council of EMC Laboratories.

Present by:

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## WEBINAR

### *Maintaining Impedance in High-Permeability, Split Core Ferrites for Low-Frequency Applications*

**2:45 p.m. – 3:30 p.m. (EDT)**

#### OVERVIEW

Ferrites are ceramic components that can be used to suppress electromagnetic interference (EMI) in certain applications. This presentation will discuss the basic properties of solid round ferrite cores, the impact an air-gap can have on the performance of these cores, and special considerations. In particular, this discussion will focus on the use of high-permeability materials, such as Fair-Rite's 75, in low-frequency suppression applications; because its permeability is relatively high compared to other soft ferrites used for this purpose, its use makes the effect of an air-gap much greater.

#### SPEAKER

**Rachael Parker** became vice president in July 2014 at Fair-Rite Products Corp. Although she oversees many operations within the company, Parker is focused primarily on the marketing aspect of the business. She has experience in product design, project leadership, and program management from her time at 3M and Oracle.

Rachael holds a Bachelor's degree in electrical engineering from University of Rochester, a masters degree in electrical engineering from Cornell University and an M.S. in engineering management from Tufts University.

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Fair-Rite Products Corp. Your Signal Solution®

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See you at EMC Live 2017!

# MIL-STD-461G: The *Compleat* Review

**KEN JAVOR**
EMC Compliance

*The deleted old,*
*The brand-spanking new.*
*That which was borrowed,*
*And that, eschewed.*

MIL-STD-461G WAS RELEASED ON 11 December 2015 and will become contractually obligatory on programs initiated after that date.

This account is more than a simple laundry list arrived at by performing a side-by-side "F" vs. "G" comparison. Instead, it is an insider account into the issues with which the Tri-Service Working Group (TSWG) was grappling, and the thought processes behind the changes, as well as, of course, the changes themselves. It also lists some of the issues brought to the table that were not incorporated in MIL-STD-461G, and why.

It will greatly assist the reader if a copy of MIL-STD-461G is available as this account unfolds.

As background, MIL-STD-461 is officially prepared by the US Air Force, but it is the product of a TSWG made up not surprisingly of representatives from the Army and Navy as well. In addition to Service members there are industry representatives, of which the author is one.

Since 1993, MIL-STD-461 has been on a five-year review cycle, to ensure that it remains current and useful. This does not mean a new revision has to be released every five years; just that a review must be performed on that cycle. It would be entirely acceptable to simply reaffirm the old version with no changes. To date, that hasn't happened.

MIL-STD-461D and MIL-STD-462D released in 1993 remain the major "revolution" in military EMI standards, with evolutionary changes following. MIL-STD-461E combined MIL-STD-461 and MIL-STD-462 into a single standard, obsoleting MIL-STD-462 in 1999. MIL-STD-461G makes the most structural changes since that time, adding two new requirements (lightning indirect effects, CS117, and personnel electrostatic discharge, CS118) while eliminating the CS106 requirement that was added the last time around in MIL-STD-461F. So we have a net increase of one requirement. There are also many other important changes, detailed herein.

One of the revolutionary aspects of MIL-STD-462D in 1993 was the inclusion of measurement system integrity checks that were performed prior to each emission measurement to ensure proper operation of the measurement system. To the author's knowledge, these checks have remained unique to MIL-STD-461 ever since.

The philosophy behind these checks gains its greatest expression in MIL-

STD-461G. The TSWG considers a real-time check of each set-up just prior to the actual measurement to be the best way to ensure an accurate measurement. To that end, several checks have been beefed up, but most importantly the regular calibration of transducers used in EMI testing has been de-emphasized. Section 4.3.11 *Calibration of measuring equipment* has been reduced in scope to devices such as EMI receivers and spectrum analyzers, oscilloscopes and (RS103) electric field sensors. The new text says, "After the initial calibration, passive devices such as measurement antennas, current probes, and LISNs, require no further formal calibration unless the device is repaired. The measurement system integrity check in the procedures is sufficient to determine acceptability of passive devices." A new SAE Aerospace Information Report, AIR 6236 has been written to support the verification of proper operation of such devices in the EMI test facility using only test equipment commonly available in an EMI test facility. The idea is that if a measurement system integrity check shows a problem, the AIR 6236 measurements will demonstrate whether or not there is a problem with a transducer. AIR 6236 is incorporated by reference only, and in the non-contractual appendix, at that. It is not part of any measurement system integrity check. Also the term "measurement system integrity check" globally replaces the inaccurate formerly used words, "calibration."

Another theme beginning with MIL-STD-461D through "G" is balancing what is technically correct vs. what it is possible to get the average test facility to do correctly. An example of this is the fixed distance for power wiring between test sample and LISNs. Since 1993, it has been a minimum of two meters, and a maximum of 2.5 meters, for all tests. Prior to 1993, under MIL-STD-462 back to 1967, the power wire length was one meter for CE/CS testing, and two meters for RE/RS testing. The idea was that for CE testing there would be better accuracy with less vswr-induced error with a shorter cable, but a longer cable was necessary for RE02 and RS03. But the sense of the TSWG was that too few people were doing that, so they compromised on one length for all tests under MIL-STD-462D and ever since. That is why CE102 only covers up to 10 MHz, instead of the previous CE03 running to 50 MHz.

Along these lines, MIL-STD-461G section 4.3.8.2 formalizes a requirement to check bond impedance between test sample and ground plane prior to EMI testing, and prior to cable-connection. It is disconcerting that this needs to be stated after a half-century of MIL-STD-461. Section 4.3.6 requires LISNs to be bonded to the ground plane with a resistance no greater than 2.5 milliohms. Section 4.3.7.2 says that the only antenna that can be in the shield room during a radiated test is the antenna in actual use. Translation: the shielded, anechoic-lined chamber is a test chamber, not a broom closet. It is distressing to see a chamber outfitted with expensive absorber, often exceeding MIL-STD-461 absorber treatment requirements, while at the same time every antenna used for RE102 and RS103 except the one in use is littered around the periphery of the chamber.

Similarly, sections 4.3.8.6.1 and 4.3.8.6.2 that describe cable layout in the test chamber now stipulate that the 5 cm above ground standoff is to be achieved using "non-conductive material such as wood or foam." And that the entire length of the cable, not just the two meters exposed to the antenna, be so-supported above the ground plane. Someone somewhere was using spare rf absorber to support cables…

A theme that began with MIL-STD-461F continues in "G", and that is responding to abuses of the standard by practitioners of EMC "law" as opposed to EMC engineering. Another way of saying this is that "lawyers" are misinterpreting the letter of the standard while ignoring the obvious intent. The use of shielded power cables where it wasn't justified resulted in a complete prohibition on the use of shielded power cables for EMI testing in MIL-STD-461F. This was described in an article on the MIL-STD-461F revision that appeared in the January 2008 issue of Conformity magazine:

> Prohibition of Use of Shielded Power Leads
>
> The wording in section 4.3.8.6 ("Construction and arrangement of EUT cables") is a little more definitive than in -461E, stating that shielded power conductors may not be used unless the platform on which the equipment is to be installed shields the power bus from point-of-origin to the load. There have been problems with equipment manufacturers asking for and receiving shielded power leads from the point-of-distribution (typically a breaker box) to the load, but with the power bus from the breaker box back to the generator being unshielded.
>
> Of course the fundamental rule is that test wiring simulate the intended installation. With a partially shielded power bus, the equipment manufacturer can claim that he gets a shielded feed on the platform while the integrator sees an unshielded main bus. MIL-STD-461E 4.3.8.6 wording was not conclusive on this subject: "Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation requirements." This problem is alleviated in MIL-STD-461F, which states in plain language precisely the above quotation, but then adds, "Input (primary) power leads, returns, and wire grounds shall not be shielded."

Similarly, the alternative field intensity pre-calibration technique using an antenna above 1 GHz that existed from MIL-STD-462D through MIL-STD-461F has now been removed, requiring real time leveling using an electrically short broadband electric field sensor over the entire test frequency range. The original alternative two-antenna technique was a grandfather clause from 1993 when many EMI test facilities lacked an electric field sensor covering 1 – 18 GHz, which were new and expensive at the time. There was and is nothing wrong with this technique, but EMC lawyers were twisting the meaning of the standard to say they could precalibrate the field in the absence of the test sample at all frequencies. The "cure" for this abuse was to remove the grandfather clause, after an informal survey of USA EMI test facilities revealed that 100% of those polled had the equipment necessary to perform real-time leveling over all frequencies from 10 kHz to 18 GHz.

Another response to EMC lawyer abuse is very subtle, and is found in section 5.17.1 RE102 applicability. In the "F" version, this sentence is found:

> "… The requirement does not apply at the transmitter fundamental frequencies and the necessary occupied bandwidth of the signal."

Find the diff rence in the "G" version:

> "… this requirement does not apply at the transmitter fundamental frequency and the necessary occupied bandwidth of the signal."

The diff rence is in the use of the plural "frequencies" in "F," and the singular "frequency" in "G." Believe it or not, EMC lawyers were interpreting the plural to mean the requirement didn't apply at any frequency to which the radio could be tuned, as opposed to the intent, which is that it doesn't apply at the frequency to which the radio is tuned during the test.

Yet another theme, this one unique to MIL-STD-461G, is an added emphasis on the testing of large, floor standing test samples whose height approaches the horizontal extent of the test set-up. In previous versions ("D" through "F") there was plenty of information on how to set up RE102/RS103 antenna positions for test set-ups with extended horizontal dimensions, but no corresponding information for vertically large enclosures, such as 19" racks. The RE102 and RS103 sections of this version of the standard now require a sufficient number of antenna positions such that the entire *area* of the test set-up has been interrogated/illuminated.

A combination of these two themes leads to a conundrum. A comment against the draft for industry review correctly pointed out that a high gain antenna of the type often used at microwave frequencies won't be able to illuminate a large enclosure such as a 19" rack and an electric field sensor placed per standard guidelines, because the illumination spot size can't cover both the enclosure and a properly placed sensor with sufficient clearance from the enclosure to avoid undue influence from it. This sort of situation calls for a precalibrated field, but that is no longer available. Such cases will require tailoring with buy-in from the customer.

There is a global clarification to requirements CS114, CS115, and CS116. The requirement to monitor cable current within 5 cm of the equipment front face is relaxed if the EMI backshell (or braid sock) extends beyond that distance. In that case, the monitor probe should be placed as close as possible to the backshell end. The 5 cm requirement is somewhat of an anachronism ever since the "E" revision, which reduced the maximum CS114 frequency from 400 MHz to 200 MHz. The concept behind the 5 cm rule was to monitor the current that was flowing into the test sample. This needs to be done within a tenth wavelength of the test sample, which is 7.5 cm at 400 MHz, but 15 cm at 200 MHz. Note the spectrum of CS115 and CS116 is lower than that of CS114, so that probe placement instructions based on CS114 suffice for these latter two requirements.

Another global change to the measurement system integrity checks is to move specified test frequencies away from the very end of a requirement frequency range, and away from a bandwidth break point, in order that the data trace show the complete response, and not a truncated version thereof.

We'll get something out of the way first even though it is out-of-order, because it is likely the most pressing concern for EMI test facilities. The two new requirements CS117 and CS118 require no test equipment diff rent from RTCA/DO-160 sections 22 and 25, with one exception. CS118 requires a contact discharge "target" as per EN 61000-4-2. If a test house has these test capabilities at present, they need buy no new test equipment. A summary table of equipment new to MIL-STD-461G is presented at the article end. It is presented at the end so that the reader can understand the context within which the new equipment is allowable and/or necessary. This table is not an endorsement, just a cross-reference of requirements, equipment and vendors.

There was a DoD input to include not only indirect eff cts of lightning, but also direct eff cts, as well. The TSWG rejected this on the basis that it doesn't belong in MIL-STD-461. Direct eff cts testing (RTCA/DO-160 section 23) doesn't naturally map into MIL-STD-461, because the pass/fail criterion is usually not proper operation, but lack of damage, or containment of damage so it doesn't propagate and cause an issue to other equipment/platform structure. Thus it more naturally falls within the purview of MIL-STD-810. It should be noted that RTCA/DO-160 "Environmental Conditions and Test Procedures for Aircraft" subsumes three diff rent military standards: MIL-STD-810 for environmental qualification, MIL-STD-704 for electrical power quality, and MIL-STD-461 for EMI control. Lightning indirect eff cts is close enough to MIL-STD-461 to be a comfortable fit there, but direct eff cts evaluation most assuredly is not.

An editorial change is that frequency ranges are no longer listed in the individual requirement titles, but rather moved to the applicability subsection, where they more naturally belong. Many requirements have diff rent start and stop frequencies depending on Service and application.

What follows is a list of what the author considers major changes of interest to the industry.

Section 1.2.2 tailoring of requirements now explicitly states that any tailoring must be approved by the procuring activity. This was always the case, but wasn't explicitly stated.

Most of the section 3 definitions have been tweaked. In particular, the definition of "Below deck" (section 3.4 in "F") has been expanded into two subsections in "G": 3.1.3 Below deck, and 3.1.5 Exposed below deck. Exposed below deck simply means not as much shielding as assumed for below deck, and equipment to be installed below deck gets the same RE102 limit as topside in Figure RE102-1, where the more stringent limit instead of being labeled "topside" as in "F," is now labeled "above deck and exposed below deck."

Supporting appendix material for section 4.2.2 Filtering (Navy only) adds extra rationale for the limits on line-to-

ground capacitance. It all makes sense, but it doesn't have the urgency of the original explanation made to the author many moons (decades) ago. The original explanation stated that ship power was ungrounded so that in the event of battle damage, one phase could short to structure and continue to operate without degradation. Therefore it was necessary to limit line-to-ground capacitance to preserve a high impedance between phases in the event of such a short circuit. To the author, that is a much more satisfying (read strong) argument in the event someone wishes to violate it than more nebulous concepts (to program management) such as hull currents, ground loops and leakage current.

Section 4.3.5.1 (metallic ground plane), augmented by brand new Figure 5 requires 2.5 meters in any direction from the edge of the test set-up boundary to the edge of the ground plane, as compared to 1.5 meters in earlier versions of the standard. The change was based on the desire to have the ground plane underneath the entire set-up, antennas used in various tests, and distance beyond the backside of any such antenna still covered with ground plane. Also note Figure 5 replaces what looked like a truck or other wheeled vehicle (but wasn't supposed to) with something that looks like a test equipment rack. It is important to always reinforce that MIL-STD-461 applies to equipments and subsystems, not vehicles/platforms.

Figures 2 – 5 have two subtle changes. The first is that the test sample enclosures are oriented so that the connector side faces the way the cables are laid down the length of the tabletop, as opposed to in previous versions, where the connector side faces the front of the table. Actually Figure 5 has side-facing connectors in both "F" and "G;" the diff rence in Figure 5 is that the test sample evokes an electronic equipment rack instead of a wheeled vehicle (which was never intended), and the cables are laid out 5 cm above a tabletop ground plane, not 5 cm above the floor, as in "F." The second change is that all these figures are now titled "general." Complex enclosures with lots of cables and/or long EMI backshells with large cable bend radii will follow the new setup, but paragraph 4.3.8.5 Orientation of EUTs is unchanged and still requires surfaces which produce maximum radiation to face the measurement antenna. So nothing to fear here, EMC lawyers: there is still plenty of opportunity to ply your craft.

A theme in MIL-STD-461G is to expand instructions on how to set-up and test when the test sample has large vertical extent. Previously, the instructions were based on avionics type equipment enclosures that mount on the tabletop ground plane. These could be large in horizontal extent and instructions have previously existed in how to lay this out and how to place antennas. Sections 4.3.8.6.1 (interconnecting leads and cables) and 4.3.6.8.2 (input primary power leads) expand on the routing of cables when the test sample is a large floor standing unit. Figures 4 and 5 also augment this topic.

Issues arise with proper antenna coverage of test samples with large vertical extent, and these are dealt with in RE102 and RS103 by requiring the entire surface *area* to be illuminated, not just the horizontal width. But another issue is cable length. There has always been a limit of 2.5 meters maximum between test sample and LISNs, in order to allow the LISN to control the line impedance (the reason why CE102 stops at 10 MHz). But with a large test sample like a floor-standing rack, especially if the cables exit near the top and a power strip runs down the height of the rack powering loads near the bottom, the 2.5 meters gets used up very quickly and a strict adherence to that limit would mount the LISNs very near the rack itself, limiting RE/RS interaction with power lines. Given the MIL-STD-462D decision to have a single power wire length for all tests, as opposed to short cables for CE testing and long cables for RE/RS as previously, it was decided to require two meters of power wiring exposed 5 cm above the tabletop ground plane regardless of where the wires emanate from the test sample, nor how long the cables are within the test sample.

Another theme in MIL-STD-461G is to expressly permit the use of certain types of test equipment that have appeared since the release of MIL-STD-461F. Perhaps the most important of these is the "time-domain" or Fast Fourier Transform (FFT) EMI receiver. Such receivers diff r from the traditional in that instead of tuning to a particular frequency using the prescribed bandwidth and then stepping to the next frequency using a not-to-exceed half-bandwidth step, these receivers look at megahertz or tens of megahertz bands, and use FFT algorithms to recover the signals that would be measured using Table II prescribed bandwidths. Such receivers are much faster than traditional receivers. Section 4.3.10 (use of measurement equipment) expressly mentions and condones use of such receivers, and Table II is augmented to show dwell times required for time domain receivers. The appendix for this section and Table II explains why the FFT-specific dwell times are necessary, and shows test data for a broadband signal with much better performance than obtainable with a traditional receiver or spectrum analyzer when Table II dwell times are used. The appendix (pages 197 – 200) also shows what happens if Table II FFT-specific dwell times are not used, with the broadband signal completely missed. The FFT receiver properly or improperly used is like the little girl in the nursery rhyme:

*"There was a little girl,*
*Who had a little curl,*
*Right in the middle of her forehead.*
*When she was good,*
*She was very, very good,*
*But when she was bad she was horrid."*

The Table II modifications pertaining to FFT receivers are designed to make sure the little girl is always very, very good, and when she is bad, she is no worse than little girls used to be.

There are much greater advantages inherent in such receivers than simply getting a test done faster. The operation of some devices (a linear actuator, for example) come to the end of their travel much faster than a traditional CE102 or RE102 sweep. Or a helicopter rescue hoist cannot deploy as much line in a shield room as in flight, and thus cannot operate continuously through an emissions sweep. The ability to capture multiple megahertz bands during a few seconds of operation can actually provide better quality data for such devices. There are also devices designed with limited life-times, in which the ability to sweep faster may make testing possible that would have been impossible otherwise.

Section 4.3.10.4.2 (modulation of susceptibility signals) doesn't say so, but now CS114 and RS103 both require demonstration that the required modulation has been applied. This is most easily done in zero-span mode and measuring the correct on-off  iming and also the 40 dB on-to-off  atio.

Section 4.3.10.4.3 (thresholds of susceptibility) now requires "zeroing in" on the frequency of greatest susceptibility within the susceptibility band.

As mentioned earlier, Section 4.3.11 (calibration of measurement equipment) removes the need for routine calibration cycles on passive transducers.

Section 5.4.1 CE101 applicability adds a note explaining when the requirement is applicable to equipment installed on Navy aircraft.

Section 5.5.3.4.a.2 is the expansion on the basic CE102 measurement system integrity check that verifies the LISN impedance at 10.5 and 100 kHz. The previous ("D" through "F") technique verified the impedance at 2 and 10 MHz, but not at the lower frequencies, and with elimination of a requirement to regularly calibrate LISNs, the expanded measurement system integrity check fills that gap. There is little extra effort besides record keeping. Because the LISN is a low impedance relative to 50 Ohms, it is already the case that the signal source output amplitude must be increased above the actual level resulting across the LISN. The extra effort is simply to document the required increase (in dB) and compare that to what is theoretically required per the LISN impedance curve of Figure 7, including both the 20% tolerance of that figure, plus the losses associated with the LISN 0.25 uF blocking capacitor. This section says what the decibel diff rence is supposed to be at the measurement system integrity test frequencies of 10.5 and 100 kHz. SAE AIR 6236 shows the LISN insertion loss curve with tolerances over the entire 10 kHz to 10 MHz frequency range, and how to measure it.

Section 5.6.1 CE106 applicability has been modified by striking the following sentence from MIL-STD-461F:

> "RE102 is applicable for emissions from antennas in receive and standby modes for equipment designed with antennas permanently mounted to the EUT."

In the author's opinion, this is a big loss, and not only for receive and standby modes, but also for low power transmitters such as Wi-Fi. RE102 is much easier to perform than RE103, and where the device either transmitting or not can be shown to be in compliance with RE102 rather than RE103, that meets the overall intent of controlling interference. Also, the -80 dBc type requirement makes no sense for a milliwatt transmitter; RE102 is the only applicable requirement at harmonics of a low-power transmitter.

Section 5.6.1 CE106 has been modified for NAVSEA (surface ship) transmitter procurements. The traditional 5% exclusion zone surrounding the transmit frequency is increased according to a formula given in this section for transmitters operating above 1 kW (60 dBm).

There is also a modification of the criterion for the highest required test frequency. The eff ct of the change is that the test must always be run to at least 10 GHz, with a maximum frequency of 40 GHz. The modification is that under MIL-STD-461F, the upper frequency was stated to be:

> "The end frequency of the test is 40 GHz or twenty times the highest generated or received frequency within the EUT, whichever is less."

Under the "G" change, the end frequency criterion depends on whether the highest generated or received frequency is above or below 1 GHz. If the highest generated or received frequency is below 1 GHz, the end frequency is twenty times that frequency or 18 GHz, whichever is greater. If the highest generated or received frequency is equal to or above 1 GHz, then the end frequency is ten times the highest frequency, or 40 GHz, whichever is less.

To illustrate how this can aff ct results, consider two devices, one with a highest generated or received frequency of 999 MHz, and the other with a 1 GHz highest frequency. Under MIL-STD-461F, the end frequencies are practically identical, at or near 20 GHz. Under MIL-STD-461G, the first device has a test stop frequency of 18 GHz, whereas the second device test stop frequency is only 10 GHz.

Of course the benefit of this approach is a lot of devices will only need to be tested to 18 GHz, instead of higher. Every test facility can test to 18 GHz because of RE102, but often testing beyond that requires the rental of a special receiver, so overall this modification is beneficial.

Section 5.6.2 CE106 has been modified for NAVSEA (surface ship) transmitter procurements. The relative limit in decibels below the carrier (e.g., -80 dBc) has been changed to a fixed level of -40 dBm. This was done to aid in co-location of high power transmitters and sensitive receivers. Note that for any transmitter power level above 10 Watts (40 dBm) this represents a more stringent limit than previously. There is a relaxation of this -40 dBm level to 0 dBm if the transmitter duty cycle is below 0.2%, which would take care of many radar systems.

Section 5.7.1 CS101 limits applicability to equipment drawing less than 30 Amps per phase, even though test equipment exists supporting testing to 100 Amps per phase. The rationale behind this is that usually such high current loads operate off high potential buses, and the CS101 ripple levels are smaller than the distortion on these buses, and the total CS101 ripple power is infinitesimal compared to the actual load power, and susceptibilities just aren't observed. However, it should be noted that CS101 limits are based on MIL-STD-704, which doesn't address bus potentials above 115 Vac or 270 Vdc. The large loads to which this 30 Amp limitation would usually apply would be upwards of 400 Vac. Note that the 6.3 Vrms ripple limit of Curve 1 is about 5% of a 115 Vac bus potential but only 1.5% of a 440 Vac bus. If the CS101 limit for a 440 Vac bus were raised to that same 5% (22 Vrms) then (in the author's opinion) it would be much more likely that issues would arise.

Section 5.7.3 CS101 test procedure allows for the use of a power line ripple detector (PRD) to measure ripple induced on an ac power line, which is very difficult to monitor. The PRD functions as an interface between the power line and the 50 Ohm input of a spectrum analyzer or EMI receiver, allowing the measurement to be made in the frequency domain so that the ripple component can be seen entirely separately from the power line frequency. This was described in an article entitled “Fifty Year-Old EMI Testing Problems Solved,” in the June 2012 issue of IN Compliance magazine. The electronic archive shows video of the ripple on the peak of the ac power waveform vs. the separate injected ripple component. Stills are shown below.

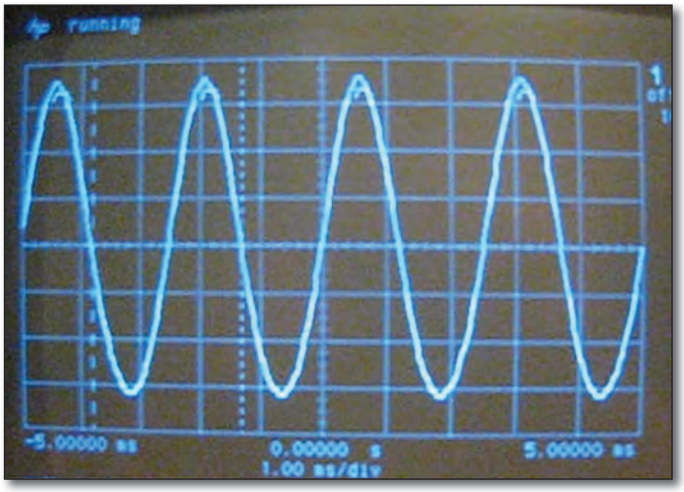


**FIGURE 1:** 800 Hz ripple riding on a 400 Hz ac power bus, traditional CS101 measurement.

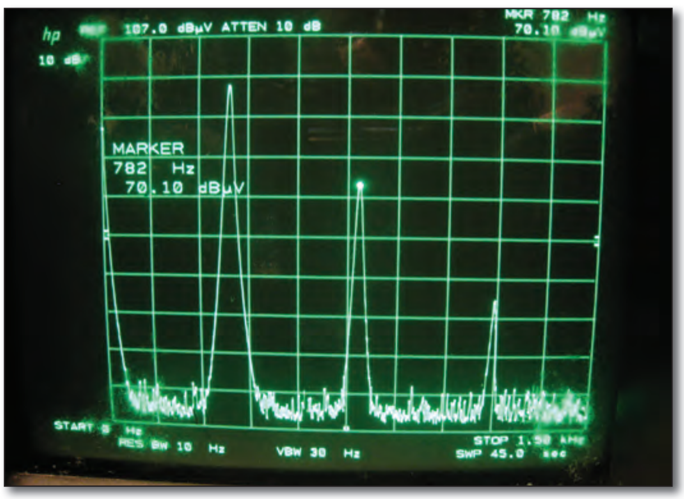


**FIGURE 2:** 800 Hz ripple riding on a 400 Hz ac power bus, measured in the frequency domain. The PRD has a -66 dB transducer factor, so 66 dB has to be added to measured values to get to values on the power bus.

The PRD allows for monitoring and injecting ripple below the power frequency, a requirement prior to 1993 but the capability to do so was lost in 1993 when MIL-STD-462D prohibited use of the phase shift network method of eliminating the power frequency from the ripple measurement. In MIL-STD-461D and onward, because of that prohibition, the limit for ac ripple started at the second harmonic of the power frequency, instead of at 30 Hz. The PRD facilitates monitoring down to 30 Hz on any type of bus, as shown in Figure 3, but the TSWG was not interested in reviving the 30 Hz start frequency for ac buses after over twenty years of not having done so.

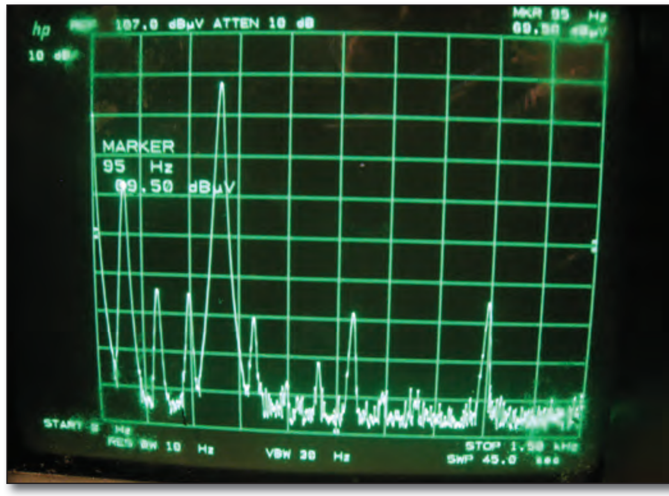


**FIGURE 3:** Injection of 100 Hz ripple on a 400 cycle ac bus.

The PRD as commercialized by Pearson Electronics contains an isolation transformer so that connection of the ac neutral to the PRD maintains isolation between the neutral and the grounded EMI receiver or spectrum analyzer chassis. That isolation is required by paragraph 5.7.3.1 of MIL-STD-461G.

CS101 figures are updated to show either the traditional measurement with floated oscilloscope or the new measurement with PRD and grounded receiver.

The CS101 supporting appendix material also includes this valuable information:

> “Below 10 kHz there is a possibility that a portion of the injected signal will drop across the power source rather than the test sample power input. Therefore, below 10 kHz when the specification limit potential cannot be developed across the test sample power input and the pre-calibrated power limit has been reached, it is incumbent on the tester to check that the missing signal level is not being dropped across the power source. If the missing potential is there (usually due to high impedance test facility EMI filters), then steps should be taken to lower the source impedance. This can be done on DC power by using a larger capacitor (~10,000 uF) in parallel with the 10 uF capacitor. With AC power that isn’t possible and the best approach is to bypass facility EMI filters entirely, bringing unfiltered power into the room.”

The PRD facilitates that measurement by having two sets of jacks for simultaneously connecting to both test sample power input and across the power source and being able to read either of these values at the flip of a switch.

CS106 was added in MIL-STD-461F and is deleted in MIL-STD-461G. The rationale for adding it was included in the MIL-STD-461F rationale appendix and is repeated here:

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## CS114/115/116

## CS101


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  - 8705C Current Probe
  - F-3 Test Fixture (accomodates both probes)
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- Max RMS Current - 4 Amps
- Max Peak Current - 15 Amps
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Greatly simplifies the measurement of injected audio-frequency ripple on an AC or DC power bus in EMI tests such as MIL-STD-461G CS101.

- Two Models - PRD-120 & PRD-240
- Measure audio frequency (CS101) ripple injected on power buses
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"The primary concern is to ensure that equipment performance is not degraded from voltage transients experienced on shipboard power systems coupling to interface wiring inside enclosures.

Electrical transients occur on all electrical distribution systems and can cause problems in circuitry which tend to be sensitive to voltage transients, such as latching circuits expecting a single trigger signal. On submarines and surface ships, these transients can be caused by switching of inductive loads, circuit breaker (or relay) bounce, and load feedback onto the power distribution system.

The 400 volt peak, 5 microsecond pulse defined in Figure CS106-1 is a suitable representation of the typical transient observed on Navy platforms. Measurements of transients on Navy platforms have shown the transient durations (widths) are predominantly in the 1 – 10 microsecond range. The large majority (> 90%) of the transients measured on both the 115 volt and 440 volt ac power distribution systems were between 50 and 500 volts peak."

The underlying issue was not the response of the power supply to the transient, but crosstalk within an equipment between the transient on the power wiring and signals carried on wiring adjacent to the power wires without adequate protection. The very purpose of the requirement was to force adequate segregation between power and signal circuitry.

However, CS115 was designed specifically to represent the coupling of transients on a power bus into cables run adjacent to it. The very short 30 ns duration and even shorter 2 ns rise and fall times represent the leading edge of a waveform such as CS106 on a power bus inductively coupling into an adjacent cable. Measurements on a one foot section of ribbon cable modeling an unprotected connection between a connector and motherboard revealed that injecting CS115 on the simulated signal wires looked very similar to the cross-coupling from injecting CS106 on the simulated power wires.

It was concluded that CS115 already meets the intent behind the reintroduction of CS106.

There are two changes to CS114. One aff cts the limit, the other is procedural.

The limit reverts back to that of MIL-STD-461D, where the primary limit is the forward power recorded in the calibration fixture when the appropriate specification limit (Curve 1 – 5) is induced in the fixture, with the only current limit being 6 dB higher than the current in the plateau region of the curve. This is as opposed to the "E" and "F" versions, where the current limit is the actual current at the specific test frequency. The reason behind the reversion to MIL-STD-461D is explained in "(More) On Field-To-Wire Coupling Versus Conducted Injection Techniques," in the October 2014 issue of IN Compliance magazine. This change will make it important to tailor the breakpoint frequency of the limit (nominally 1 MHz) for platform or actual cable dimension, in order to avoid over-testing. In order to perform that tailoring, it is necessary to understand that the breakpoint represents the frequency at which a platform or cable is one-half wavelength long. A 1 MHz break point is a physical length of 150 meters. So if a platform is instead about 15 meters long, the breakpoint would shift to 10 MHz.

The procedural change is that in addition to the traditional measurement of the forward power required to induce the specification limit current in the calibration fixture, the current in the fixture must be measured using the current probe that will be used to monitor current on the cable-under-test. This is an augmentation of the measurement system integrity check, because again a current probe will not require periodic calibration.

CS117 (lightning induced transients on cables and power leads) is one of the two new requirements in MIL-STD-461G. It was borrowed from RTCA/DO-160 section 22, and it is a subset of RTCA/DO-160 section 22. There is nothing in CS117 that doesn't exist in section 22, but many aspects of section 22 were left out of CS117. There was a desire to simplify, but the simplification was not performed for its own sake, but rather in keeping with two philosophical tenets of MIL-STD-461 since the "D" revisions in 1993. These are that cable-related tests are performed at the bulk cable level, no pin injection, and second that platform installations are divided into two categories, internal and external (relative to a metallic platform).

MIL-STD-461B/C had EMP-like damped sine injection requirements CS10/11/12/13 two of which injected on the entire bundle, and two of which were injected at the pin level. These were all subsumed into bulk cable injection (BCI) requirement CS116 in 1993. Likewise CS114 and CS115 began as BCI requirements and have stayed that way. CS117 is adopted as a BCI requirement only, eschewing the pin injection requirements in section 22. This greatly simplifies the test campaign on the types of equipment to which CS117 applies, such as flight and engine controls that have multiple cables with lots of pins. Pin injection is important with shielded cables where the installed length is greater than the ten meters required in MIL-STD-461. For this small subset of cables, some thought will need to be given to possibly boosting the injected current to make up for the lower shield transfer impedance of the set-up vs. installation.

CS117 has six waveforms borrowed from section 22, but only two levels, internal and external. In addition to that simplification vs. five diff rent levels in RTCA/DO-160G section 22, another simplification is that there is no separate table for a single stroke application. Instead, the single stroke levels of section 22 Table 22-3 have been incorporated into the multiple stroke Table VII of CS117. Table 22-3 levels 3 and 4 become the first stroke of the multiple stroke requirement in CS117 Table VII. Level 3 maps to internal, and level 4 maps to external. Subsequent strokes in CS117 Table VII are from section 22 Table 22-4, except that for Waveforms 4/5A, there was some mixing and matching from levels under Waveform 4/1 in section 22 Table 22-4.

Multiple bursts in the same CS117 Table VII are exactly the same as section 22 Table 22-5 levels 3 & 4, again mapping to internal and external installations, respectively.

One other wrinkle is that RTCA/DO-160 uses the 5 uH LISN, vs. the MIL-STD-461 default to 50 uH. This means that the same waveform applied in a CS117 set-up will apply less potential to the load than if the test were performed to section 22, because the power source impedance is higher with CS117. This was considered by the TSWG and accepted as part of maintaining consistency with the default 50 uH LISN used throughout the standard.

CS118 (personnel borne electrostatic discharge) is the second new requirement in MIL-STD-461G. Before getting into requirement and test details, some background is in order. In the run-up to the MIL-STD-461G revision process, proponents of including an ESD requirement discussed failures in the field and how those could be tied to ESD problems. Such damage would most likely occur during remove-and-replace operations, not during powered up use, else the failures would be much more dramatic and noticeable (i.e., hardware working during a mission and suddenly failing, as opposed to installing hardware and running a built-in test - BIT - and with a BIT failure, installing a different box). The application of ESD pulses to an unpowered box and then subsequently running BIT or some other acceptance test procedure (ATP) was argued to not fit within MIL-STD-461, just like lightning direct effects doesn't, but rather to belong in MIL-STD-810. But this argument didn't fly, not least because the candidate test methods were based on RTCA/DO-160 section 25 and IEC 61000-4-2, which apply ESD pulses to fully operational hardware and look for *malfunction*.

The test set-up and "gun" are based largely on RTCA/DO-160 Section 25, with the addition of a "target" borrowed from IEC 61000-4-2 for calibrating the current discharge waveform, and a contact discharge electrode design not found in RTCA/DO-160 because it only requires air discharge. The section 25 set-up was chosen over IEC 61000-4-2 because of the obvious similarities in a metal vehicle application, with the test sample enclosure directly grounded to structure, as opposed to the 61000-4-2 approach with a nonconductive table top 80 cm removed from ground, with at most a green wire ground connection. The use of the 61000-4-2 target prior to each test is part of the measurement system integrity check philosophy, rather than relying solely on a "gun" calibration sticker. Likewise CS118 requires an electrostatic assessment of the gun potential prior to the discharge. Contrast these two measurements with RTCA/DO-160G section 25.5.2: "…The ESD generator shall be calibrated to produce a positive and negative 15,000 volt (+10%, -0%) peak output pulse. The generator setting required to produce this output shall be recorded."

Applicability is limited to non-ordnance connected electronics; ordnance response to ESD is covered elsewhere, but not in MIL-STD-461G. Limits are 8 kV for contact, 15 kV for air discharge. Contact discharge is the preferred method unless the test item has nonconductive surfaces requiring an air discharge approach. Air discharges are performed not only at the 15 kV limit, as per RTCA/DO-160 section 25, but also at 2, 4, and 8 kV. This is because air discharge current waveforms can have higher amplitudes at lower potentials, due to smaller arc distances and hence lower arc resistance. It is most often the coupling from the radiated field of the ESD event that causes upset, and the higher the waveform di/dt, the large the transient coupled to (potential) victim circuits.

Section 5.18.1 RE102 applicability removes the conditional limit on the upper test frequency and makes it 18 GHz, regardless of test sample clock speeds. It was deemed that the time saved not testing to 18 GHz was insignificant.

The most notable RE102 changes relate to illuminating/interrogating the entire test set-up area, as opposed to width, as already noted. A change in the RE102 measurement system integrity check for the 41" rod antenna acknowledges that the assumed Thevenin model output impedance of a 41" rod is not always 10 pF, because some large diameter rods have larger output capacitance. The standard now invokes the manufacturer's suggested value. But there is another much more subtle change, and it is important in the same way that the tip of an iceberg is important to a ship at sea.

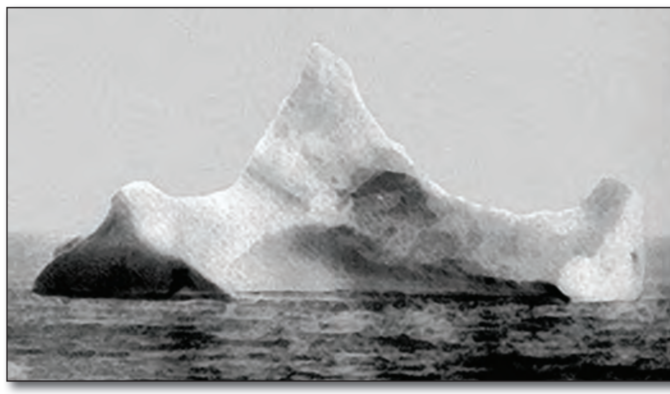

**FIGURE 4:** Some say this is a photo of the iceberg that sank the Titanic.

MIL-STD-461F introduced a change in how the rod antenna is configured. The purpose of that change was to detune an observed resonance that occurs between 20 – 30 MHz. Part of the change included clamping a ferrite sleeve around the coaxial transmission line between rod antenna base and EMI receiver. MIL-STD-461 cannot specify a manufacturer or part number, but the previously referenced MIL-STD-461F update article identified one candidate as a Fair-Rite Part Number 431176451. The salient feature of that bead as shown in Figure 5 is that its impedance is mainly resistive/absorptive in the 20 – 30 MHz frequency range of interest, as is appropriate for detuning a resonance. But that information never made it into the standard; the only description other than the actual impedance range cited in

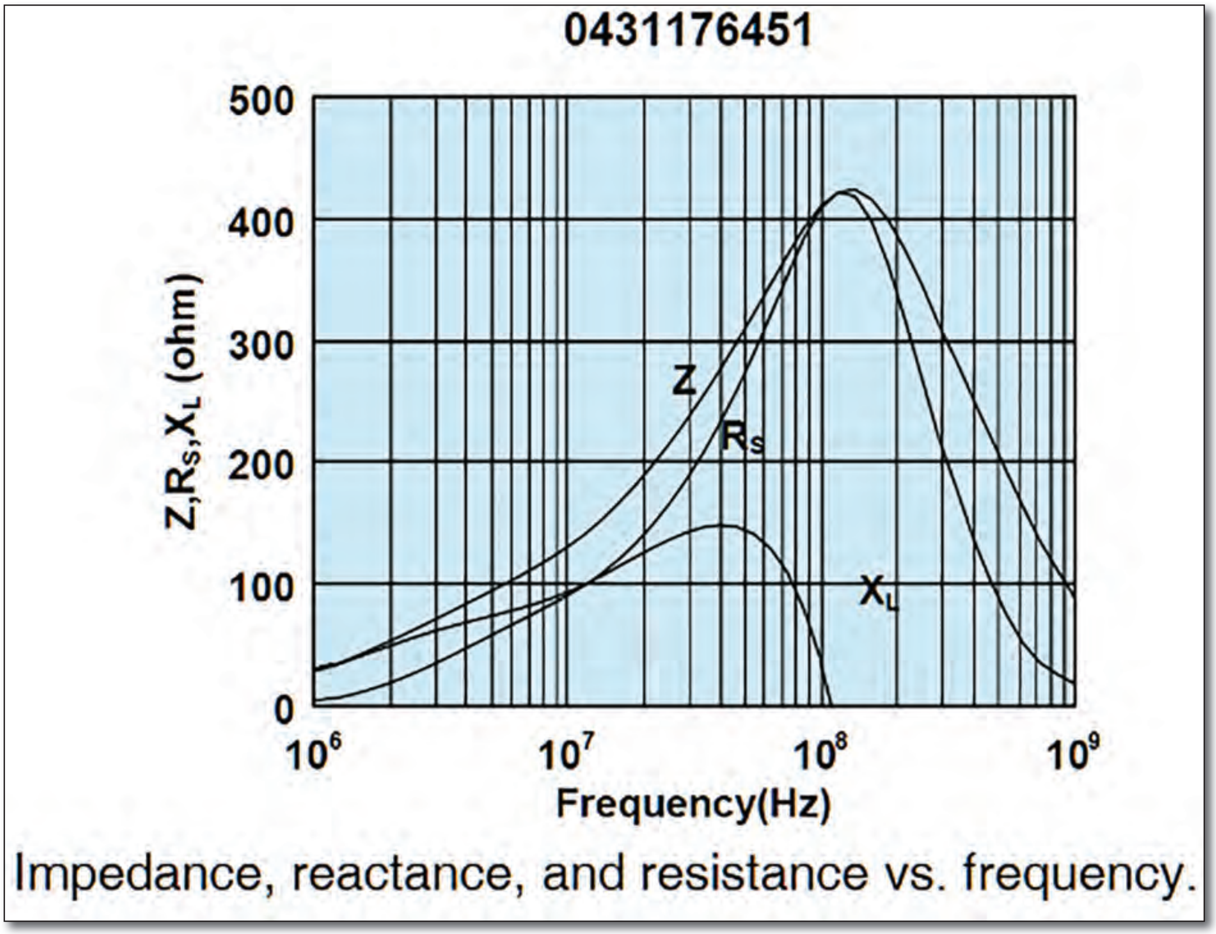


**FIGURE 5:** Characteristics of MIL-STD-461F rod detuning rf sleeve (from Fair-Rite catalog)

Figure RE102-6 was in the MIL-STD-461F RE102 appendix stating that, "Floating the counterpoise with the coaxial cable electrically bonded at the floor with a weak ferrite sleeve (lossy with minimum inductance) on the cable produced the best overall results." That description was routinely ignored by many test engineers, which resulted in said engineers criticizing the MIL-STD-461F technique as flawed. Of course, attempting to detune a resonance by adding a largely reactive component isn't going to help matters any, only shift the resonance downwards in frequency. MIL-STD-461G moves that impedance description to the main body section 5.18.3.3.c(1): "…A ferrite sleeve with 20 to 30 ohms impedance (lossy with minimal inductance) at 20 MHz shall be placed near the center of the coaxial cable length between the antenna matching network and the floor."

But this subtle change of moving a recommendation from the appendix to the main body is just the tip of the rod antenna configuration iceberg. Much work remains to be done which will have to wait for MIL-STD-461H. This work is now described.

An article published in the 2011 ITEM entitled, "On the Nature and Use of the 1.04 m Electric Field Probe," explained in its conclusion that the only way to make an accurate field intensity measurement with a rod antenna was to either use the floor for a ground plane, or if the counterpoise was elevated above ground, then it must be totally floated above ground. The recommended technique was the insertion of an isolation transformer in the coaxial cable connection between the rod antenna base and the EMI receiver. Another separate suggestion from another researcher recommended a fiber optic link. Both these suggestions were evaluated during the MIL-STD-461G revision process, but both came up short for reasons described presently. Also, a test equipment vendor introduced a rod antenna that was inherently floated using a fiber-optic link to a laptop computer controller. Unfortunately, they were unable to make one available to the TSWG for evaluation during the MIL-STD-461G revision process.

Inserting a fiber optic link in the connection to a conventional rod antenna failed due to what appeared to be parasitic capacity between the green wire ground in the laboratory power and the bias potentials fed to the opto-electronic converters. The plan was to replace the power supply with batteries to see if that eliminated the problem, but time ran out. The problem with isolation transformers is there is always some degree of inter-winding capacitance between winding banks, and at these frequencies it cannot be ignored. While the original problem dealt with by MIL-STD-461F was a par-


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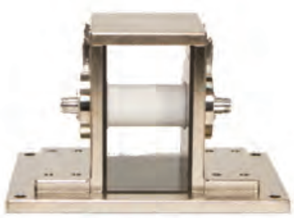

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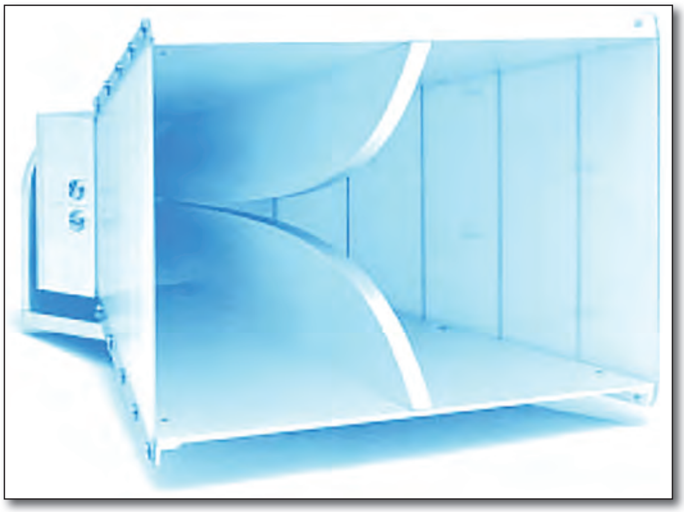

**FIGURE 6:** Traditional microwave DRG horn as specified in MIL-STD-461E/F and newer version not specified in MIL-STD-461

allel L-C trap with capacitance between the counterpoise and floor and the inductance supplied by the coaxial shield connection, when an isolation transformer is inserted a new series L-C trap is formed from the inter-winding capacitance and the coaxial shield inductance. The combination of capacitance and inductance have to be limited such that the resultant resonance (which cannot be eliminated, only moved around) is above 30 MHz. Given that different models of transformers have different and unspecified inter-winding capacitance, it would have to be measured by the test facility and then a maximum length cable would need to be specified to work with it to keep the resonance above 30 MHz. This is difficult to write into a standard. We hope that all this will be ironed out in time for routine incorporation into MIL-STD-461H. Stay tuned for progress updates in the form of articles on the subject either in future editions of ITEM or IN Compliance magazine.

Another RE102 change that was slated to happen but didn't was wording that would allow the use of the new ETS/Lindgren Model 3117 antenna to be used above 1 GHz in addition to the original double ridge guide horn as presently specified in MIL-STD-461 via its physical aperture of 24.2 by 13.6 cm opening. As can be seen from Figure 6 showing both antennas side-by-side, the newer antenna doesn't have any sides as does the more traditional looking horn, and therefore specifying it via its physical aperture would be quite ambiguous. MIL-STD-461 cannot specify test equipment by manufacturer and model, so a generic description that nevertheless conveys the desired characteristics is required. We didn't get a satisfactory description from the manufacturer, and discussed including salient performance characteristics instead such as beamwidth, which was where the new antenna was much better than the old one. But in the end it was decided that would be too complicated because we would have physical apertures for all other antennas, but performance characteristics of the new one, and no one wanted to change to performance characteristics for all antennas.

And finally, there was quite a bit of interest in adding a reverberation chamber alternative test procedure to RE102, much as for RS103, which was added in MIL-STD-461E. There are several advantages to a reverb RE test method, and none of the drawbacks of RS reverb, namely the schedule hit.

Reverb RE testing captures all test sample emissions, rather than those emanating from the front face. A reverb technique removes test chamber resonance issues due to the partial absorber liming coverage allowed by MIL-STD-461. The test chamber is much less expensive. There is the potential for making more sensitive measurements than in an absorber-lined chamber because we are capturing constructive interference of all the emanations at once. The degree of improvement is based on the room "Q," offset by the difference in gain between the traditionally required antennas and the biconicals that would be necessary. Reverb purists who believe antenna gain doesn't factor into a reverb measurement hang on until you have read the next paragraph, which outlines a reverb technique for making near field measurements.

RE reverberation techniques exist, such as in RTCA/DO-160 section 21, but these all work on an assumption that the collected power is available to radiate from a dipole antenna using a far field equation to analytically determine the field strength limit. It was felt that this might not be the optimal approach, and an investigation based on the work of Norm Wehling, retired chief engineer at Elite Electronic Engineering Company as published in the 1993 issue of ITEM is underway.[1] Although that effort was aimed at RS testing, the author realized it was eminently better suited for RE testing. The basic idea is to use biconical antennas all the way

[1] Wehling, Norman. Repeatable Low-cost Radiated Susceptibility Test in a Standard Shielded Enclosure. ITEM 1993, p16ff.

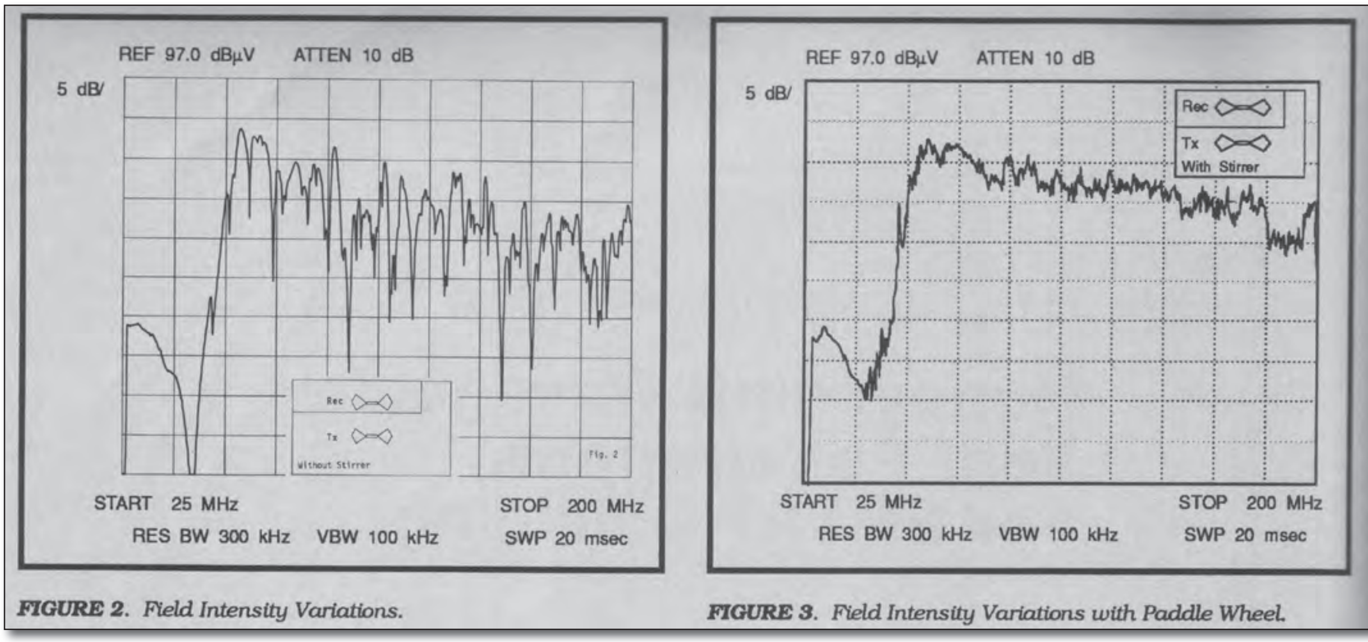


**FIGURE 7:** Field uniformity without and with stirring in a typical MIL-STD-461-sized test chamber from 30 – 200 MHz, from Wehling.

from 30 – 1000 MHz and position them close to the normal placement for RE102 measurements, but put a paddle behind the antenna. In an unlined chamber and the paddle stopped, this would be equivalent to the MIL-STD-462 test method prior to 1993, where unlined test chambers were the norm, and any RE measurement was in fact a mode-tuned measurement, except a single mode. The paddle allows multiple modes, and the spectrum analyzer/EMI receiver performs multiple fast sweeps in max hold mode during a single revolution of the paddle, which sweeps continuously at 6 – 7 rpm. This means that a single frequency domain sweep over in milliseconds represents a single mode because the paddle is nearly motionless in that time period. If an unlined chamber were the basis of RE measurements, as they were prior to 1993, there would be nothing to add to the method, because basically the paddle just captured the peaks of the constructive interferences instead of recording peaks and valleys (destructive interference), as in Figures 7 from Wehling. But since the last twenty years have used an absorber-lined chamber, it is now necessary to back out the "boost" factor of the unlined chamber, which is evaluated by performing an ARP-958 antenna calibration in the stirred chamber and comparing the measured antenna factor to the normal calibration. The difference is the "Q" of the room, and that must be backed out of the measured field intensity in the chamber in order to make the reverb measurement no more stringent than that in a lined chamber. At least, that is the author's theory and plan.

The author's investigation was nowhere near complete during the "G" revision process, but might bear fruit for the next revision cycle.

Section 5.19 RE103 has the same sort of changes in it as already described for CE106.

Section 5.20.1 RS101 applicability adds a note explaining when the requirement is applicable to equipment installed on Navy aircraft. "For Navy aircraft, this requirement is applicable only to equipment installed on ASW capable aircraft, *and external equipment on aircraft that are capable of being launched by electromagnetic launch systems*." The italicized clause is new in "G."

In addition to the RS103 changes already cited, there is a subtle change in the applicability of the requirement at the tuned frequency of a radio receiver. A little historical background.

MIL-STD-461D and previous versions of MIL-STD-461 did not require RS103 testing at the tuned frequency of a radio receiver. The reason for this is that the radio electronics are less exposed to the external electromagnetic environment (EME) than the antenna, and the radio receiver is tested with antenna port dummy loaded, so that it was clear that the antenna would conduct much more signal into the electronics than through the platform and through the radio enclosure. During the revision process culminating in "E", a case of two radios mounted side-by-side interfering with each other was brought forth. One radio was tuned to the local oscillator (LO) of the other radio, and the LO leaked enough to couple into the victim radio. This case resulted in a change where the RS103 requirement at the tuned frequency of a radio was the appropriate RE102 limit relaxed by 20 dB. The limit basis was that the culprit would meet RE102, but the intensity a few centimeters away would be higher than the limit at one meter. Under MIL-STD-461F, this interaction was de-emphasized, but NAVSEA (surface ships) had a concern for radio receivers mounted below decks far from their topside antennas but exposed to wireless networks and adjacent used handheld radio transmitters. So there was no exception whatsoever at the tuned frequency of a radio for this Service and application. MIL-STD-461G builds on this with further explanation (from the appendix):

> "Revision G of this standard has further changed the applicability of RS103 for tuned receivers. The exemption at the tuned frequency to meet RS103 is in place for Air Force and Army equipment. For Navy equipment, RS103 is applicable at the tuned frequency unless the antenna is permanently attached to the equipment being tested. The reason for this is that on Navy installations, the antenna may be situated a far distance from the receiver, so these services want the test to apply to a receiver. Since the exemption at the tuned frequency is installation dependent, it may be extended to other systems as tailoring to this standard with procuring activity approval. For equipment where the antenna is permanently attached to the equipment, such as portable equipment or WiFi transmitters, the expectation is that there will be interference at the tuned frequency that is a "front door" event. In those cases, the requirement is that the antenna/receiver work after application of the E-field. Therefore, during the test, responses when RS103 is at the tuned frequency are allowed."

MIL-STD-461G RS103 Section 5.21.3.3.d. Placement of electric field sensors has slightly diff rent wording than MIL-STD-461F RS103 section 5.20.3.3.d.1 on the same subject, but the change is only to make position information clearer; there is no change to the positioning requirement.

Section 5.22.1 RS105 applicability adds a note explaining when the requirement is applicable to equipment installed on surface ships. And the oscilloscope single-event bandwidth is updated to 700 MHz from the previous 500 MHz, even though the limit itself is unchanged.

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**Table of New Equipment Allowed/Required in MIL-STD-461G**

| Requirement | Equipment Type | Vendor(s) | Websites |
|---|---|---|---|
| General | Time Domain EMI receivers* | Gauss Instruments<br>Keysight<br>Rohde & Schwarz | http://www.gauss-instruments.com/en/products/tdemi<br>http://www.keysight.com/en/pdx-x201870-pn-N9038A/mxe-emi-receiver-3-hz-to-44-ghz?cc=UG&lc=eng<br>https://www.rohde-schwarz.com/us/products/test-measurement/emc-field-strength-test-solutions/emc-field-strength-test-solutions_105344.html |
| CS101 | Frequency domain ripple monitoring transducer* | Pearson Electronics | http://www.pearsonelectronics.com/news/179 |
| CS114 | Current probe calibration fixture | ETS/Lindgren<br>Fischer Custom Communications<br>Pearson Electronics<br>Solar Electronics | http://www.ets-lindgren.com/EMC (fixture not listed on web site but should be part of current probe/injection clamp line-up)<br>http://www.fischercc.com/ViewProductGroup.aspx?productgroupid=141<br>http://www.pearsonelectronics.com/news/180 (fixture holds both injection clamp and current probe)<br>http://www.solar-emc.com/RFI-EMI.html (scroll to bottom of page) |
| CS117 | Indirect lightning test systems | HV Technologies<br>Thermo Scientific<br>Solar Electronics | http://www.hvtechnologies.com/TestsTrack/Lightning/tabid/408/Default<br>http://www.thermoscientific.com/en/product/ecat-lightning-test-system-lts.html<br>http://www.solar-emc.com/2654-2.html |
| CS118 | ESD gun | EMC Partner<br>EM Test<br>Haefly<br>Kikusui<br>LISUN Group<br>Noiseken<br>Thermo Scientific<br>TESEQ | https://www.emc-partner.com/products/immunity/esd/esd-generator<br>http://www.emtest.com/products/product/135120100000010183.php<br>http://www.haefely-hipotronics.com/product/product-category/electrostatic-discharge-test-systems-esd/<br>http://www.kikusui.co.jp/en/product/detail.php?IdFamily=0020<br>http://www.lisungroup.com/product-id-318.html<br>http://www.noiseken.com/modules/products/index.php?cat_id=1<br>http://www.thermoscientific.com/en/product/minizap-15-esd-simulator.html<br>http://www.teseq.com/product-categories/esd-simulators.php |
| RS103 | 1 – 18 GHz electric field probe (most test facilities already have one) | Amplifier Research<br>ETS/Lindgren<br>NARDA | http://www.arworld.us/html/field-analyzers-field-monitoring.asp<br>http://www.ets-lindgren.com/EMCProbes<br>http://www.narda-sts.us/products_highfreq_bband.php |

* Specified as acceptable for use, but not required.

# Why Is There AIR (in MIL-STD-461G)?

**KEN JAVOR**
EMC Compliance

*(with a tip of the hat to a great performer...)*

**AS NOTED IN THE** compleat MIL-STD-461G review also found in this issue of Interference Technology, SAE Aerospace Information Report (AIR), AIR 6236, *In-House Verification of EMI Test Equipment* was written specifically to support MIL-STD-461G. Specifically, section 4.3.11 *Calibration of measuring equipment* has been reduced in scope to devices such as EMI receivers and spectrum analyzers, oscilloscopes and (RS103) electric field sensors. Section 4.3.11 now says, "After the initial calibration, passive devices such as measurement antennas, current probes, and LISNs, require no further formal calibration unless the device is repaired. The measurement system integrity check in the procedures is sufficient to determine acceptability of passive devices." AIR 6236 was written to support the verification of proper operation of such devices in the EMI test facility using only test equipment commonly available in an EMI test facility. The idea behind the AIR was that if a measurement system integrity check was problematic, the AIR 6236 measurements would demonstrate whether or not there was a problem with a transducer. AIR 6236 was published in December 2015. Also, the procedures in the AIR can be used in-house to routinely self-check EMI test equipment, if desired.

This synopsis, by the AIR's author, discusses what's in it, and why, and includes a test procedure for one piece of equipment that was left out of the AIR.

Th *Introduction* says that the AIR provides guidance on how to self-check the devices listed below, using equipment commonly found in EMI test facilities. The purpose is not to calibrate these devices, but to check that they have not varied significantly from manufacturer's specifications.

Th *Scope* says that the AIR provides guidance to the EMI test facility on how to check performance of the following types of EMI test equipment:

- Current probe
- Line Impedance Stabilization Network (LISN)
- Directional coupler
- Attenuator
- Cable loss
- Low noise preamplifier
- Rod antenna base
- Passive antennas
- Power-line ripple detector (CS101 transducer)*

*The last device is not described in the AIR, but should have been, an oversight on the author's part. The power-line ripple detector is new in the MIL-STD-461G CS101 section. The PRD allows the use of a spectrum analyzer or EMI receiver to monitor injected CS101 ripple, in lieu of an oscilloscope, which is very helpful when injecting ripple on an ac bus.

All the AIR 6236 performance checks can be performed without software. A computer may be required to generate an electronic or hard copy of data. This is not to say that custom software might not be helpful; just that the procedures as written intentionally eschew the necessity of automated operation.

The *Purpose* of AIR 6236 is not to reproduce the procedures used by an accredited calibration facility, but rather to provide simple and accurate methods available using only test equipment found in an EMI test facility. For simplicity, all set-ups are shown using a network analyzer, but a spectrum analyzer or EMI receiver with built-in tracking generator may be used in lieu of a network analyzer, and if that isn't available, a separate signal generator may replace the tracking generator. The effects of these substitutions are discussed in the final section.

AIR 6236 measurement methods are not exclusive, but found to work well with a minimum of complexity. This is why it is an AIR – aerospace information report – rather than an ARP – aerospace recommended practice. There are many ways to skin the cats included in the AIR, and others may be judged better than those included, depending on the value system of the person holding judgment. The standard of value in selecting the included measurements was that they could be performed by an EMI test facility with equipment they already own and which would have NIST-traceable calibrations.

MIL-STD-461 is listed as an "*Applicable Document*."

The following *Performance Checks* form the main body of AIR 6236.

*1. Current Probe*

Various models of current probes based on transformer action are used from frequencies as low as 1 Hz to at least 1 GHz. All these probes may be calibrated as per Figure 1.

In Figure 1, the network analyzer source drives current through the calibration fixture, which the current probe senses. The attenuator values (excepting the 10 dB pad on the input side of the calibration fixture) are so chosen that the ratio of the current probe output (T-port) to the reference (R) input is directly the transfer impedance in dB Ohms, with no data reduction required. They also perform impedance-matching functions reducing vswr-related errors at higher frequencies. The 10 dB pad is solely for impedance matching and vswr-reducing, and need not be included if unnecessary, typically at audio frequencies where extra signal level into the calibration fixture is required. Its value does not affect the transfer impedance calculation.

At radio frequencies where there is plenty of dynamic range, the source setting should be set 10 dB below maximum in order to place 10 dB of impedance matching attenuation between the source and coaxial transmission line. Also at radio frequencies where loss in the coaxial cable becomes appreciable, the length and type of coaxial connection between current probe output and "T" port and between the 20 dB pads on the output of the calibration fixture and the "R" input must be the same.

*2. LISN*

While there are several methods for measuring the LISN impedance specified in MIL-STD-461, none has the simplicity and ease of measuring the insertion loss the LISN presents to a 50 ohm signal source. Insertion loss is the potential measured at the LISN port relative to at a 50 ohm load. Above 1 MHz, where the 50 uH LISN approximates 50 Ohms, the insertion loss is 0 dB. At lower frequencies, insertion loss increases with decreasing frequency. Figure 2a shows the measurement set-up, and Figure 2b shows expected results, including error bars representing the MIL-STD-461 20% tolerance on LISN impedance. This method and limit account for the 0.25 uF blocking capacitor loss. Note that the upper tolerance above 1 MHz is strictly academic; there is no way the LISN impedance can be higher than 50 Ohms, so the insertion loss cannot exceed 0 dB. At frequencies where coaxial cable loss is significant, the type and length of the cables con-

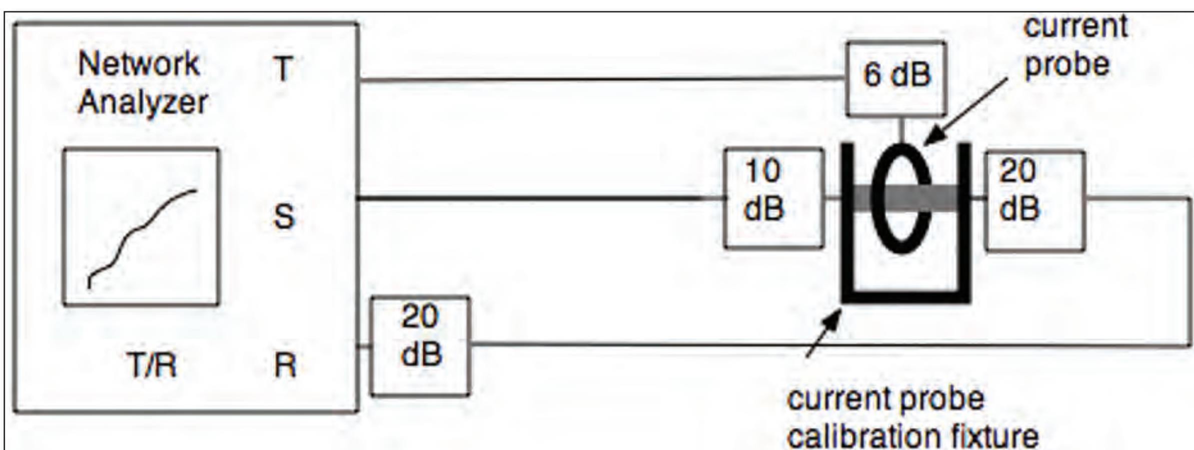


**FIGURE 1:** Current Probe Calibration - T/R ratio is the transfer impedance in dB Ohms.

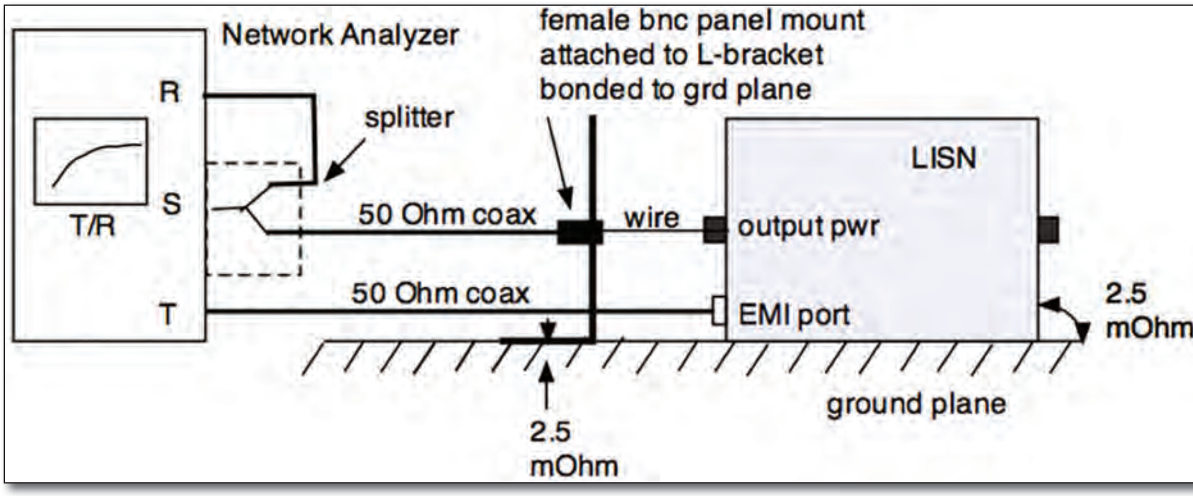


**FIGURE 2A:** LISN insertion loss measurement set-up

necting to the "T" and "R" ports must be the same. The connection between splitter and LISN output power connector must be short enough to have no significant loss. Insertion loss is measured as the T/R ratio.

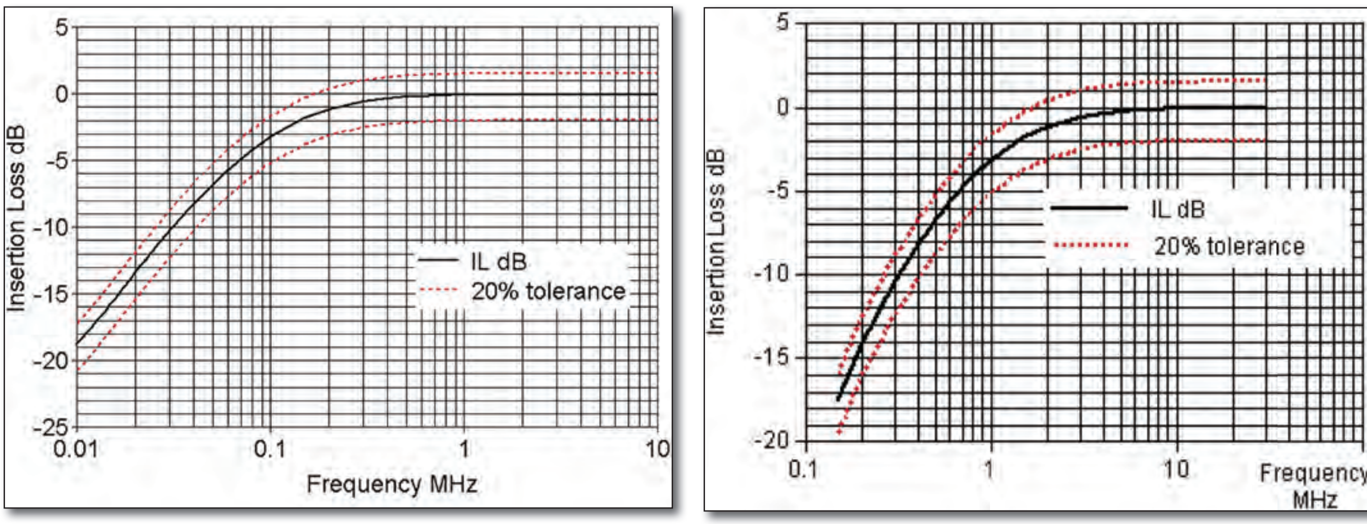


**FIGURE 2B:** MIL-STD-461 50 uH (left plot ) & 5 uH LISN (right plot) insertion loss, including losses in the 0.25 uF blocking capacitor with 50 uH curve

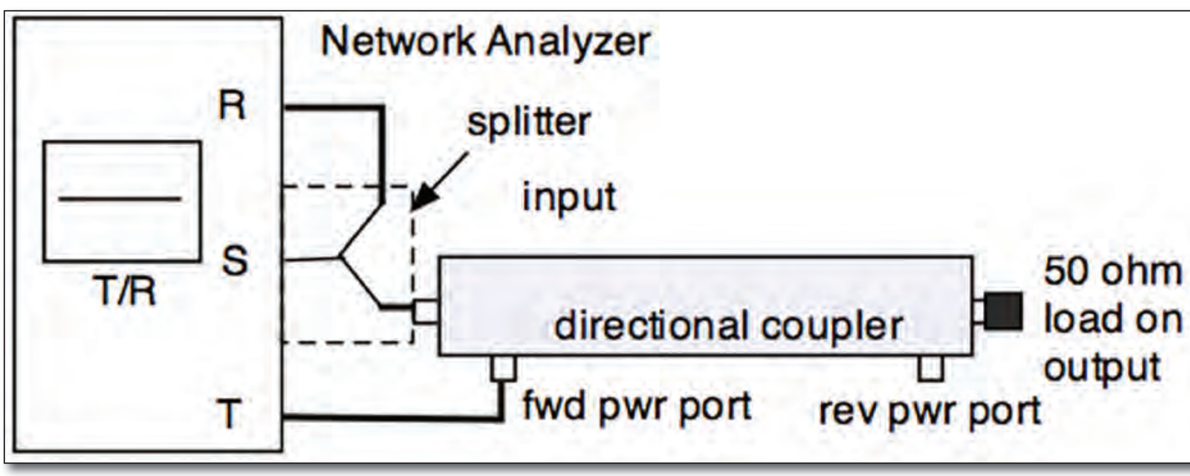


**FIGURE 3A:** Directional coupler forward power coupling factor measurement

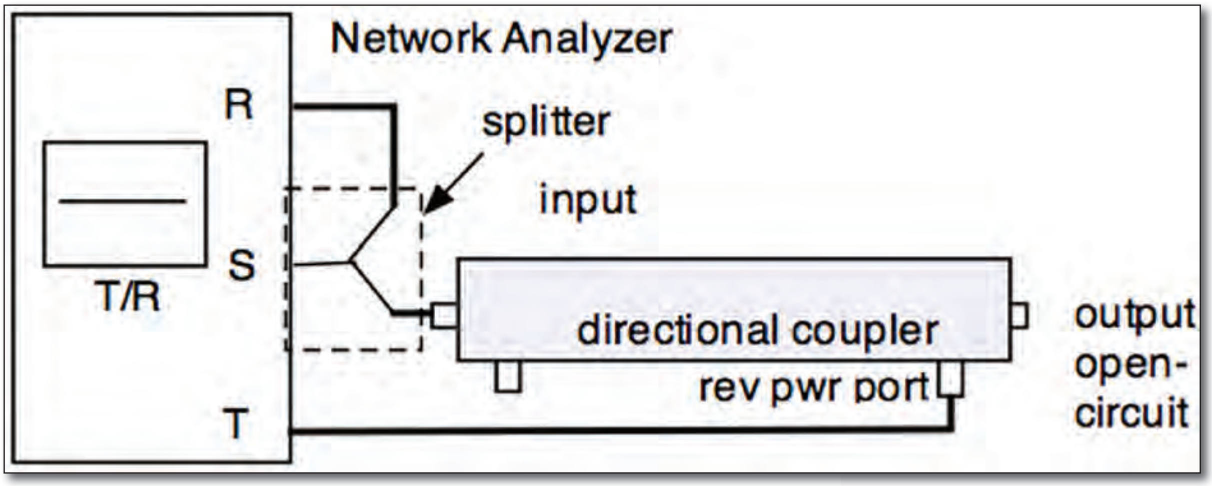


**FIGURE 3B:** Directional coupler reverse power coupling factor measurement

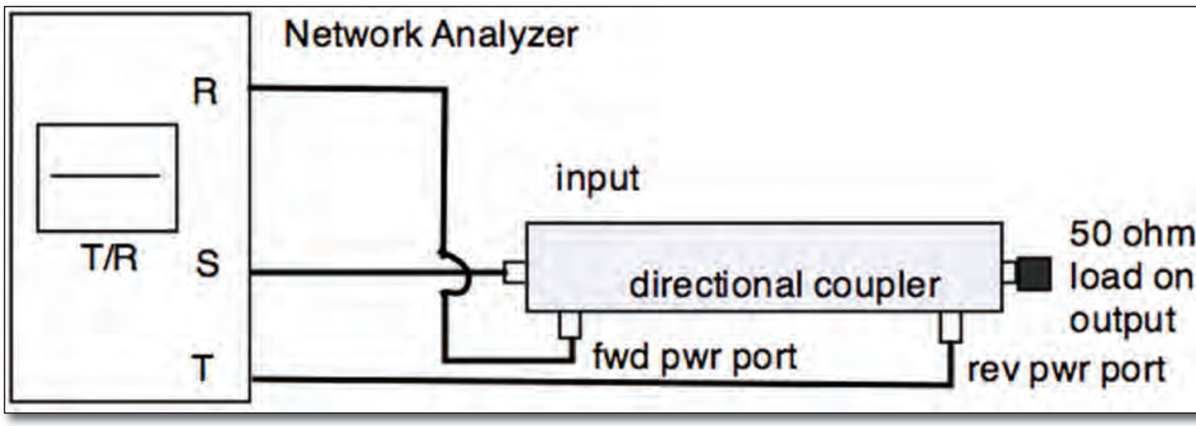


**FIGURE 3C:** Measurement to determine the minimum vswr that can be determined using the return loss method.

*3. Directional Coupler*

The forward power port coupling factor is used in some MIL-STD-461 measurements. This procedure measures that factor, as shown in Figure 3a. The T/R ratio is the coupling port factor. At frequencies where coaxial cable loss is significant, the type and length of the cables connecting to the "T" and "R" ports must be the same.

Because return loss can be used to verify antenna performance (see section 8), the following set-up and description explain how to characterize the reverse power port. Figure 3b is similar to Figure 3a and measures the reverse power port coupling factor. The T/R ratio is the reverse power coupling port factor. At frequencies where coaxial cable loss is significant, the type and length of the cables connecting to the "T" and "R" ports must be the same. Connection between splitter and directional coupler should be as short as possible, with negligible loss.

Figure 3c shows how to determine the limit on return loss measurement associated with a good match to 50 Ohms. The return loss so measured represents a minimum vswr value that can be ascertained using this method.

*4. Resistive Attenuator*

Attenuators are used in a variety of tests, both emissions and susceptibility. This procedure measures attenuation, as shown in Figure 4. The T/R ratio represents the attenuation. At frequencies where coaxial cable loss is significant, the type and length of the cables connecting to the "T" and "R" ports must be the same. Connection between attenuator and splitter should be as short as possible, with negligible loss.

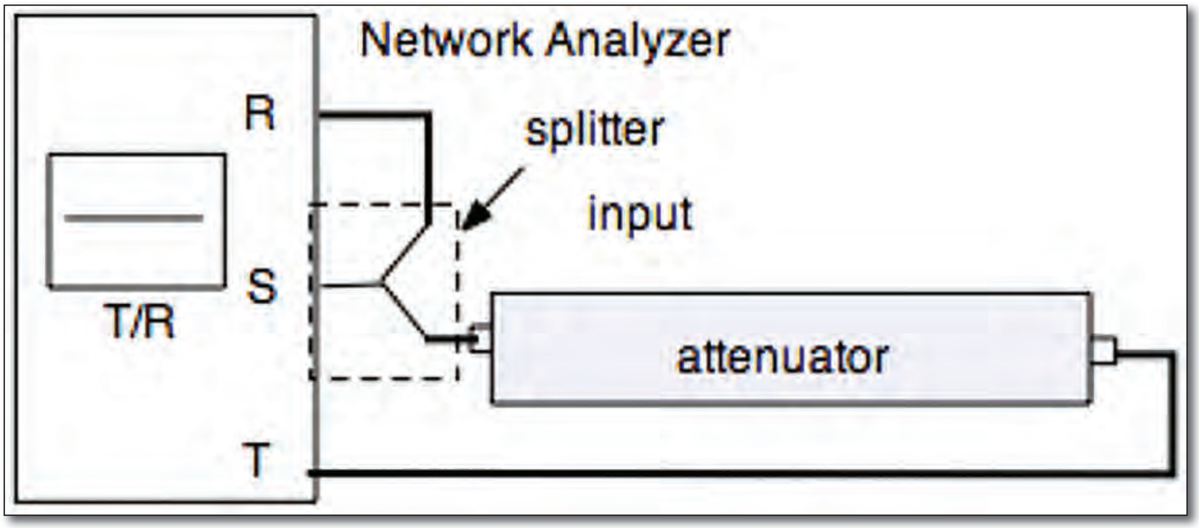


**FIGURE 4:** Attenuator measurement

*5. Cable Loss*

Coaxial cables are used in all measurement set-ups. This procedure measures cable attenuation, as shown in Figures 5a/b. The T/R ratio represents the attenuation. The type and length of the cables connecting to the "T" and "R" ports must be the same, and for this measurement they must be measured to be the same, as in Figure 5a. Once these cables have been shown to be the same, or their differences accounted for, they may be used to measure the loss of the cable-under-test, as in Figure 5b. Because small losses are measured, vswr can be a perturbing factor. Attenuation placed between the test and reference cable can minimize any impedance discontinuity effects.

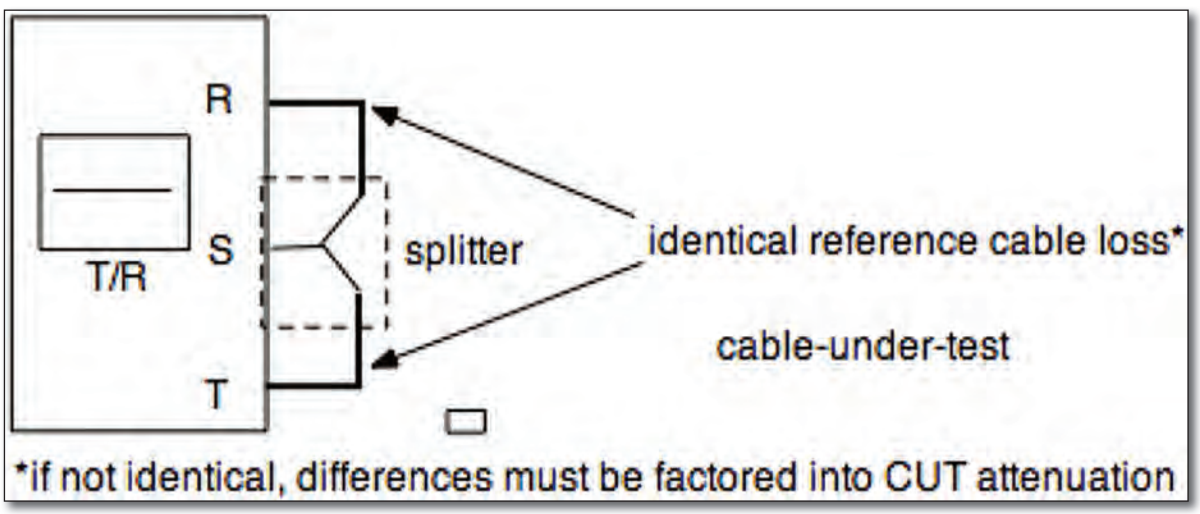


**FIGURE 5A:** Reference cable loss measurement

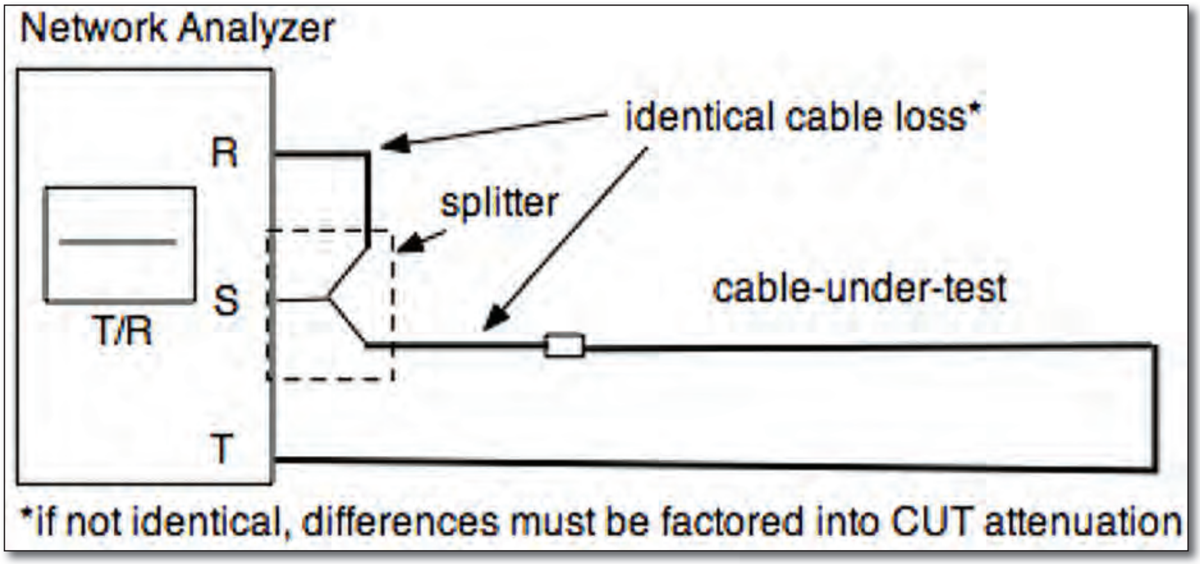


**FIGURE 5B:** Cable loss measurement

*6. Low noise Preamplifier Gain*

Low noise pre-amplifiers are often employed to make sensitive measurements such as radiated emissions, where the noise figure performance of the spectrum analyzer or EMI receiver is in itself not good enough to measure to the required limit. This procedure measures the amplifier gain, which must be accounted for when reducing data measured using the preamplifier. Figure 6 shows the set-up. The T/R ratio represents the gain. Care must be taken to use a very low input so the amplified output is well below the 1 dB compression point of the preamplifier. This method can also be used to ascertain the 1 dB compression point, by repeatedly measuring the gain while increasing the input, until gain compression is realized. At frequencies where coaxial cable loss is significant, the type and length of the cables connecting to the "T" and "R" ports must be the same. The connection between the splitter and preamplifier should be as short as possible with negligible loss.

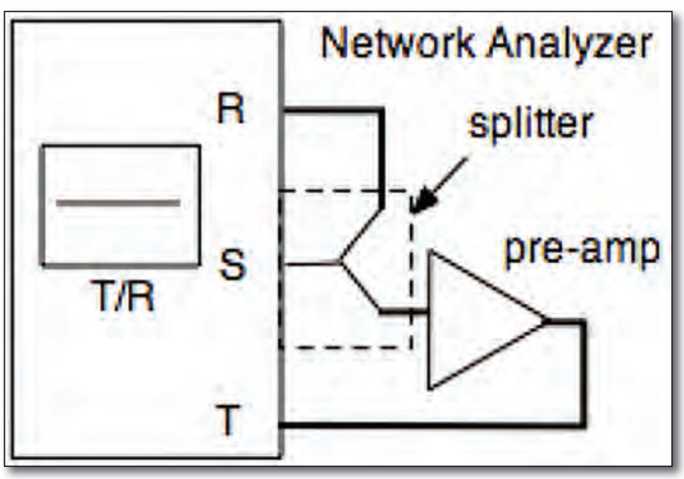


**FIGURE 6:** Low noise preamplifier gain measurement

*7. 41" Rod Antenna Base Transducer Factor Measurement*

The base of a 41" rod antenna, whether active or passive, acts as an impedance matching device between the capacitive output impedance of the rod, and the 50 Ohm connection into the spectrum analyzer or EMI receiver. A capacitor simulating the rod output impedance must be used in series between the network analyzer 50 Ohm source output, and the point at which the rod antenna mates with the antenna base, as per MIL-STD-461F/G Figure RE102-8, and as depicted below in Figure 7. The rod antenna factor is the measured transducer factor (gain or loss) less 6 dB, to account for the half-meter effective height of the 41" rod. The ratio T/R represents the gain or loss of the rod antenna base. Care must be taken in case of an active rod antenna to select a sufficiently low source signal level in order to avoid overload of the preamplifier in the rod antenna base.

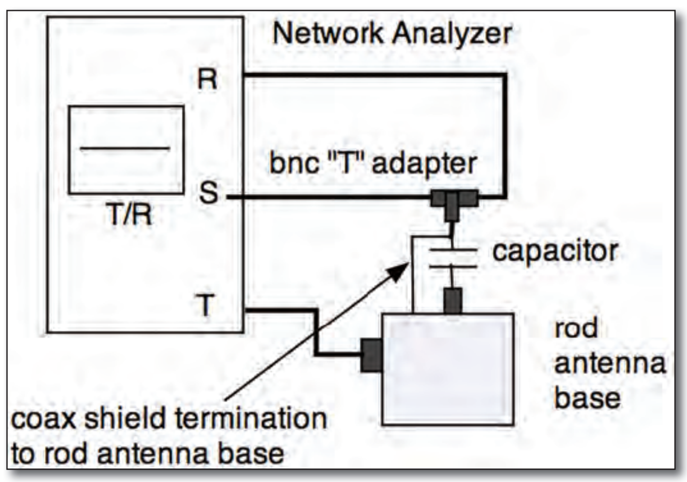


**FIGURE 7:** 41" rod antenna base transducer factor measurement

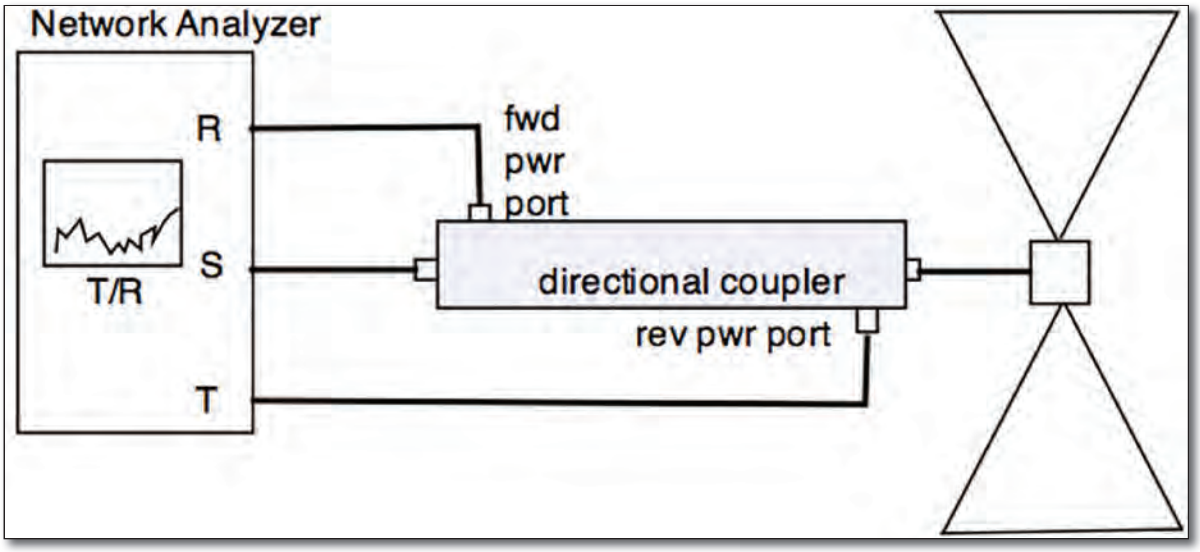


**FIGURE 8:** Antenna vswr measurement

*8. VSWR Check of Antenna Matching Network*

The most accurate check of an antenna's performance is its physical dimensions. If the radiating elements have not suffered damage, and the matching network between the 50 Ohm coaxial input to the radiating elements is also intact, antenna performance will be as advertised. While the radiating elements may be inspected visually, the matching network cannot, and its performance must be measured to ascertain integrity. While a simple device such as the small loop used for MIL-STD-461 test RE101 may be measured with an ohmmeter to verify continuity, more complex antennas such as the biconical and double ridge guide horns cannot be so checked. A check of their match to 50 Ohms in-band to their operating frequency band can verify that the matching network is not damaged. Such a check also checks any damage to coaxial connectors.

There are many ways to measure vswr, directly and indirectly. The vswr measurement method shown in Figure 8 was specifically chosen to use only equipment found in an EMI test facility.

Return loss is related to vswr as shown.

$$\text{Return loss (dB)} = -20 \log [(\text{vswr}-1)/(\text{vswr} + 1)]$$

Low vswr means a good match and return loss is high, meaning the measured T/R ratio will be low. Conversely, a poor match results in high reverse power, and the T/R ratio will be higher. In general, antennas have poor vswr characteristics near band edges, and best performance mid-band. In particular, the 137 cm tip-to-tip biconical antenna below 80 MHz has such poor vswr characteristics / high return loss as to be nearly indistinguishable from a bad balun. Therefore, vswr should be measured mid-band, and compared to manufacturer's specifications there. Table 8 gives a range of vswr vs. return loss values useful in characterizing antenna matching networks.

| VSWR | Return Loss dB |
|---|---|
| 1:1 | -∞ |
| 1.22:1 | -20 |
| 1.5:1 | -14 |
| 2:1 | -9.5 |
| 2.5:1 | -7.4 |
| 3:1 | -6 |
| 3.5:1 | -3.5 |

**TABLE 8:** Vswr vs. return loss

Note that return loss at values in excess of -20 dB will be difficult to measure, and in general aren't necessary, since they correspond to matched impedances very close to 50 Ohms, a condition not normally encountered with broadband antennas, where vswr of 2:1 to 3:1 is typical.

*9. Power-line Ripple Detector – not part of AIR 6236*

The power-line ripple detector (PRD) acts as a resistive voltage divider and a transformer in order to allow a 50 ohm tunable voltmeter (spectrum analyzer or EMI receiver) to monitor audio frequency ripple superimposed on an ac or dc bus via the CS101 test method. The transducer factor is the constant of proportionality between the ripple potential on the bus and what is measured at the 50 Ohm tunable device. This test method uses a bnc-tee instead of a 50 ohm splitter because it is not a 50 ohm measurement, it is audio frequency, and it is critical that the reference reading be exactly what is applied to the PRD bus connection jacks. The measurement is swept from 30 Hz to 150 kHz. The PRD has two transducer factors; one is flat and represents voltage division and the transformer winding ratio, and the other rolls off above 5 kHz at the same rate but opposite slope to the

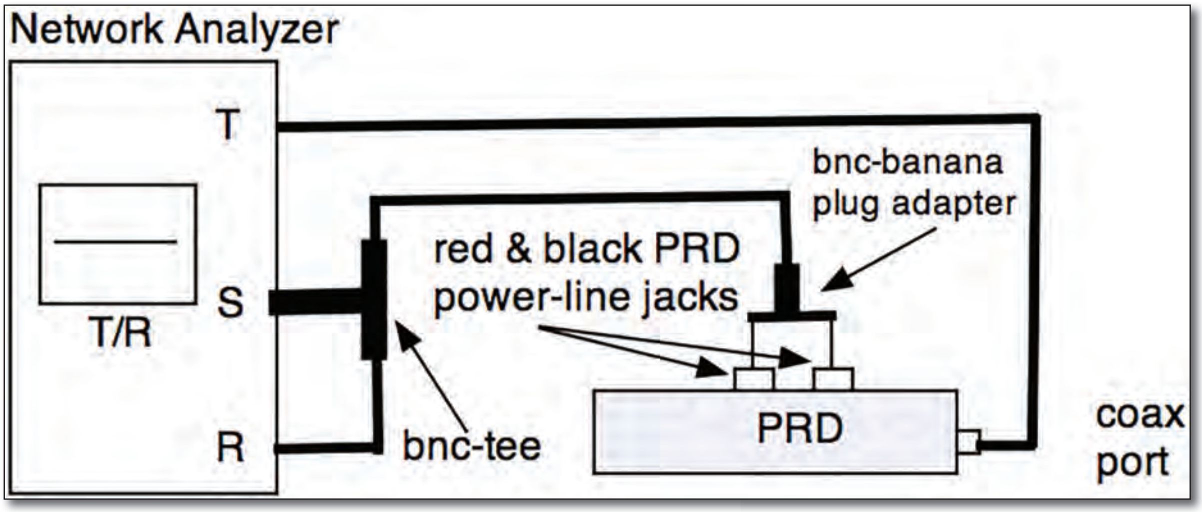


**FIGURE 9:** Power-line ripple detector transducer factor measurement

MIL-STD-461 CS101 limit so that the 50 ohm tunable device measures a constant value even when the limit is decreasing with increasing frequency. This aids in making manual measurements, and also facilitates better signal-to-noise ratio as the limit gets lower at higher frequencies.

The last section is *Measurement Options When a Network Analyzer Is Not Available*.

In lieu of a network analyzer, which is not ordinary EMI test equipment, a spectrum analyzer or EMI receiver with a built-in tracking generator may be used. If that isn't available, a spectrum analyzer/EMI receiver may be used along with a separate signal generator.

In each case, the rf input of the analyzer/receiver replaces the "T" (test) port on the network analyzer, while the tracking generator or signal generator replaces the "S" (source) port. For those measurements involving 50 ohm devices, it is advantageous to us a 0 dBm signal source so that the lack of a reference measurement has no effect: the trace on the analyzer effectively is the "T/R" plot that would be obtained with a network analyzer.

An analyzer/receiver with the capability to display two traces may be used in the cases where the device-under-test loads the source and that must be taken into account. A sub - 1 GHz splitter such as used with a network analyzer for this purpose may be obtained for petty cash. A microwave splitter is more expensive, but still relatively inexpensive as test equipment goes.

If a tracking generator is not available, and an external signal source is used, then two options are available. Absent any controlling software synchronizing the sweep (and thus effectively creating a tracking generator) the signal source and analyzer/receiver sweep are unsynchronized, which requires placing the analyzer/receiver in "max hold" display mode and performing multiple sweeps until the observed trace has no dropouts. This requires more time than the other approaches, but requires no extra instrumentation, and no investment in computer control.

Some newer digital network analyzers are two port devices, requiring sequential measurements for reference and test measurements rather than traditional simultaneous measurements. The measurement principle is the same.

# The IEMI Threat and a Practical Response

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MPE Ltd

## IEMI THREAT

**WITH THE INCREASING USE** of electronics to control so many aspects of modern life, from smart grids to driverless cars, Intentional Electromagnetic Interference (IEMI) is a threat gaining concern. Various initiatives have been set up to address the needs of specific market areas, and new standards are being worked on.

However, to offer protection one must start by understanding what is being protected against and how that compares and contrasts with other EM protection standards. Figure 1 below shows the frequency and comparable magnitudes of the various EM threats. Please note that EMI refers to the typical background EMI that can be experienced from benign intentions such as radio and TV broadcasting, radar, microwave, networking and GPS systems.

It can be seen that IEMI differs from most other EM threats in that it typically occupies a narrow frequency band, dependent upon which specific malicious source is being used. This contrasts with other threats such as

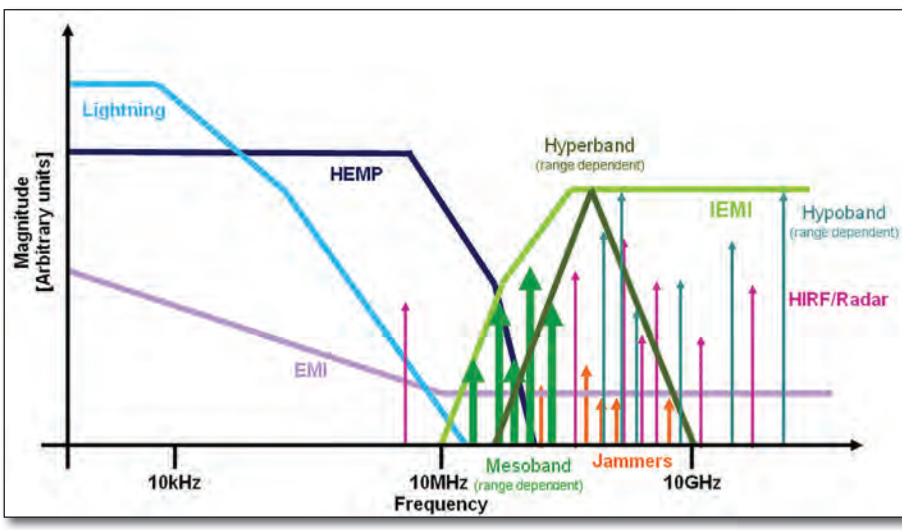


**FIGURE 1**

 

lightning and HEMP (high-altitude EMP), which are very broadband in nature.

The other notable difference is the area of the spectrum occupied: IEMI-radiated threats are almost never below 10MHz, as the coupling efficiency of such a threat would be much reduced. Instead the frequencies used tend to be much higher, to improve the effectiveness and penetration of any attack. The exception to this is for pulses directly injected into power and communications conductors, where lower frequencies are able to travel long distances with minimal attenuation.

## METHODS OF THREAT DELIVERY

The biggest problem with protecting against IEMI is that the sources can vary massively between different aggressors and the way any attack is launched.

IEC 61000-4-36 is the standard for IEMI immunity test methods for equipment and systems and should be considered essential reading for anyone attempting to protect against IEMI. IEC 61000-4-36 defines categories of aggressors as Novice, Skilled and Specialist. These definitions are based on their capability, and IEC 61000-4-36 gives examples of the types of attack one could anticipate from those categories.

Generally Novice attacks will be short-ranged or require some direct access and take the form of technologically very simplistic and low-cost methods such as modified microwave ovens, ESD guns or even EM jammers that can be bought online for a hundred Euros. Although unsophisticated, such attacks should not be underestimated and could easily cause persistent disruption or damage without leaving an evidence trail of an attack. An example of what can be constructed from rudimentary everyday components is shown in Figure 2.

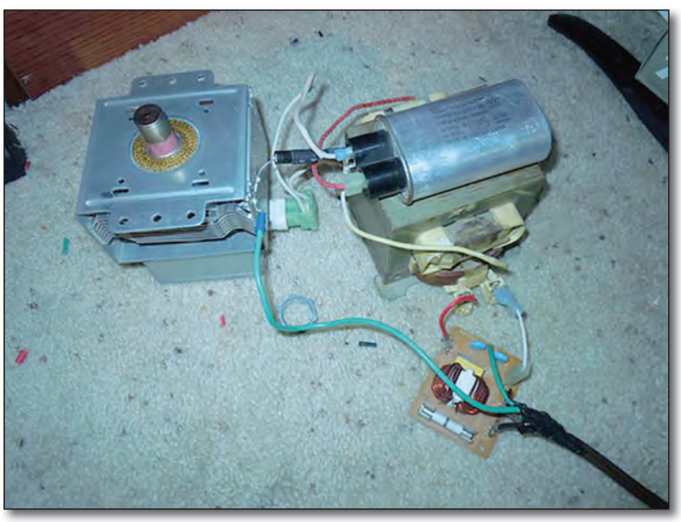

**FIGURE 2**

The next category of skilled aggressors comprises those with good understanding and experience or who have access to commercially available equipment. That equipment could be something like the Diehl pulser pictured in Figure 3.

**FIGURE 3**

This is an off-the-shelf "interference source" capable of emitting a 350MHz damped sine wave output and 120kV/m at 1m continuously for 30 minutes. With an appropriate antenna, it would be capable of disruption or damage at a greater distance.

In the Novice and Skilled categories one could also anticipate conducted attacks where access is possible, involving direct pulse or continuous wave injection onto the power and/or communication lines. These should not be underestimated and can have huge impact on systems, with effects such as: triggering of safety protection devices or disruption of switched mode PSUs, causing power cuts as well as physical denial of services (DoS) by flooding xDSL or ISDN systems. The ultimate threats are high-power pulses that bring about physical damage to equipment.

The third category of Specialist is in the realms of research laboratories and high-end military programs with accordingly high capabilities. This covers systems such as the Boeing CHAMP missile and the Russian-developed RANETS-E, which is capable of a 500MW output and range of 10km. Plentiful information on both systems is available in the public domain. Although it would be obvious if a large truck with antenna was parked outside, or a missile had been launched overhead, a Specialist aggressor's equipment can be much more subtle than that, especially if fixed equipment can be set up nearby – in a building across the street or even an ad-joining room. This allows complex equipment to be set up and an attack to go unnoticed for a long time, or perhaps not be noticed at all.

This raises the most critical question concerning protection from IEMI – access. Access is in terms of distance either from threat to target in radiated systems, or to incoming power and communications cables for injected conducted disturbances.

## EFFECTS ON OPERATIONS

Numerous papers have been written on the disruptive and damaging effects of IEMI attacks on electronic systems, and covering that in detail is beyond the scope of this paper. Readers are encouraged to review the many papers and presentations on the subject.

What can be said here is that the effects can vary from the very subtle – errors in data streams and microprocessor instruction operation through to system lockups, hard resets and even permanent damage which renders a system beyond repair.

The exact effect of a particular aggressor's action against a particular system is very case-specific and would require thorough analysis. However there is one general rule that applies, and it may appear obvious: the greater the interference, either as a conducted or radiated disturbance, the more likely effects will be seen and the more severe they will be.

It has been shown many times that a radiated or conducted disturbance will cause damage at higher power levels, but at lower power levels can cause only minor upsets or even no significant effect at all. This makes disturbance attenuation the key to protection.

## ASSET PROTECTION

While the internal resilience of equipment is a key part of IEMI protection, it is known to vary even between equipment made by the same manufacturer. So often it is not possible to influence that characteristic, especially where third-party equipment is concerned, so one must look instead at how those assets can be protected by external measures.

As can be seen in Figure 1, there is little frequency overlap between traditional threats and IEMI. One should bear this in mind when planning the protection strategy for a system. However it does not mean that existing protection systems or even infrastructure are completely useless, just that they shouldn't be considered the whole solution.

What one does need to consider is the type of IEMI threat likely to be experienced. For example, it is unlikely that a small company in the UK will suffer an attack from a Boeing CHAMP missile directly overhead, but it's plausible it could be subject to interference from a malicious individual with some pulse generator plans from the internet. It's plausible that a company of national significance could be subject to organised terrorists, with whatever equipment and skills their organisation possesses.

Bearing this in mind, there are different strategies one could adopt for protection. The obvious and technically naïve strategy is to assume that, because all equipment must be to the standard of the EMC directive, it is adequately protected. However the various EMC directive immunity tests are all significantly below the levels and frequency that could be experienced during an IEMI attack (V/m against kV/m), and typically EMC directive conducted compliance focuses on the lower bands – where SMPS and similar switching noise problems exist that do not arise at the higher bands where most IEMI threats exist. ESD protection only has limited relevance: as it only mandates no permanent damage, disruption is acceptable.

The second approach is to go to the other extreme and apply the traditional metal box / Faraday cage solution shown in Figure 4, as often seen in high-end military applications and EMC test chambers. This assumes no inherent resilience in any equipment and is the same strategy adopted for MIL-STD 188-125 HEMP (nuclear EMP) protection on critical military infrastructure, where even a minor disruption isn't tolerable. For IEMI protection applications where that same 'work-through' requirement exists, then this really is the only guaranteed solution: one would simply need to ensure that the shield performed up to at least 18GHz and the same for the filters on incoming power and communications lines.

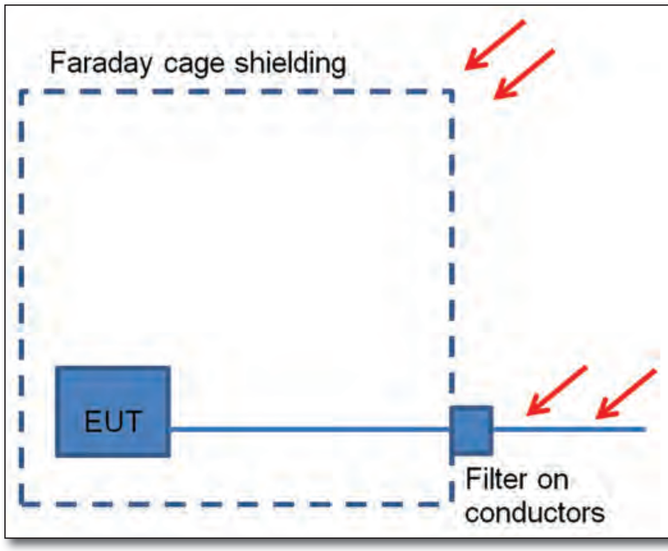


FIGURE 4

As confirmation of this principle, MPE recently tested their filters against the Diehl pulser pictured in Figure 3 to try out the hypothesis. As shown in Figure 5, the LEDs were positioned both inside and outside the shielded cabinet. At this stage it was only a qualitative test, with the power source outside filtered using one of MPE's HEMP filters. The effects were very clear, with no LEDs being damaged inside the cabinet even at very short ranges from the Diehl source: however most of the LEDs outside suffered failure at this and greater distances.

There are plans to do more detailed quantitative tests against this and other IEMI sources, including the often touted modified microwave oven. However, knowing that the same filter construction has been proven in 40GHz filtering / shielding applications and the energy from IEMI is still below that of MIL-STD 188-125 (150kV 2500A conducted), the outcome is expected to again be positive and to show

FIGURE 5

that standard MPE HEMP filters also protect against IEMI. The assessment is likely to take a similar approach to that of HEMP filter testing described in IEC 61000-4-24, where residual currents and voltages are measured on the protected side of the filter against a known incoming pulse.

For lesser applications taking this approach, one would only need adequate shielding and filtering to the appropriate level for the anticipated threat. The reality is that such a shield wouldn't be worth providing unless it was giving at least an overall 60dB reduction. This approach could be scaled appropriately to what is desired to be protected: if only a server cabinet is deemed critical, then only that needs shielding and filtering. The downside of such protection is the cost – for a cabinet alone, it could run to over £1000.

Protecting a large, high-end military facility can cost in excess of £100,000 in filters and more than £1m in shielding and architectural work, even if done at the point of construction. Retrofit would add even further to the costs. Such a facility would also require significant maintenance, adding to the bill. This cost can be very off-putting for all but the most critical of applications.

Another approach to the problem is to assess what protection is already there, the threats that are likely to be a problem, what really needs protecting, and to apply a staged protection scheme.

This concept doesn't rely on a single component providing huge signal attenuation, but on multiple smaller and often incidental components to give a similar attenuation at a much reduced cost. The concept is shown in Figure 6. This is a tailored solution to suit individual scenarios and equipment.

It is here where the EMC directive (and other regulatory EMC standard) immunity tests become useful: they provide a good baseline for building upon with other protection methods. Caution should be exercised here, as there is a danger of "building on sand". The EU "CE" mark is a self-certification system, meaning that a CE mark is only as trustworthy as the company placing the mark upon the product.

One only has to look at the many analyses of USB phone chargers and LED lighting systems to know that many products do fall far short of the standard (not just for EMC) when put to test. Assuming that the regulatory immunity can be trusted, then a typical attenuation of 60dB might be required from perhaps 10MHz to 1GHz. It becomes less clear above this frequency, as many items of equipment stop testing at 1GHz, and so the base equipment immunity is often unknown above this.

The next asset in the protection scheme also comes for free – the architecture around the system. Several studies have shown that some buildings can provide up to 20dB of shield-

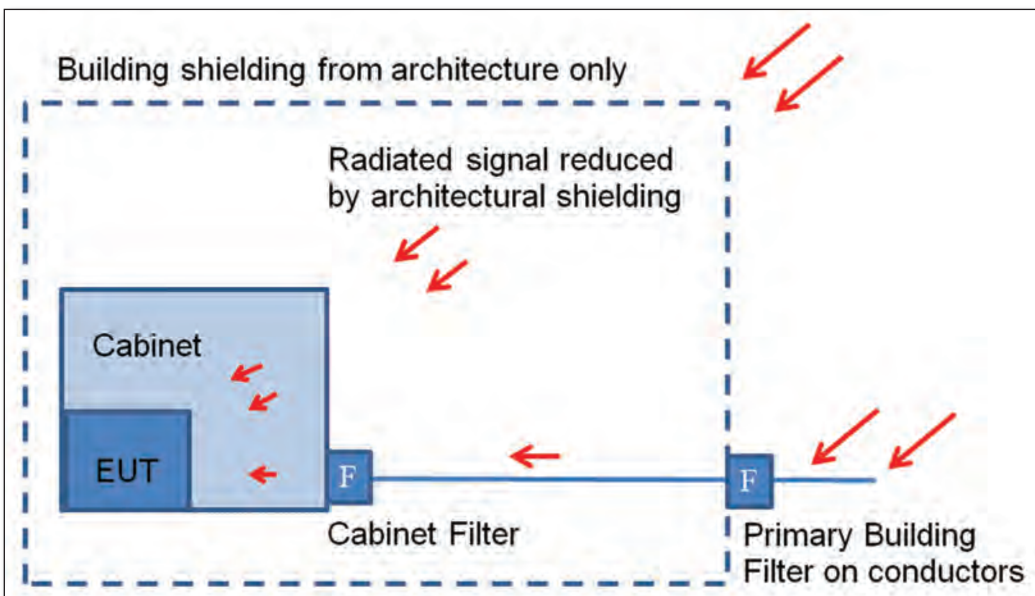


FIGURE 6



MILITARY

ing, while others provide almost nothing, the diff rence being due to the materials used and their construction style.

For instance, concrete rebar can give 11dB of shielding, yet wooden buildings would do well to give 4dB. As with all areas of IEMI, details and specifics can make a huge impact, for instance a metal clad building may appear to off r a rudimentary Faraday cage, but if unfiltered conductors are penetrating that cage, its benefit can drop from what would be 30dB to -10dB, creating a stronger field inside the building than outside. In this case applying appropriate filtering would rectify the situation and provide a solid 30dB. Note that these figures are for particular frequencies, and a proper study of the specific case should be done, with measurements taken if necessary.

The distance between a potential aggressor and a protected system should not be underestimated either and could be quite long relative to the wavelengths used in an attack. If the site has an extensive perimeter with security, or only a specific room needs to be protected in a large building or complex, this gives a natural attenuation to any radiated or conducted attack originating off-site.

As an example of the benefits of distance, basic RF theory tells us a 1GHz radiated attack could be attenuated by more than 50dB over just 10m. This is a practical, controlled perimeter distance for many sites, but caution is advised as this simple illustration is based on isotropic antenna gain and should be considered in that context.

Equipment cabinets and cases can also have protective capability. A typical commercial EMC cabinet compared to an unshielded rack could provide a consistent 30dB of attenuation up to1GHz and could still be providing some up to perhaps 5GHz.

The conducted protection should try to coincide with the shielding to avoid bypass coupling and prevent any compromises to the inherent shielding protection. If the building has very good shielding, then a large incoming filter at the entry point would be best. But if shielding is very poor or with potential access issues, then the cabinet or individual equipment must carry the majority of the shielding, and this is where the filtering should be located.

Distributed filtering can be used with several lower performance filters in place of a single high-attenuation filter. Some of those filters could be part of the original equipment, but bear in mind that, although most equipment has incoming power filters, these are often only low frequency for EMC compliance and not really suitable for IEMI protection. Furthermore the combination of filters in the system should cover the entire frequency spectrum of concern. This requires assessment against the probable threats and tolerable disruption: there is a standardised way to define these in the appendices of IEC 61000-4-36.

A vital part of the filtering solution is the surge suppression performance against pulse-type IEMI attacks, which can have very high power content and fast rise times. Those rise times can be in the order of nanoseconds or even picoseconds, billionths or trillionths of a second.

Compare this to the most common type of surge suppression – lightning protectors, typically spark gap or MOV varistor types. These typically only need to operate in the microsecond timescale for lightning: although some of the technologies can operate far faster than this, in practice they don't when used in lightning applications, due to many factors including installation and connectivity styles. This makes any lightning protection very ineff ctive against IEMI, except for the very slow conducted pulses, i.e. those already in the lightning area of the frequency spectrum.

This is where the crossover with HEMP is important: the MIL-STD 188-125 E1 pulse also has a fast rise time in the nanosecond scale and energy content far exceeding that of any likely IEMI attack. As the performance won't suddenly cease at the top of the HEMP spectrum, this means that a MIL-STD HEMP protection device will protect against all but the fastest conducted pulses seen with IEMI threats. Nevertheless MIL-STD HEMP devices, as previously discussed, are expensive and quite likely excessive in all but the most sensitive and critical cases where HEMP protection is also likely to be a concern.

Therefore in most cases what is desired is in eff ct a lower cost and performance HEMP filter, with performance stretching to at least 18GHz. Fortunately the update of IEC 61000-4-24 is nearing publication. It will define a range of performance criteria for HEMP protection on civilian applications which are based on more relaxed residuals than the MIL-STD (it also includes the MIL-STD as the special case) but are still required to respond to the same nanosecond timescale pulse.

This provides a good basis for specification of IEMI surge suppressors and conductor filtering, as it requires demonstration of all the key attributes – fast pulse response, prevention of shielding bypass and ability to handle the power levels expected during such an attack.

## THREAT DETECTION

If the system in question can tolerate interruptions or damage without serious unrecoverable consequences, and the business case is not currently strong enough to invest in protection, there is an intermediate step before protection that is complementary to it even when installed.

This takes the form of detection of any incidents and profiling it in the specific scenario, with an aim to gather evidence for the purposes of the cost/benefit analysis of protection systems – and for logging IEMI attacks or disruptions in order to positively identify threats against system faults. This has the added benefit of logging unintentional EMI eff cts in the increasingly crowded spectrum.

This approach has only become viable recently thanks to a shift in the philosophy of detection systems. Traditional IEMI monitoring equipment is very large, expensive and complex, requiring highly skilled staff to operate. These can give a full profile of any attack or threat detected, with analysis of the specific source in real time, etc. However the cost and maintenance of such a detection system can approach or

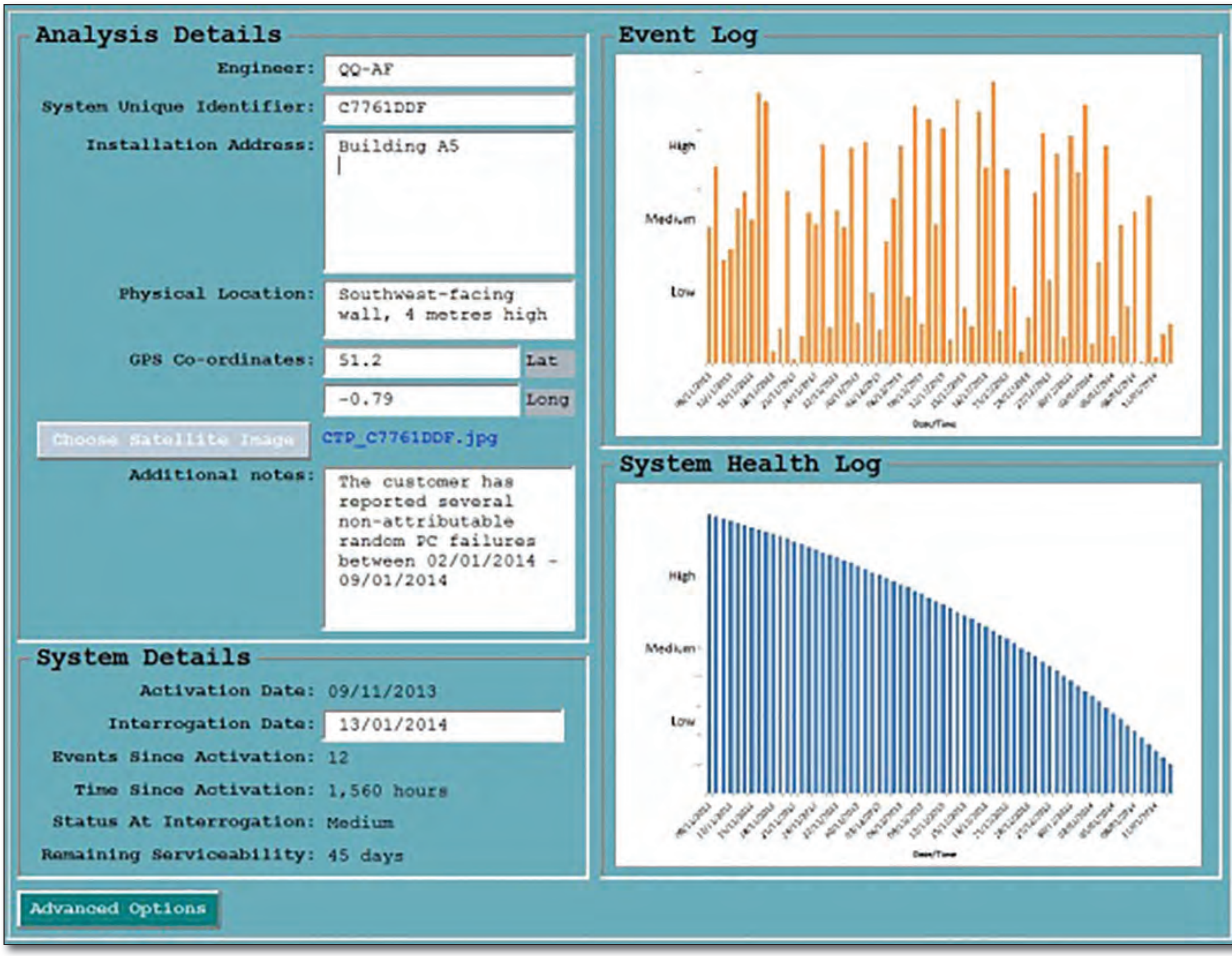


FIGURE 7

exceed that of system protection, making detection a costly intermediate step for general use.

To make logical sense, what is required is a detection system of lower cost and complexity. This differs from the traditional detection approach by simply detecting anything that causes a large enough EM disturbance and logging it in the time domain.

By logging the disturbance in enough detail in the time domain, offline analysis can then be performed as shown in Figure 7, removing the need for complex analysis, and thus cost, within the detector. By keeping the costs low, large sites could deploy multiple detectors, giving a far more detailed view of the threat. Information that this could give to the analyser includes increased accuracy on wave shape and triangulation of the threat source, and attenuation provided by existing buildings, infrastructure or shielding.

This solution gives the two desired outcomes from detection: an evidence trail for any cost/benefit assessments for stakeholders to invest in protection, and the time-stamping of disturbances, to be correlated with any CCTV or other evidence in legal proceedings.

## SUMMARY

It can be seen that the IEMI threat is real regardless of application – whether in security or defence, public or private sector – and that existing protection systems cannot be assumed to be adequate and in most cases will be found wanting by a well-planned attack.

The steps required to effectively and adequately protect against the risk of IEMI are clear – understanding the nature of the threat, taking advantage of existing protection systems and supplementing them with IEMI-specific measures where necessary.

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# Have Suspect Counterfeit ESD Packaging & Materials Infiltrated the Aerospace & Defense Supply Chain?

**BOB VERMILLION**
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**ACCORDING TO THE 12** February 2016 edition of the EE Times, President Barack Obama indicated a day earlier that he will sign into law a customs bill passed by the U.S. Senate that includes a provision to combat counterfeit semiconductors[1]. This bill will be called the Trade Facilitation and Trade Enforcement Act of 2015 (H.R. 644/S.1269). In eff ct, the U.S. Customs & Border Protection will be mandated to share information and samples of suspect counterfeit EEE parts for inspection and testing identified as counterfeits. In 2011, the Semiconductor Industry Association estimated that counterfeiting costs U.S. based semiconductor companies more than $7.5 billion per year.

Over the past several years, U.S. based organizations have sacrificed the traditional "internal auditing process" with reliance upon contract manufacturers, distributors and suppliers to do the right thing. To compound the problem, organizations have accepted supplier specifications as adequate proof in qualifying a product for use. The inspection of ESD sensitive devices or EEE parts is very important, but without special safeguards, the additional handling to remove and repack a product for validation can cause both physical and ESD damage in the process. For electronic ESD sensitive components, including those not sensitive to static electricity, measures must be utilized to detect, inspect and validate the packaging as well as incoming EEE parts.

First to present at the NASA QLF (Quality Leadership Forum) 2010 on issues of suspect counterfeit ESD packaging & materials (Figure 1) in the DOD Supply Chain, the Author stated that a Supplier Technical Data Sheet is no longer enough to verify a product's compliance with ANSI/ESD S541 (ESD Standard for Packaging and Materials). In 2012, Dr. Doug White (US Army, DAC) and the Author presented: "*ESD Packaging for Supplier Non-conformance & The Importance of Proper Training & Qualification Testing as an Effective Countermeasure for Mitigation*" at the National Institute of Packaging & Handling Logistics Engineers (NIPHLE) Annual Conference, Washington, DC. Results from the White Paper provide evidence that due diligence in the initial test of a protective package constitutes a major first step toward supplier compliance.

[1] http://www.nytimes.com/2016/02/12/business/international/sweeping-trade-enforcement-law-gets-final senate-approval.html?_r=0

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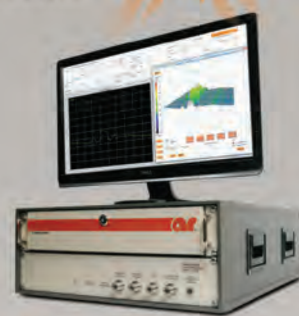

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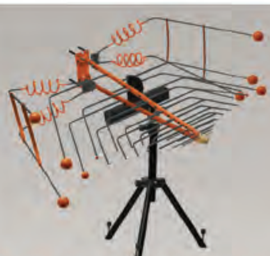

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BUILT TO LAST


**FIGURE 1:** Different Types of Static Control Packaging types. Label and Indication Card in Table 1

| | |
|---|---|
| Blister Pack | Antistatic Pink Poly Pallet Wrap |
| Antistatic Pink or Blue Poly Bags | ESD Cleanroom Paper |
| Conductive Carbon Loaded Bags | Antistatic 8" x `11" Paper |
| ESD Static Shielding Bags | Antistatic Tape |
| ESD Aluminum Moisture Barrier Bags (Type I) | Clear, Blue and Pink Antistatic Work Carriers |
| ESD Grid Bags | ESD Polystyrene Peanuts (Not Allowed) |
| ESD Corrugated Containers | ESD Safe Tape & Reel |
| ESD Polymer (Plastic) Boxes | ESD Rubber bands and straps |
| ESD Paperboard | ESD Safe Antistatic Dip Tubes (IC Carriers) |
| ESD Plastic Corrugated (Extruded) | Antistatic End Caps (Pink and Back) |
| Plastic Hinged Clear Antistat Coated Boxes | ESD Symbol Labels |
| Plastic Hinged Conductive Carbon Loaded Boxes | Antistatic Labels |
| Antistatic Clamshells | ESD Wafer Boats |
| Antistatic Trays | ESD Wafer Carrier |
| Static Dissipative Trays | ESD Wafer Separators |
| Inherently Conductive Polymer Trays | ESD Torn Bag with Tubing, IC Carrier or Dip Tubes |
| Carbon Loaded Trays | Antistatic Bubble |
| Carbon Coated Trays | Blue Dissipative Bubble |
| ESD P E Films | ESD JEDEC Trays |
| Antistatic Films | ESD Cordless Wrist strps |
| ESD Foams | Humidity Indicator Cards |
| Cross-linked foams | Sorbent (Absorbent) Pads, Antistatic |

**TABLE 1**


**FIGURE 2:** Tape and Reel Photograph showing components in carrier tray and clear film

Today's US based products are now commonly substituted by offshore manufacturers without traceability in the global supply chain. In contrast to aerospace & defense, the pharmaceutical sector is actively engaged in a sound packaging engineering approach that differentiates non-conforming or suspect counterfeit products to be tracked, identified, inspected and then placed into quarantined (Figure 3).


**FIGURE 3:** Static shielding bag housing IC Carrier Rails (Dip Tubes)

Scope of the Problem: Supplier non-conformance and suspect counterfeit packaging can represent an electrostatic discharge (ESD) hazard to sensitive devices or components by facilitating high voltage discharges during transport, parts inspection and manufacturing. Several aerospace related issues involve long-term storage with antistatic foam, antistatic bubble, vacuum formed antistatic polymers and Type 1 moisture barrier bags.

The late John Kolyer, Ph.D. (Boeing, Ret.) and Ray Gompf, P.E., Ph.D. (NASA-KSC, Ret.) were advocates in the utilization of a formalized physical testing material qualification process. Today, the DoD, prime contractors and CMs rely heavily upon a visual inspection process for ESD packaging materials. Over the past decade, suspect counterfeit ESD packaging materials have entered the supply chain largely unnoticed due to the practice of accepting a Supplier Technical Data Sheet in lieu of testing.

A common practice of visually inspecting an outer package label in combination with bar code scanning has not prevented suspect counterfeit static control packaging from entering the DoD supply chain. To compound the matter, an inexpensive *walnut blasting* method to remove a component's lettering is used by suspect counterfeiters with little to no evidence of tampering as illustrated in Figure 4.

Another countermeasure for detection is the use of RFID in packaging for incoming inspection and inventory tracking. "Hands on" training is a reliable method to teach Incoming Inspection personnel in the use of advanced ESD testing techniques. For example, ESD sensitive components are typically protected by packaging that industry identifies by "color", i.e. "Pink" or "Blue" for antistatic bubble and "Black" for carbon loaded polymer (JEDEC trays and Tape & Reel). Color is no longer an indicator of static control packaging performance. This identification marker is widely accepted by Aerospace & Defense. A simple and cost effective electrical surface or volume resistance test can be utilized to determine if packaging is ANSI/ESD S20.20 compliant.

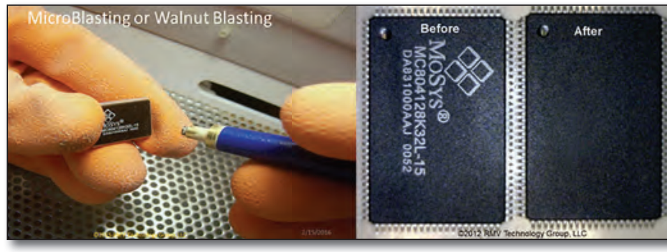


**FIGURE 4:** Walnut Blasting of Lettering from Rejected or Outdated EEE Part

A counterfeiter is not motivated to package fraudulent ESD sensitive components in compliant ESD safe packaging as material costs can be 40% or more. Whether the protective packaging is non-compliant or suspect counterfeit, the EEE device could be compromised.

Even though some Federal agencies may not use dip tubes in manufacturing, many primes, CMs and electronic distributors continue to source EEE parts housed in antistatic IC carriers that are not designed for long term storage.


**FIGURE 5:** IC Carrier or Dip Tubes which were Quarantined by User

Since 1997, our lab has evaluated static control products and packaging for major federal agencies, commercial end users, OEMs, CMs and distributors. For the past several years, many ESD materials and packaging from the Pacific Rim have failed standardized ANSI/ESD testing. For example, the reader can see that an "ESD labeled" reel is insulative at 1.5 x $10^{12}$ ohms in Figure 6; the limit is <1.0 x $10^{11}$ ohms. In addition, the reel charged to -15,080 volts that could be a cause for Field Induced Model discharge (FIM).


**FIGURE 6:** 2-Point Resistance Test of Reel on Left and Non-Contact Voltage Reading on Right

ESD

As stated earlier, the RMV & U.S. Army Defense Ammunition Center (DAC) white paper for the NIPHLE Conference, Washington, D.C. produced the following:

1. Fast Packs (Failed)
2. Antistatic Bubble (Passed)
3. Antistat Pink Poly Film (Failed)
4. Type I Aluminum ESD Moisture Barrier Bag (Failed)
5. Type III Metallized ESD Shielding Bag (Failed)

In short, initial qualification of a package or material must be followed by "periodic verification though physical testing." Therefore, mission critical EEE parts and components that require ESD packaging should be re-validated on a periodic basis for EEE parts and components.

## ARTICLE ABBREVIATIONS OR ACRONYMS:

ANSI - American National Standards Institute
CM – Contract Manufacturer
Dip Tube – IC Carrier
DoD – Department of Defense
ESD – Electrostatic Discharge
EEE parts – Electrical, Electronic (ESD Sensitive Devices) and Electromechanical
EE – Electrical Engineer
Fast Packs – Outer Sleeve weather resistant Fiberboard Stiched Container with Convoluted Foam Pad
IC – Integrated Circuit
JEDEC – JEDEC Solid State Technology Association, formerly known as the Joint Electron Device Engineering Council
JEDEC Tray – Waffle Tray or IC Matrix Carrier to transport, store and stage ESD Sensitive Devices
[All JEDEC matrix trays are 12.7 x 5.35 inches (322.6 x 136mm)]
KSC – Kennedy Space Center (NASA)
NASA QLF – NASA Quality Leadership Forum
NIPHLE - National Institute of Packaging & Handling Logistics Engineers
OEM - Original Equipment Manufacturer
Type 1 – Aluminum ESD Safe Moisture Barrier Bag (MBB), see Mil-PRF-81705E
Tape and Reel - A format for packaging, transporting, storing, and placing components and devices. The desired components and devices, such as capacitors or chips, are securely adhered to a tape which is wound upon a reel, providing a simple and protective manner of packaging, transporting, and storing. The reels can then be utilized with special equipment which provides for automatic insertion or placement of the parts so held. Its abbreviation is tape & reel packaging[2]

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***InCompliance***
*By Bob Vermillion,*
*CPP/Fellow September 2014*

***The Silent Killer:***
***Suspect/Counterfeit Items and Packaging***

*Over the past several years, U.S. based organizations have curtailed traditional internal verification efforts due to reli- ance on contract manufacturers, distributors and suppliers to do the right thing. The inspection of ESD sensitive parts is very important, but without special safeguards, the addition- al handling to remove and repack a product for validation can cause both.*

*By Bob Vermillion, CPP/Fellow*
***The Dip Tube***

***Interference Technology***
*By Bob Vermillion, CPP/Fellow*
*June 1, 2010*

*This article illustrates that removal of ESD sensitive components from non-conforming or suspect dip tubes will generate ESD events.*

*Source (Page 72) http://www.interferencetechnology.com/the-dip-tube/*

*JEDEC and Tape & Reel Issues*
***Interference Technology UK***
*by Bob Vermillion, CPP/Fellow*
*November 2010*

*Handling today's architectures in combination with ultra sensitive electronic components packaged in suspect counterfeit or non-conforming materials leads to issues during the inspection process and in use. Issues in the handling of ultra sensitive (Class 0) ESD devices are discussed in this groundbreaking article.*

*Source URL: http://www.interferencetechnology.com/jedec-and-tape-reel-issues/*

[2] http://www.dictionaryofengineering.com/definition/ ape-and-reel-packaging.html

# What's New: IEC 61000-4-5 Second Edition vs. Third Edition

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## INTRODUCTION

**IEC 61000-4-5 IS PART** of the IEC 61000 series, which describes surge immunity testing caused by over-voltages from switching and lightning transients. The second edition of IEC 61000-4-5 was released in 2005 and has been in use for many years. The third edition was released as an EN standard in 2014. The general philosophy of the third edition is unchanged from the second edition. However there have been a number of refinements to the standard: additional explanation to clear up ambiguities, new descriptions that were not included in the second edition, and new (informative) Annexes that can be used to help in the application of the standard. The purpose of this article is to outline the changes and additions that are now part of IEC 61000-4-5 3rd edition.

## CRITICAL TRANSITION DATES

Transition from the second edition to the third edition is already taking place within the EU according to the following dates:

19 Mar. 2015 - Date of Publication (dop): The third edition has to be implemented by publication of an identical national standard by CENELEC member countries.

19 June 2017 - Date of Withdrawal (dow): National standards that conflict with the third edition must be withdrawn (i.e. the second edition can no longer be used).

## WAVE SHAPE CHANGES

One simple, seemingly benign addition to the third edition was to add a definition for "duration": actually three definitions because one voltage waveform duration and two current waveform durations have been defined. This changes how the time of the waveforms are measured, and may have a significant impact on the equipment used to perform some tests. The change most greatly impacts the 8x20uS short-circuit current waveform. Figures 1 and 2 compare the measurement from the 2nd and 3rd editions of the standard. Compare T2 in the second edition to Tw and Td in the third edition.

Another important change to the impulse waveform is that the 1.2x50/8x20 µs wave shape must be within the limits of the standard when the impulse is applied *through a Coupling-Decoupling Network* (CDN); specifically the 18µF coupling capacitor. This requirement was ambiguous in the second edition: Figure 3 of the second edition shows an 8x20 µs current waveform with no CDN connected, and Table 7 in a following section describes an 8x20 waveform at

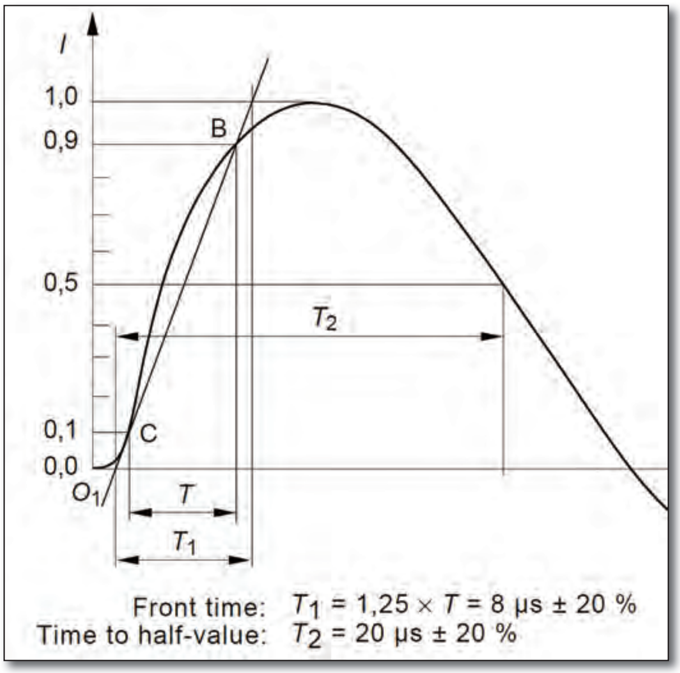


**FIG. 1:** waveform definition in 2nd edition (T2)

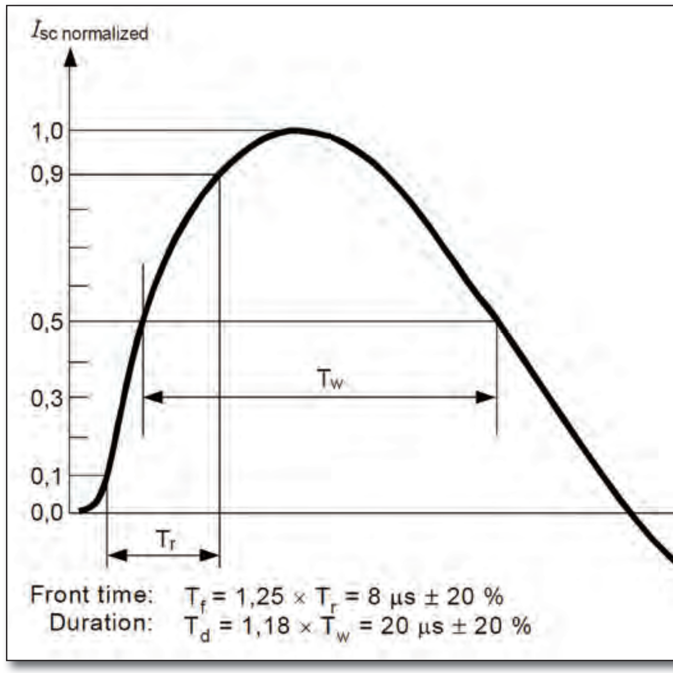


**FIG 2:** waveform definition in 3rd edition (Td)

the EUT port of the CDN (through the 18µF coupling capacitor). Clearly it is not possible to generate the same impulse waveform with and without the 18µF coupling capacitor in the same generator/CDN system. While the open-circuit voltage waveform is not affected, the 8x20 µs short-circuit current wave shape will be significantly distorted by the addition of the 18µF capacitor, and the peak output current will be reduced by approx. 10% (depending on the design of the impulse generator). Figure 3 illustrates the problem: the normalized short-circuit output current of a nominal impulse generator[1] is plotted against the same generator output into a 18µF capacitor. With the addition of the 18µF capacitor the

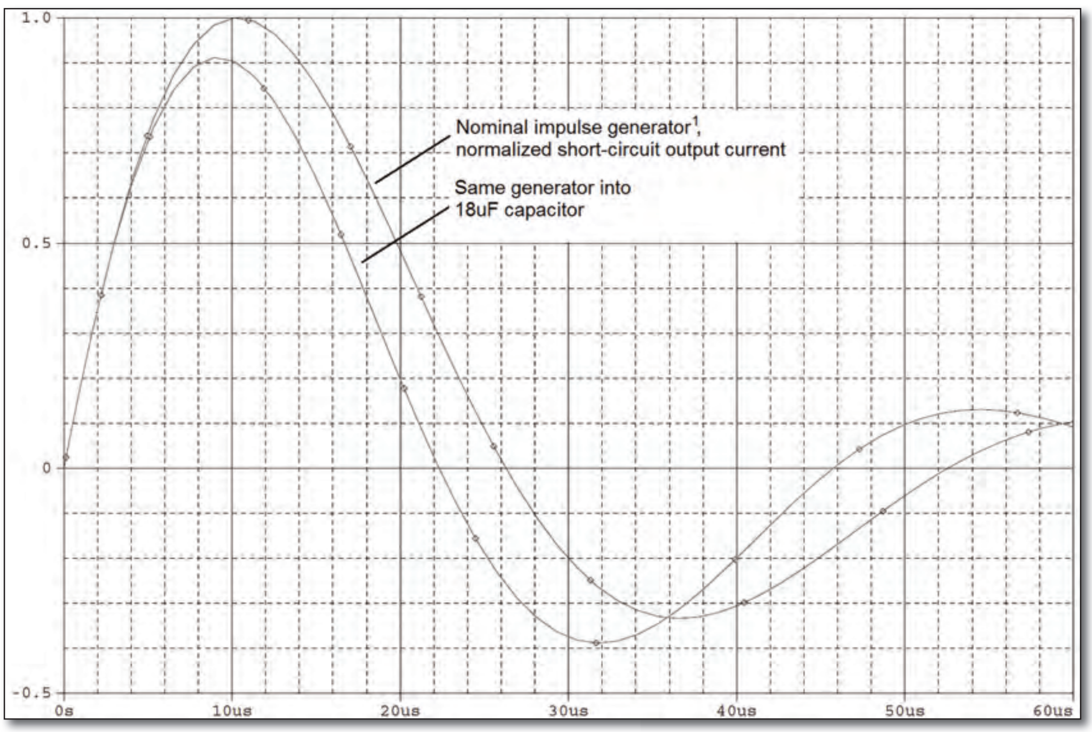


**FIGURE 3:** Normalized Short-circuit Output Current

[1] C. F. M. Carobbi and A. Bonci, *Elementary and Ideal Equivalent Circuit Model of the 1.2/50 – 8/20 µs Combination Wave Generator*, IEEE Electromagnetic Compatibility Magazine, Volume 2, Quarter 4, 2013.

peak current is significantly lower, and the waveform duration is shorter.

Table 3 in the second edition seems to imply that the impulse parameters are specified not including the CDN (Figure 4). In the third edition, Table 6 is used to provide the same information, but it explicitly states that a CDN is to be included when measurements are made (Figure 5). Table 6 also includes a specification for short-circuit current when the (9μF + 10Ω) CDN is used (for line-to-ground testing). In this case, note that the short-circuit current is significantly reduced, due to the 10-Ohm resistor in the CDN.

| Open-circuit peak voltage ±10 % | Short-circuit peak current ±10 % |
|---|---|
| 0,5 kV | 0,25 kA |
| 1,0 kV | 0,5 kA |
| 2,0kV | 1,0 kA |
| 4,0kV | 2,0 kA |

**FIG. 4:** Table 3 from 2nd ed.

| Open-circuit peak voltage ± 10 % at EUT port of the CDN | Short-circuit peak current ± 10 % at EUT port of the CDN (18 μF) | Short-circuit peak current ± 10 % at EUT port of the CDN (9 μF + 10 Ω) |
|---|---|---|
| 0,5 kV | 0,25 kA | 41,7 A |
| 1,0 kV | 0,5 kA | 83,3 A |
| 2,0 kV | 1,0 kA | 166,7 A |
| 4,0 kV | 2,0 kA | 333,3 A |

**FIG. 5:** Table 6 from 3rd ed.

In the second edition of the standard, the 10x700/5x320 μs surge waveform is described hand-in-hand along with the 1.2x50/8x20 μs waveform. In some cases within the standard it is not clear which waveform is to be used for a particular test. This is clarified in the third edition: The 10x700 μs impulse is only to be used on external ports that connect to lines which exit the building (more details on this point later in this article). These external lines are typically longer than 300m. The inductance and distributed capacitance of these transmission lines provide wave-shaping of any real-world transients, such that the equipment connected to the external lines sees a transient that is slower - more like the 10x700/5x320 μs waveform. Further explanation is provided in the new Annex A of the third edition.

## NEW CDN AND CALIBRATION REQUIREMENTS

This new Annex A now contains the full description of the 10x700 μs impulse, including the waveform generator, calibration of the generator, the CDN to be used, and the calibration of the CDN. In the second edition (section 6.2) only the waveform, and calibration of the waveform were described. The new Annex A does not change any requirements other than the waveform duration definition previously mentioned. However, new requirements have been added, especially relating to CDN performance.

In the second edition, calibration of the 1.2x50/8x20 μs generator was described in section 6.1.2. In the third edition this is covered in section 6.2.3, and additional details have been added. The updates provide clarification regarding the type of equipment that should be used to perform calibrations, including specifications for current transformers (if used to measure short-circuit current). Similar details have been included in Annex A regarding the 10x700 μs impulse waveform. Section 6.2.3 also makes reference to Annexes E and G of the standard (both are new in the third edition). Annex E is quite useful, as it includes many figures that show the various waveform measurements in detail (rise and duration) for all of the waveforms.

Annex G is less useful unless one has an advanced degree in mathematics. The purpose of Annex G is to point out the fact that it can be quite difficult to make accurate measurements of single-shot, high frequency events. A common example that may be more familiar to the reader is the calibration of a typical 10x oscilloscope probe. The usual method to adjust the probe is to connect to a square-wave generator, and adjust the capacitance of the probe while observing the waveform on the oscilloscope (usually a screwdriver slot is provided on the probe to make the adjustment). The probe is adjusted so that the wave shape looks "square": the rise time is as fast as possible with minimal overshoot, or ringing, on the front edge.

Clearly a probe that is not adjusted properly, or a probe-scope combination with a low (poor) frequency response can cause an impulse voltage or current waveform to appear diff rent on the oscilloscope screen than it actually is. So in layman's terms, Annex G could be summarized as follows: "When measuring impulse waveforms for calibration, make sure that your measurement instruments can capture the *true* waveform and do not distort the results". Fortunately Annex G is only a recommended practice (informative), not a requirement (normative).

CDN's have become a bigger part of the 61000-4-5 standard in the third edition. The flowchart that is used to select particular CDN/test configurations has been updated to re-

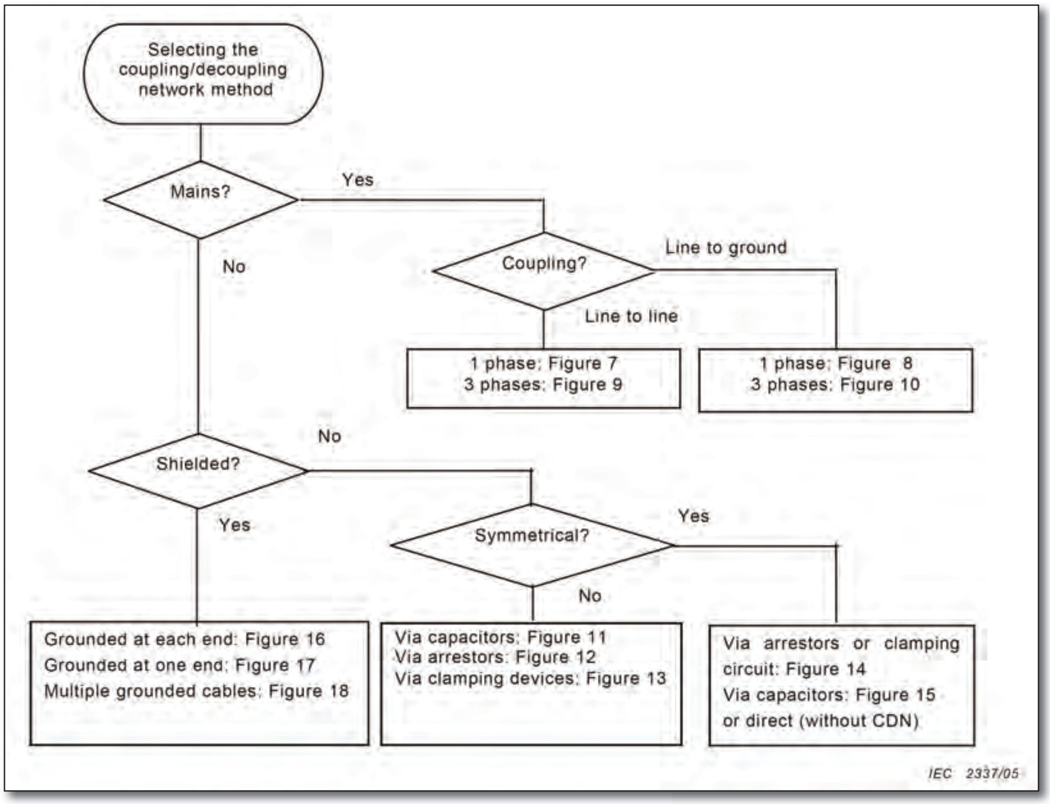


**FIGURE 6:** CDN selection flowchart from second edition

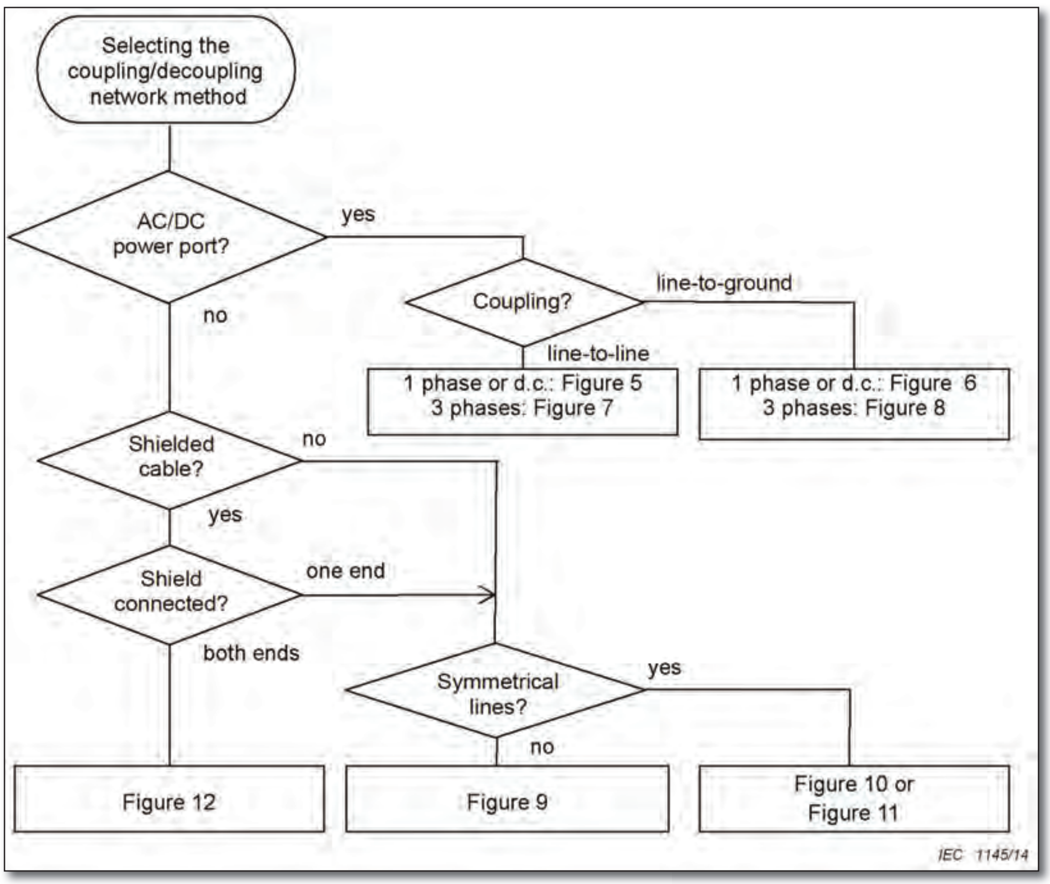


**FIGURE 7:** CDN selection from third edition

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flect newer test practices. Figure 6 shows the flowchart from the second edition; figure 7 shows the same flowchart from the third edition. Additional figures have been added in the third edition standard, which show new test setups, and at least one test configuration (Fig. 13, 2nd ed.) has been eliminated. It is important to carefully study the new test setups to ensure compliance with the third edition.

The third edition adds a peak voltage specification at the EUT port of the CDN (Table 4). The voltage tolerance varies based on the current rating of the CDN. Both the old and new standard include a tolerance specification for front time and waveform duration (Table 6, 2nd; Table 4, 3rd) but the tolerances have been relaxed slightly in the third edition, and the table now goes up to 200A (the second edition went only to 100A). This will probably not aff ct most users, because most CDN's and products being tested are rated 16 Amps or less. A related note in the new section 7.3 of the third edition points out that care must be taken regarding the tolerances of the CDN: a high-current rated CDN is allowed wider tolerances, but this CDN can not be used with lower-current rated products unless this CDN meets the tighter tolerance specifications that apply to lower-current CDN's.

Focus on CDN's continues with new calibration requirements in the third edition: Section 6.4 for the 1.2x50/8x20 µs waveform generator, and Annex A Section 4 for the 10x700/5x320 µs waveform. In general it is no longer possible to separately calibrate an impulse generator and the CDN; both need to be considered and calibrated together. In the past, the CDN was considered more of a passive component - now the interaction of the CDN with the impulse generator is identified and described, which should allow for more consistent test results for tests performed in diff rent laboratories, or with diff rent impulse test equipment.

Annex F is new in the third edition. It covers measurement uncertainty (MU), specifically relating to impulse waveforms. MU is a topic that that has received more coverage in recent years. Awareness has increased that it is no longer "good enough" to simply trust the calibration sticker on equipment. The user of the equipment is obliged to better understand *what parameters* are being calibrated, and the eff cts that variation has on measurements. In the past there were generally accepted "margins of error" that were used on specification limits to ensure compliance even when equipment that is only nominally calibrated is used in testing. More recently, organizations such as the IECEE Committee of Testing Laboratories (CTL) are concerned about measurement accuracy and have published a number of decisions and operational procedures on this topic. This movement is also reflected in the transition to risk-based assessments for some product categories (Medical and Test/Measurement Equipment). Expect more applications of measurement uncertainty and other statistical tools in future standards as well.

## OTHER UPDATES AND CLARIFICATIONS

Both the old and new standards describe Test Setups in Section 7. This section has changed quite a lot in the third edition, although the changes are mostly for clarification - the requirements are essentially the same. The text changes of Section 7 primarily follow the flow chart changes that were described previously in this article. The third edition adds a new section for verification of test instrumentation (Section 7.2). Basically, the standard now requires that the test setup and resulting impulse waveform be verified prior to connection of the EUT. This methodology has been considered best practice for many years, but now it is required, and therefore must be documented. Another best practice that is now explicitly stated in Section 10 of the third edition is to document the test setup in the test report using drawings and/or photos.

For AC equipment, impulses are applied at 0, 90, 180, and 270-degree phase angles. The third edition provides some clarification for testing three-phase equipment: the phase angle is measured between the two Lines being tested (not Line to Neutral). Also, the new edition points out that when testing from Neutral to Ground, phase matching is not needed (because there should be no voltage from Neutral to Ground) and so this test should be treated similar to DC testing (five positive impulses and five negative impulses).

Section 8.2 of the second edition specifies that testing of secondary protection should be conducted at a voltage just below the breakdown voltage of the protection device (in addition to the standard voltage levels). This requirement was problematic because it required further investigation by test laboratories regarding the equipment design, and in some cases a judgment call regarding the breakdown voltage of protective circuitry. This requirement has been removed from the third edition (missing from Section 8.3) but there is still some ambiguity on this point: In the last paragraph of C.2.2.2 (Annex C) of the third edition, there is a statement that system-level testing should be conducted considering the breakdown voltage of protective components, and voltages adjusted accordingly. However since Annex C is informative (not normative) it is left to the user how to apply the statements in this section.

## CLARIFICATION OF TEST PROCEDURES

Annex B (Annex A in the second edition) provides guidance on selection of test voltages for impulse testing. The new Annex B makes clear the distinction between internal and external ports, and which impulse waveform (1.2x50 µs or 10x700 µs) is to be applied. Table A.1 in the second edition has been split up into two tables in the third edition (B.1 and B.2), which makes the test recommendations easier to interpret. A comparison of the tables is shown in Figures 8-10.

| Installation class | Test levels (kV) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AC power supply and a.c. I/O directly connected to the mains network<br>Coupling mode | | AC power supply and a.c. I/O not directly connected to the mains network<br>Coupling mode | | DC power supply and d.c. I/O directly connected thereto<br>Coupling mode | | Unsymmetrical operated [d,f] circuits/lines<br>Coupling mode | | Symmetrical operated [d,f] circuits/lines<br>Coupling mode | | Shielded I/O and communication lines [f]<br>Coupling mode | |
| | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | All lines-to-ground | Line-to-line | Line-to-ground |
| 0 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1 | NA | 0,5 | NA | NA | NA | NA | NA | 0,5 | NA | 0,5 | NA | NA |
| 2 | 0,5 | 1,0 | NA | NA | NA | NA | 0,5 | 1,0 | NA | 1,0 | NA | 0,5 |
| 3 | 1,0 | 2,0 | 1,0 [e] | 2,0 [b,e] | 1,0 [e] | 2,0 [b,e] | 1,0 [c] | 2,0 [b,c] | NA | 2,0 [b,c] | NA | 2,0 [c] |
| 4 | 2,0 | 4,0 [b] | 2,0 [e] | 4,0 [b,e] | 2,0 [e] | 4,0 [b,e] | 2,0 [c] | 4,0 [b,c] | NA | 2,0 [b,c] | NA | 4,0 [c] |
| 5 | [a] | [a] | 2,0 | 4,0 [b] | 2,0 | 4,0 [b] | 2,0 | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [c] |

[a] Depends on the class of the local power supply system.

[b] Normally tested with primary protection.

[c] The test level may be lowered by one level if the cable length is shorter or equal to 10 m.

[d] No test is advised at data connections intended for cables shorter than 10 m.

[e] If protection is specified upstream from the EUT, the test level should correspond to the protection level when the protection is not in place.

[f] High speed communications lines could be included under unsymmetrical, symmetrical, shielded I/O and/or communications lines.

The surges (and generators) related to the different classes are as in the following:

| | |
|---|---|
| Classes 1 to 4: | 1,2/50 µs (8/20 µs). |
| Class 5: | 1,2/50 µs (8/20 µs) for ports of power lines and short-distance signal circuits/lines. |
| Class 1 to 5: | 10/700 µs (5/320 µs) for symmetrical communication lines |

The source impedance shall be as indicated in the figures of the test setups concerned.

**FIG. 8:** Table A.1 from the second edition

| Installation class | Test levels (kV) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AC power supply and a.c. I/O<br>External ports [a] | | AC power supply and a.c. I/O<br>Internal ports [a,d] | | DC power supply and d.c. I/O<br>External ports [a] | | DC power supply and d.c. I/O<br>Internal ports [a,d] | |
| | Coupling mode | | Coupling mode | | Coupling mode | | Coupling mode | |
| | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground |
| 0 | NA | NA | NA | NA | NA | NA | NA | NA |
| 1 | NA | 0,5 | NA | NA | NA | NA | NA | NA |
| 2 | 0,5 | 1,0 | NA | NA | NA | NA | NA | NA |
| 3 | 1,0 | 2,0 | 1,0 | 2,0 | NA | NA | NA | NA |
| 4 | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] |
| 5 | [c,b] | [c,b] | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] |

[a] No test is advised if the cable length is shorter than or equal to 10 m.

[b] Where the port is always intended to be used with specified primary protection, testing is performed with the primary protection in place to ensure coordination with the protection elements. If primary protection is required to protect the interface but not provided, testing is also performed at the maximum let through level of the specified primary protection and with a typical primary protector.

[c] Depends on the class of the local power supply system.

[d] The testing of intra-system ports is generally not required.

**FIG. 9:** Table B.1 from the third edition

| Installation class | Test levels (kV) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unsymmetrical operated circuits/lines [a,c,e] | | | | Symmetrical operated circuits/lines [a,c,e] | | | | Shielded circuits/lines [a,d,e] | | | |
| | External port | | Internal port | | External port | | Internal port | | External port | | Internal port | |
| | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Line-to-ground | Line-to-line | Shield-to-ground | Line-to-line | Shield-to-ground |
| 0 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1 | NA | NA | NA | 0,5 | NA | NA | NA | 0,5 | NA | NA | NA | NA |
| 2 | NA | NA | 0,5 | 1,0 | NA | NA | NA | 1,0 | NA | NA | NA | 0,5 |
| 3 | NA | NA | 1,0 | 2,0 | NA | NA | NA | 2,0 | NA | NA | NA | 2,0 |
| 4 | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [b] |
| 5 | 2,0 [b] | 4,0 [b] | 2,0 [b] | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [b] | NA | 4,0 [b] |

[a] No test is advised for data connections intended for cables shorter than 10 m.

[b] Where the port is always intended to be used with specified primary protection, testing is performed with the primary protection in place to ensure coordination with the protection elements. If primary protection is required to protect the interface but not provided, testing is also performed at the maximum let through level of the specified Primary protection and with a typical primary protector.

[c] Line-to-line surges (transverse) may occur in networks where SPDs (surge protective devices) with connection to ground are used for protection. Such surges are outside the scope of this standard. This phenomenon can however be simulated by applying common mode surges through the defined primary protection elements.

[d] The testing of ports connecting to antennas is outside the scope of this standard.

[e] The testing of intra-system ports is generally not required.

**FIG. 10:** Table B.2 from the third edition

In addition to the internal/external distinction, note that there are other changes as well: testing of Installation Class 3 DC systems is no longer required. Also, compare the following text (Figure 11) from Annex B of the third edition to the text below Table A.1 of the second edition (Figure 8 in this article): The selection of the proper impulse waveform is made much clearer.

The surges (and generators) related to the different classes are as follows:

Classes 1 to 5: 1,2/50 µs (8/20 µs) for ports of power lines, short-distance signal circuits/lines and local area networks (e.g. Ethernet, token ring, etc.) and similar networks.

Classes 4 to 5: 10/700 µs (5/320 µs) for symmetrical communication lines intended to interconnect widely dispersed systems via such means as direct connection to multi-user telecommunications networks (e.g. public switched telecommunications networks (PSTN), x-type digital subscriber lines (xDSL), etc.); lines typically greater than 300 m in length.

**FIG. 11:** impulse waveform selection from Annex B (third edition)

Annex C in the third edition (Annex B in the second) is essentially unchanged except for one important clarification: DC power ports, such as ports for providing power to a laptop do not need to be tested.

The new Annex H concerns impulse testing of equipment and power lines rated above 200 Amps. This is probably not something that most readers of this article will need to deal with. Since the impedance of such circuits is so low, any energy from an impulse test is likely to be absorbed. This consideration is reflected in Annex H as well.

## SUMMARY

In summary, the changes in the third edition of IEC 61000-4-5 are likely to impact any organization that performs impulse testing or calibrates impulse test equipment. Manufacturers of products that are tested to the second edition will most likely not require any product redesign, as the actual impulse tests are relatively unchanged. The third edition should result in a more consistent application of impulse testing, and greater repeatability of test results.

One final comment: both the old and new versions of IEC 61000-4-5 include the following statement: " Equipment shall not become dangerous or unsafe as a result of the application of the tests..." (see end of Section 10/9 of edition 2/3 respectively). While the statement seems virtuous and straightforward, it complicates matters significantly if it is strictly interpreted. The IEC 61000 standards do not define "dangerous or unsafe", nor do they list any requirements or tests that can be used to determine if the EUT is dangerous as a result of the applied impulse tests. In product safety standards, a product is considered unsafe if it fails dielectric withstand testing, or if there is excessive leakage current. Both of these situations could occur as a result of a component breakdown during impulse testing (clamping of an MOV or GDT for example). The equipment could remain operational, and otherwise have no indication that it is unsafe. Does this mean that EMC test labs are now obliged to perform electrical safety tests after the completion of impulse testing? Hopefully this is not the case.

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# Radio Equipment Directive, 2014/53/EU

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## ABSTRACT

THIS ARTICLE PROVIDES AN update on changes occurring as a result of the new Radio Equipment Directive (RED) 2014/53/EU which can be used from June of 2016. It looks at the changes in the product and regulatory landscape and at what it means to equipment manufacturers.

More detail on the history of the RED can be found in the article, *Radio Equipment Directive*, in the Interference Technology 2015 EMC Directory and Design Guide.

## SCOPE OF THE DIRECTIVE

The scope of the RED has been widened to include:

- "Radio determination" equipment, such as radars and RFID devices. These devices were considered to be within the scope of the R&TTE Directive, but the RED's scope is much clearer making it more obvious that they are included and must comply.
- "Sound and TV broadcast receivers" – these were excluded under R&TTE, so will now have additional requirements for radio spectrum performance.
- "Receiver performance" – whilst this was covered in a number of ETSI product standards, its importance in an increasingly congested radio spectrum has made it part of the Directive.
- "Devices operating below 9 kHz" – the lower frequency limit of R&TTE was 9 kHz, but that has been removed.
- In line with other directives there is a specific exclusion for *"Custom-built evaluation kits destined for professionals to be used solely at research and development facilities for such purposes."*

## TIMESCALES AND TRANSITION PERIODS

The European Commission has confirmed that there are four scenarios relating to the application of Directives 2014/53/EU, 2014/35/EU and 2014/30/EU.[i]

| Product type | Compliance requirements and dates |
|---|---|
| Currently in scope of EMC and LVD and not in scope of R&TTE or RED | • Products placed on market before 20 April 2016: old LVD/EMCD<br>• Products placed on market on or after 20 April 2016: new LVD/EMCD |
| Currently in scope of R&TTE and remain within scope of RED | • Products placed on market before 13 June 2016: R&TTED<br>• Products placed on market between 13 June 2016 and 12 June 2017: R&TTED or RED<br>• Products placed on market after 12 June 2017: RED |
| Currently outside scope of R&TTE but within scope of RED | • Products placed on market before 20 April 2016: old LVD/EMCD<br>• Products placed on market between 20 April 2016 and 12 June 2016: new LVD/EMCD<br>• Products placed on market between 13 June 2016 and 12 June 2017: RED or new LVD/EMCD<br>• Products placed on market after 12 June 2017: RED |
| Currently in scope of R&TTE but falls outside scope of RED | • Products placed on market before 13 June 2016: R&TTED<br>• Products placed on market after 12 June 2016: RED is not applicable; new LVD/EMCD, if applicable to the product in question |

It has been noted that following the dates above could create a large administrative burden on manufacturers in updating documentation and Declarations of Conformity, particularly for devices that fall out of the R&TTE directive and into EMC and LVD as they cannot take advantage of the transition period written into the RED.

Guidance on content of Declarations of Conformity specifies minimum content, but does not generally specify maximum content and additional useful information is generally accepted. Based on this there are a couple of proposals currently under discussion within The Commission to allow manufacturers to list both current and new directives on their Declarations of Conformity, e.g.

> “The object of the declaration described above is in conformity with the relevant Union harmonisation legislation: Directive 1999/5/EC (until 12 June 2016), Directive 2014/30/EU (from 13 June 2016) and Directive 2014/35/EU (from 13 June 2016).”

**Please note:** at the time of publication this proposal had **not been formally accepted**. It was expected to be accepted early in March and will be published in the EU Docs Room[ii]. We will bring you an update as soon as we have it.

## SOME KEY POINTS FOR MANUFACTURERS UNDER RED:

- The CE marking must appear on the device and on the packaging – the RED no longer requires CE mark to be in the user manual
- The Notified Body number only goes on the product when the Full Quality Assurance route (R&TTE annex V / RED annex IV) and is not used where a NB has just reviewed the technical file.
- The list of permitted countries should still go on the packaging and the user manual but there is no requirement for the alert mark, ⓘ, for class 2 equipment and country notifications are no longer required.
- The user manual must include frequency bands of operation and the maximum transmit power in each of those bands and this information must be in a language easily understood by the end user.
- Any product containing a piece of “radio equipment” as defined in RED Article 2, falls under the RED – so a washing machine with a Zigbee radio falls under RED and not EMC and LVD.

## DEVELOPMENTS OF NEW STANDARDS FOR RED

### EMC

The radio equipment directive does not allow application of the EMC Directive as was possible under the R&TTE, so

[i] http://ec.europa.eu/DocsRoom/documents/11983/attachments/1/translations/en/renditions/pdf

[ii] http://ec.europa.eu/DocsRoom/?locale=en

[iii] https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=47231

all products containing radio equipment must be assessed against the Radio Equipment Directive.

- ETSI are developing guide EG 203 367[iii], *"Electromagnetic compatibility and Radio spectrum Matters (ERM); Guide to the application of harmonized standards covering Articles 3.1b and 3.2 of the Directive 2014/53/EU (RE-D) to multi-radio and combined radio and non-radio equipment"* which provides guidance on the application of Harmonised Standards to multi-radio and combined equipment. The document is still in a draft

    - Examples of equipment to be covered by the document include, but are not limited to, combination of multiple radio products in one radio equipment, combination of radio and IT or electro-technical equipment, RLAN enabled domestic appliance, radio controlled heating system, radio controlled lighting system, etc.

**Radio Spectrum**

- ETSI are currently updating 156 article 3.2 radio spectrum standards for the RED, 34 of these are due for publication in the Official Journal during 2016 with the majority of the remainder following in 1st half of 2017.
- Following a review of compatibility between LTE operating in the 800 MHz band and UHF Short-Range Devices, ETSI has started work on the restructuring of EN 300 220. Work items have been adopted as follows:

    - EN 300 220-2: Harmonised Standard for non-specific radio equipment. Two versions are being developed: a version 3.1.1 with "category 3" receivers, intended to be replaced by v 3.2.1 with improved "category 2" receivers by December 2018.
    - EN 300 220-3-1: Social Alarms equipment operating in the designated frequency band (869.2 - 869.25 MHz)
    - EN 300 220-3-2: Wireless Alarms equipment operating in the designated frequency bands
    - EN 300 220-4: Metering radio equipment operating on designated frequency bands (169.4 - 169.4875 MHz)

- ETSI has already published draft standards for TV and Broadcast receivers that are moving into RED due to the change in scope of this directive:
    - Draft ETSI EN 303 340 V1.1.0[v], *Digital Terrestrial TV Broadcast Receivers; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU*
    - Draft ETSI EN 303 345 V1.1.0[vi], *Radio Broadcast Receivers; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU*

**Transition periods**

In common with normal practise, there will be a transition period during which time existing standards may continue to be used, but manufacturers should keep an eye on the ETSI work program[iv] and keep up to date with standards as they are published.

## ABOUT

Sulis Consultants is an independent CE marking and Product Approvals consultancy based in Hampshire, England and specialising in helping manufacturers comply with the requirements of R&TTE, EMC, LV and RoHS Directives as well as radio certification for North America.

Charlie Blackham is a Chartered Engineer who has been working in the field of product approvals and CE marking for over 20 years. After working for several manufacturers as Approvals Manager, Charlie set up Sulis Consultants in 2005 to off r advice and assistance to a wide range of clients. A former Notified Body technical expert, Charlie has helped clients CE mark a wide range of radio products operating from 1 MHz to 78 GHz and can be contacted on charlie@sulisconsultants.com or via www.sulisconsultants.com.



[iv] http://webapp.etsi.org/ena/cvp.asp?search=RADIO

[v] https://www.etsi.org/deliver/etsi_en/303300_303399/303340/01.01.00_20/en_303340v010100a.pdf

[vi] https://www.etsi.org/deliver/etsi_en/303300_303399/303345/01.01.00_20/en_303345v010100a.pdf

# Assembling A Low Cost EMI Troubleshooting Kit – Part 1 (Radiated Emissions)

**KENNETH WYATT**
Wyatt Technical Services LLC

THOSE OF US WHO are either in-house or independent EMC consultants can benefit greatly by assembling our own EMI troubleshooting kit. I've depended on my own kit for several years and it has proven not only valuable, but depicts a sense of professionalism in dealing with your own product development engineers, their managers, or your clients, as the case may be. Mine is designed around a Pelican 1514 roller case (http://www.pelican.com) that includes a padded divider, so it is easy to transport to the area needed. You'll also want to order the optional lid organizer, model 1519, for carrying extra tools, cables, and other small parts. See Figure 1.

This article will summarize what I've included in my own kit, and because everyone's needs might be a little different, you'll want to use this information as a guide. Feel free to add or subtract tools and test equipment as desired. You

**FIGURE 1**: Troubleshooting kit with most of the major components shown. The spectrum analyzer is the Thurlby Thandar model PSA6005 and tunes from 10 MHz to 6 GHz. Everything fits inside a Pelican 1514 roller transit case. The contents are described in Part 1 and Part 2 of this article.

should expect to spend about $3k to $5k for the complete kit, depending on whether you make a lot of DIY probes or buy commercial, but this price range *includes* a spectrum analyzer.

I'll list just the most important items for assessing radiated emissions in Part 1. Part 2 will be available as a download and will include additional items required for assessing various immunity tests, along with many other useful tools and equipment. A bonus will include how to use an oscilloscope to evaluate EMI. Some of this information is based on the book, *EMI Troubleshooting Cookbook for Product Designers*[1], by Patrick André and Kenneth Wyatt, with foreword by Henry Ott.

## SPECTRUM ANALYZERS

You're probably wondering about the spectrum analyzer, so we'll start with that first. The spectrum analyzer is the one piece of gear that's essential for EMI troubleshooting, but has traditionally been the most expensive item in anyone's kit. Many smaller or mid-sized companies may not have the budget to purchase a lab quality analyzer, which can start at a base price of $10k, or more. While you may find older used spectrum analyzers on sites, such as eBay or from used equipment dealers, several manufacturers are now making lower cost quality instruments that are perfectly adequate for troubleshooting and pre-compliance work. I've listed several instruments from which to choose – in categories, good, better, and best.

**GOOD** - I've run into a very low cost spectrum analyzer solution; the Triarchy Technologies (http://triarchytech.com) USB-controlled spectrum analyzer, which is about the size of a large thumb drive (Figure 2). Triarchy makes several models covering up to 12 GHz, but their Model TSA6G1 covers most of the commercial frequency range of 1 MHz to 6.15 GHz, can measure signals from -110 to +30 dBm, and costs just $629 through their eBay store or through their North American distributor, Saelig Electronics (http://www.saelig.com). The unit comes with Windows PC software and works perfectly well for troubleshooting. I wouldn't necessarily use it for pre-compliance testing, but it should still provide a good enough indication as to whether you're in the ballpark of passing or failing.

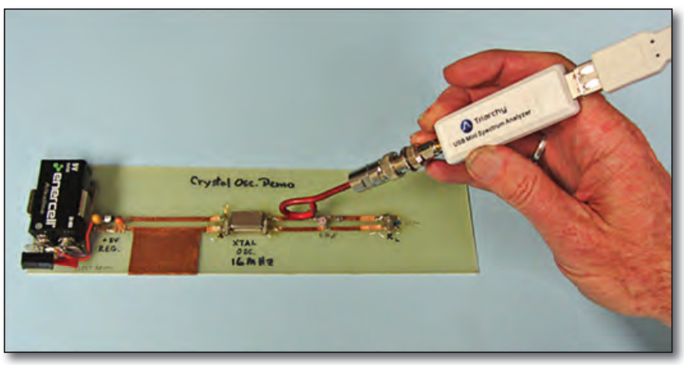


**FIGURE 2:** Here's an example of a low cost USB powered spectrum analyzer. This one is made by Triarchy Technologies and is sensitive enough for general EMI troubleshooting. The model TSA6G1 tunes from 1 MHz to 6.15 GHz.

**BETTER** -You may want to consider a better quality analyzer. I've been using the Thurlby Thander (TTi) PSA2702T (1 MHz to 2.7 GHz handheld, at $1695) for several years now (Figure 3) and recently upgraded to the model PSA6005. TTi is a British company (http://www.aimtti.com in the UK and http://www.aimtti.us in the U.S.), well known for their lines of test and measurement equipment. Newark (http://www.newark.com) and Saelig Electronics (http://www.saelig.com) are the North American distributors. Many other independent consultants are also using this one. It's truly handheld and will easily fit into the recommended transit case. TTi also sells a similar handheld model PSA6005 that tunes from 10 MHz to 6 GHz and costs about $2,700.

These analyzers offer most of the usual settings for resolution bandwidth, frequency setting, saving/recall of instrument setups, different detectors, averaging, and max hold. The controls are all laid out at the bottom of the screen in a hierarchical fashion top to bottom. They also include two cursors, which can read out both frequency and amplitude simultaneously. There is also USB connectivity for control by free PC software. Battery life is very good at four to six hours. I can plug in a near field probe directly to the RF input and use the entire unit to quickly evaluate a large system for EMI issues.


**FIGURE 3:** The Thurlby Thandar PSA2702T is an affordable portable spectrum analyzer that covers 1 MHz to 2.7 GHz. The cost is just $1,695 from Saelig or Newark Electronics (Photo, courtesy Thurlby Thandar Instruments).

**BEST** – There are several affordable choices of quality bench top analyzers. My two favorites include the Rigol DSA815 (Figure 4) and Siglent SSA3000X-series (Figure 5). Rigol Electronics, a test & measurement company based in China (http://www.rigolna.com), offers their $1,295 Model DSA815TG (9

[1] *EMI Troubleshooting Cookbook for Product Designers* is available from Amazon and Stylus Publishing in the U.S., and from The IET in Europe. Go to http://www.emc-seminars.com or http://www.anderconsulting.com for specific links.

kHz to 1.5 GHz) spectrum analyzer with optional tracking generator ($200). The extra EMI option ($599) will give you the three EMI resolution bandwidths (200 Hz, 120 kHz and 1 MHz) and quasi-peak detector. The front panel is nicely laid out and easy to use. Screen captures may be made for documentation purposes and software is available to control the analyzer from your Windows PC. The unit includes all the usual features of a more expensive lab-grade analyzer, but is accurate enough for all your pre-compliance and troubleshooting needs. Besides the usual controls, you can display up to three traces and six markers. The tracking generator allows you to evaluate filters, antennas, and resonances.


**FIGURE 4:** The Rigol DSA815 is an affordable spectrum analyzer that covers 9 kHz to 1.5 GHz. The base cost is just $1,295. Rigol also has models in the series that cover up to 7.5 GHz. (Photo, courtesy Rigol Electronics).

Another recent offering from Siglent Technologies (http://www.siglent.com), also based in China, is their SSA3000X-series of low-cost spectrum analyzers. It uses the same compact form factor as the Rigol, but is a little wider to accommodate the wider video display. The base unit tunes from 9 kHz to 2.1 GHz, with another model going to 3.2 GHz. There is a similar EMI and tracking generator option. The control layout is similar to the Rigol and easy to use. Both models offer slightly improved specifications in amplitude accuracy and frequency resolution. The free Windows PC software will also help define limit lines and perform automated pre-compliance testing and documentation.

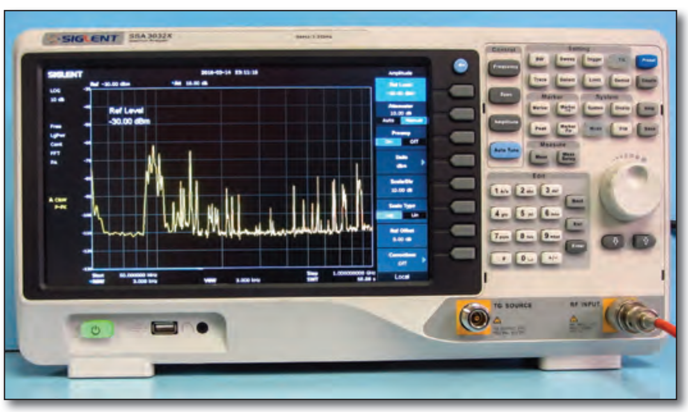


**FIGURE 5:** The new Siglent SSA3000X-series spectrum analyzer tunes from 9 kHz to 2.1 GHz or 3.2 GHz, depending on the model.

Finally, there's a third option to consider that's very affordable, considering it has similar specifications as lab quality analyzers. Rohde & Schwarz (https://www.rohde-schwarz.com/us/home_48230.html) recently announced their FPH "Spectrum Rider" portable analyzer, whose base price starts at $5,280 (Figure 6). I also recommend you purchase the built-in preamplifier option for $440. I had a chance to review this and was pleasantly surprised. The unit has much of the functionality as much pricier analyzers, but is a compact battery-operated portable. It *will* exceed my price total budget for the total troubleshooting kit, though!

The instrument controls are all laid out clearly and I really didn't need the user guide to start using it. The unit tunes from 5 kHz to 2 GHz, with 3 or 4 GHz as options. While there's no tracking generator option, the unit does have a lot to offer as far as accuracy and useful features. The battery life is rated at eight hours and the unit is moisture proof with an easy to read display, even in full sunlight. Perfect for field use!

**FIGURE 6:** The Rohde & Schwarz FPH "Spectrum Rider" portable spectrum analyzer tunes from 5 kHz to 2 GHz or an optional upper limit of 3 or 4 GHz as budgets allow. The specifications are very similar to much higher-priced lab quality analyzers and the base price is just $5,280.

Any of these analyzers should do well for you, but my preference (if traveling light) remains the TTi PSA2702T because it's fast to use and fits so well into the transit case, avoiding my carrying a second piece of gear. The advantage of the Rigol or Siglent analyzers is that they are more accurate than the TTi PSA2702T and include a preamp, tracking generator, the EMI bandwidths and quasi-peak detector. However, for the base price, they're limited to just 1.5 or 2.2 GHz respectively. The tracking generators are a valuable troubleshooting tool for determining resonances and filter responses. Of course, both Rigol and Siglent have models that go higher in frequency (7.5 and 3.2 GHz, respectively) for additional cost. The Rohde & Schwarz analyzer has even better specifications and is battery-powered, but has no means to add a tracking generator.

## REAL TIME SPECTRUM ANALYZERS

If your products include wireless or fast serial data streams, you might wish to consider one of these affordable real-time spectrum analyzers. A real-time spectrum analyzer has the ability to capture brief intermittent signals and are perfect for capturing modulated wireless or digital signals, as well as general EMI troubleshooting. Low-cost examples might include the Tektronix (http://www.tek.com) RSA306 (Figure 7) or Signal Hound (http://signalhound.com) BB60C (Figure 8). Both include feature-rich PC software. Either model should fit nicely into the transit case, as both are relatively small.

For a more detailed review of these two analyzers, as well as several other lab-quality models, be sure to download the new *2016 Real-Time Spectrum Analyzer Mini Guide*[2] from Interference Technology.


**FIGURE 7:** The Tektronix RSA306 USB-controlled real-time spectrum analyzer covers 9 kHz to 6.2 GHz and has a real-time bandwidth of 40 MHz. The base cost is $3,489 and there are several digital modulation display options.


**FIGURE 8:** The Signal Hound BB60C USB-controlled real-time spectrum analyzer covers 9 kHz to 6 GHz and has a real-time bandwidth of 27 MHz. The cost is $2,879.

Real-time analyzers can detect and capture very short intermittent pulsed signals. For example, within the 2.4 GHz ISM band, you'll see the entire spread spectrum Wi-Fi signal, as well as the frequency-hopped Bluetooth signals very clearly. You can even observe multiple Wi-Fi access points on the same channel. This isn't possible with normal swept-frequency spectrum analyzers. They also commonly include "waterfall" displays of frequency and amplitude versus time – a very powerful troubleshooting tool for intermittent EMI issues.

## TROUBLESHOOTING WITH SPECTRUM ANALYZERS

Typically, we'll use E-field and H-field probes, clamp-on current probes, or voltage probes with spectrum analyzers. These are described more fully later.

For troubleshooting purposes, it's also possible to use standard oscilloscope probes with spectrum analyzers. Just make sure any scope probe or E-field probe is capacitively coupled in the signal line (or use a capacitive isolation adapter or DC block at the analyzer input), so that large DC voltages won't be introduced at the analyzer's sensitive input. That's a good way to damage the front-end circuitry. Don't put much faith in the absolute measurement, as a 10:1 probe connected to a 50-Ohm spectrum analyzer input won't likely be very accurate. However, you can still measure relative improvements as the troubleshooting process progresses. Rigol Electronics has an application note on how to use an oscilloscope probe with a spectrum analyzer[3]

## NEAR-FIELD PROBES

Near-field probes, or "sniffer" probes, are small electric or magnetic field pickup devices used to determine the source of emissions generated by a circuit or component (Figure 9). The E-field probe is essentially a stub antenna at the end of a coaxial line. An E-field probe can be made by cutting away about 1/4-inch of the outer shield, exposing the center conductor. Insulate the end, so it won't short to anything. The H-field probe is generally a small loop of coaxial cable made by connecting the center conductor to the outer shield. The size of the stub or loop determines the sensitivity of the probe but can also limit its upper frequency range and its ability to localize the source. These near-field probes are easy to make yourself from regular or semi-rigid coax cables.

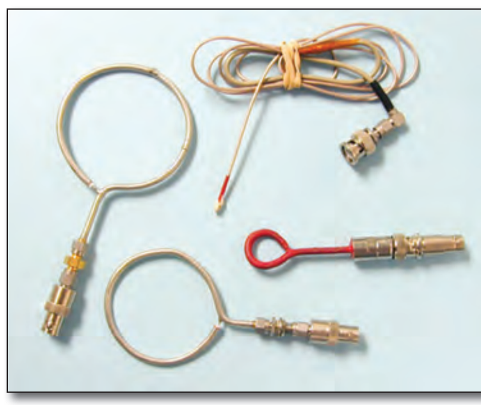

**FIGURE 9:** A few E-field and H-field probes made from short pieces of semi-rigid or flexible coax cables.

[2] Download the *2016 Real-Time Spectrum Analyzer Mini Guide*, from Interference Technology here: http://itemmedia.wufoo.com/forms/p17royzx0hl32fe/.

[3] How To Use A Probe with a Spectrum Analyzer: http://www.rigolna.com/products/spectrum-analyzers/dsa800/dsa815/

Near-field probes can be either very useful or very misleading. Larger probes, which are more sensitive, can pick up ambient readings from high-powered broadcast radio and TV. One way to determine an individual probe's sensitivity to ambient signals is to measure the frequency range of 88 to 108 MHz in the FM broadcast radio band. If your favorite station shows up on the oscilloscope or spectrum analyzer, you need to be careful to ignore ambient signals. To do this, move the probe away from the unit and power down the unit if possible. If the signal does not go away, you should ignore that particular frequency as an ambient.

H-field probes couple best when oriented in the same plane as the wire, cable, or circuit trace because this allows the most H-field lines of flux to penetrate through the loop (Figure 10). The larger loop probes will be the most sensitive, but not as high a spatial resolution as the smaller loop probes. The smallest probes can trace RF noise currents to a single trace or integrated circuit pin.

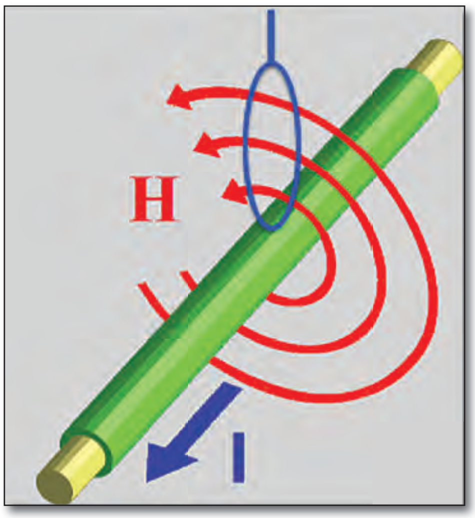


**FIGURE 10:** Proper positioning of an H-field probe for maximum coupling.

Most H-field loop probes are shielded for E-fields, but the capacitance between the shielding and circuit being measured adds a parasitic capacitance that can cause a high-frequency resonance (about 700 to 1,000 MHz, depending on the probe design). By constructing an unshielded loop you can avoid this resonance, but then you also sacrifice rejection of E-fields.

Because most circuit traces are low impedance, and are therefore relatively high current structures, H-fields tend to dominate in digital products. We tend to use H-field probes to locate "hot" signal sources on cables or circuit traces (Figure 11). By carefully sweeping the probe around on the circuit board and interior cables, areas of high emissions can be located. On the other hand, E-field probes are most useful for detecting leakage in chassis seams or gaps, where there might be high levels of E-fields.

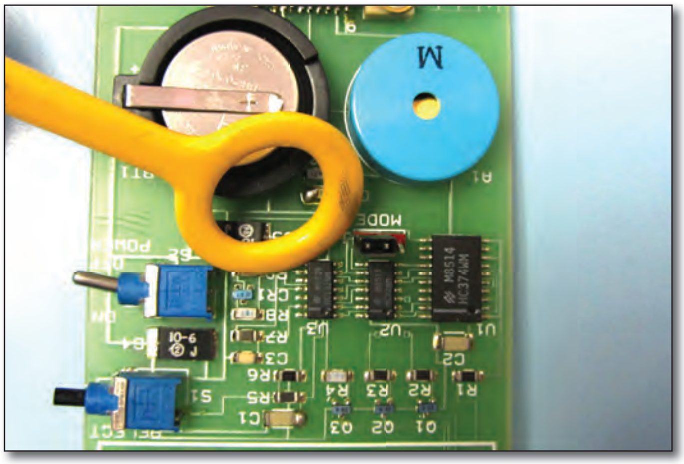


**FIGURE 11:** Using an H-field probe to locate hot spots on a circuit board. For higher resolution measurements, smaller probes should be used.

You need to be careful when mapping out "hot spots" of RF energy. Just because you measure a high field level in a certain part of the circuit board or cable, does not necessarily mean that energy will be coupled out and radiate. It all depends on whether there is a coupling path from the RF energy source to some "antenna-like" structure, such as an I/O or power cable. Generally, near field probes are good for identifying potential emission sources, but I rely on nearby antennas to troubleshoot actual emissions from a product.

If you prefer low cost commercial probes, I can recommend the set from Beehive Electronics (http://beehive-electronics.com) or Tekbox Digital Solutions (http://www.tekbox.net). The Beehive probe set is $300 and you'll also want to include the 1m long SMB to SMA cable for $50 (Figure 12). Tekbox sells a set of four probes with cable for $200 and the probe set with broadband preamplifier for $330. Saelig Electronics (http://www.saelig.com) is the North American distributor for Tekbox. The Beehive probes may be ordered directly from Beehive Electronics.


**FIGURE 12:** A typical near-field probe set. In this picture, there are three H-field loop probes and one E-field probe. (Courtesy, Beehive Electronics.)

## CURRENT PROBES

Clamping a current probe around a wire or cable will measure the common-mode RF currents flowing in that wire or cable. They typically use a toroidal core of broadband ferrite or similar material. The frequency range and sensitivity of the probe will depend on the type of material used and the number of turns of wire wound around the core as a pickup. On emission-only probes, a resistive network is often used to control the impedance and flatten the response. This response is known as the correction, transfer impedance, or transducer factor. Similar current probes can be used to inject RF energy into a cable and are called bulk current injection (BCI) probes. They are used for conducted RF immunity tests.

Current probes are very useful as a troubleshooting tool. Measuring current on certain cables can indicate which cables may be the main cause of radiated emissions. The reduction of RF currents on those cables can often reduce the radiated emissions from the equipment under test. Importantly, by knowing the harmonic common-mode current flowing in the cable at a certain frequency you can calculate the expected E-field emission level and compare to the radiated emission limit. In other words, you can predict pass/fail for a particular cable by simply measuring the RF current through that cable. Refer to the article referenced below for details.

It's possible to make your own current probes from ferrite toroids or clamp-on chokes (Figure 13). I published an earlier article, *The HF Current Probe: Theory and Application*, on making and using current probes for Interference Technology in the 2012 EMC Directory and Design Guide[4] and would refer you to that resource for more detail.

**FIGURE 13:** An example of simple current probes you can make to measure harmonic RF currents in cables.

The advantage of commercial current probes is that they easily clamp around the wire or cable to be evaluated and they are calibrated to accurately read RF current. While the Fischer model F-33-1 probes *(http://fischercc.com)* are used as an example (see Figure 14), there are many other good manufacturers of current probes, such as Pearson, Rohde & Schwarz, Teseq, Solar, and ETS-Lindgren.

[4] *The HF Current Probe: Theory and Application:* http://www.interferencetechnology.com/the-hf-current-probe-theory-and-application/.

**FIGURE 14:** A matched set of clamp-on Fischer Custom Communications model F-33-1 current probes. While not imperative to purchase, a matched set is very useful for advanced troubleshooting I/O cable emissions. They can sense RF currents of a few microamps.

## ANTENNAS

EMI antennas can be very expensive, so I recommend smaller, low-cost antennas, such as the rabbit ears TV antenna still available in some TV and electronic parts stores (Figure 15). UHF TV "bowtie" antennas also work well from 300 to 800 MHz. They will perform just fine for troubleshooting purposes.

Remember, EMC troubleshooting relies more on relative changes, rather than absolute changes. For example, if you know you're product is failing by 4 dB, reducing the problem harmonic by 10 dB at your own facility, as measured with a nearby antenna, should provide a reasonable assurance of passing.

**FIGURE 15:** Simple rabbit ears TV antennas may be used to pick up radiated emissions from a product under test. It will tune from 85 to about 220 MHz depending on how long the elements are extended. Epoxy a BNC connector to the housing and connect each terminal to the telescoping elements.

Also available are low-cost (under $30) PC board broadband log-periodic antennas from Kent Electronics (www.wa5vjb.com) in Figure 16. These are designed for several frequency bands, starting at 400 MHz and have about a 6 dB gain across the band. They work well for general troubleshooting and are what I currently use. Being flat, they fit easily into the transit case.

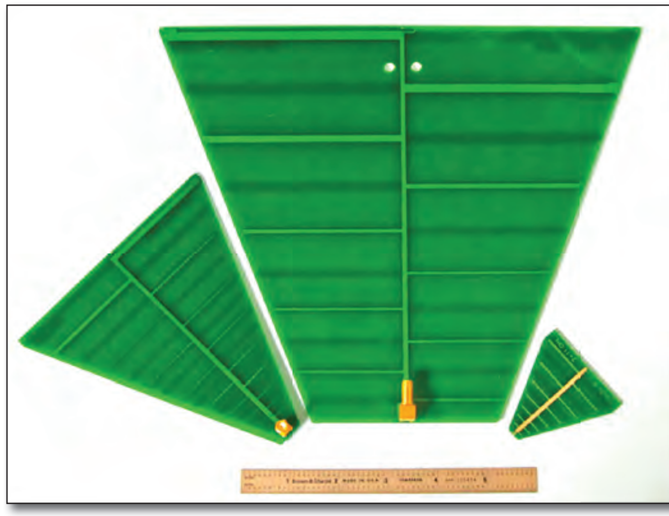

**FIGURE 16:** These PC board log-periodic antennas are low in cost and are resonant in several bands from 400 MHz to 11 GHz. They are available from http://www.wa5vjb.com.

I mount mine using a small tabletop photo tripod and a DIY fixture made from PVC pipe (Figure 17). I tapped and threaded the 90-degree coupling to fit the tripod and used a handsaw to cut a narrow slit in the other end. The PC board just presses into the slot. I left the horizontal piece unglued, so I can rotate the antenna for horizontal or vertical polarization.


**FIGURE 17:** One of the PC board log-periodic antennas mounted to a tabletop camera tripod. By setting this up near the product under test, the emissions may be observed during troubleshooting.

For a little more cost, I also like the small active broadband antenna from Aaronia AG (Figure 18). Their model BicoLOG

30100X covers 30 to 1000 MHz and includes a battery-operated broadband preamplifier. The cost is just $1,299 and may be ordered directly from Aaronia AG in Germany (http://www.aaronia.com/products/antennas/BicoLOG-30100-X/) or their North American distributors, Kaltman Creations (http://kaltmancreationsllc.com) or Saelig Electronics (http://www.saelig.com). Aaronia also has compact antennas that tune from 700 MHz to 6 GHz.

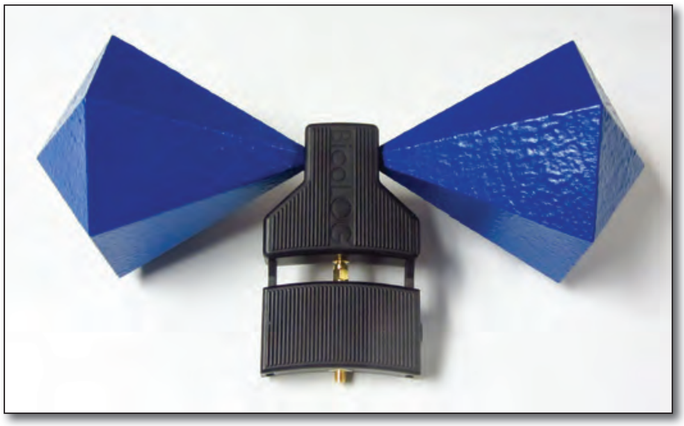

**FIGURE 18:** A small broadband active antenna from Aaronia that is very useful for bench top troubleshooting of radiated emissions.

Whether an antenna is resonant at the frequency harmonic of concern is not that important. So long as you can observe the RF harmonics at a distance of 1m, or more, the troubleshooting process can start. Figure 19 shows my typical setup for evaluating and troubleshooting radiated emissions. By monitoring the spectrum analyzer as you try various fixes, you can see immediately whether progress has been made. The best part is that you can do this testing right at your lab bench.

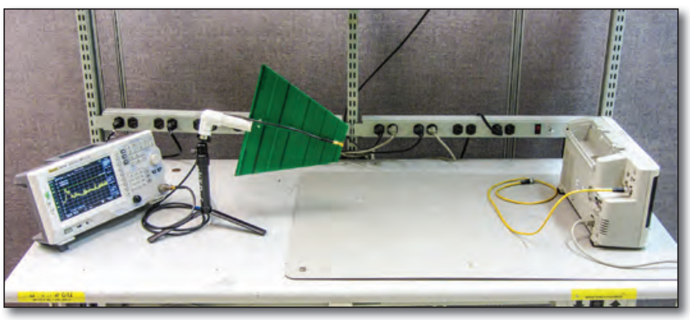

**FIGURE 19:** The typical setup used to troubleshoot radiated emissions. Position the antenna and spectrum analyzer about 1m away from the product under test so you can observe progress in real time.

## FERRITE CORES AND CHOKES

RF currents on cables (and associated radiated emissions) may usually - but not always - be reduced by clamping a ferrite choke around the I/O or power cable nearest the source of RF noise. Adding a few of these chokes in various sizes to your kit would be helpful for troubleshooting (Figure 20). It's sometimes best to use a large (2.4 inch) toroid ferrite core of 31, or similar, material with multiple turns through it for use in frequencies below 30 MHz. This is a common cure for interference to (or from) consumer equipment. Most common beads and clamp-on ferrites are generally more effective at frequencies in the 100s of MHz, unless the ferrite material is specifically designed for lower frequencies.

**FIGURE 20:** Examples of various clamp-on ferrite chokes.

## MISCELLANEOUS

Adhesive copper tape is also useful for sealing enclosure joints temporarily during troubleshooting. Rolls of this tape may be purchased from electronics distributors at $30, or more, per roll. I've also found that "snail tape" (under $10) used in gardening may be substituted. This may be found in garden stores or on Amazon. Take care not to cut yourself on the sharp edges.

Aluminum foil is also handy as a troubleshooting tool for wrapping around an interfering product to assess whether additional shielding might help. Note that aluminum foil is not as effective at power line frequencies.

Finally, a selection of capacitors, resistors, inductors, and common-mode chokes is useful for applying filtering to I/O, microphone, and power line cables.

For additional troubleshooting techniques and equipment reviews, please check out my EMC blog at http://www.design-4-emc.com.

Part 2 of this article will describe the tools and techniques for testing various immunity tests, with a special emphasis on radiated immunity and electrostatic discharge (ESD) – two very common issues. Part 2 will be available as a download by the end of April 2016. Please sign up for the Interference Technology newsletter to receive notice of availability.

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# Is EMC prepared to handle the challenges of the Internet of Things?

**GUNTER LANGER**
Langer EMV-Technik GmbH

**THE NUMBER OF MOBILE** devices such as smart phones, tablets and wearables has risen significantly over the past years. At the same time, wireless communication has increased due to higher data rates. Will the growing number of wireless devices multiply the EMC problems? Is today's industry able to cope with the EMC requirements that the Internet of Things has in store for us?

If more devices have to interact with each other and their EMC quality remains at the present level, this will lead to more EMC problems from a statistical point of view. Furthermore, a device may be incompatible in practice even though it has passed the compliance test. Let us assume that an electronic device has passed the emission compliance test according to IEC 61000-6-3, IEC 61000-6-4, for example. In contrast to the test, the electronic device may be located near a metallic object such as a housing in practice. This may lead to field coupling which in turn results in higher emissions than in the test. The dimensions of the metallic object are essential in this context. The field may stimulate standing waves that fit the dimensions of the metallic object and then cause additional emissions.

This means that in future, not only will wireless transmission problems arise but also problems due to emissions from devices.

Stricter device standards will not necessarily solve this compatibility issue.

The example above shows that the current compliance tests usually do not take any field coupling mechanisms into consideration. The field coupling mechanisms may induce some helpful ideas on how to solve the problem.

It remains to be seen whether the measuring principles specified by the current standards are sufficient or whether new measuring principles will have to be developed.

Furthermore, new requirements are emerging in the field of EMC standards for ICs (IEC 61967 and IEC 62132). Concrete IC EMC parameters will be needed as input values for EMC development tools / simulation programs for PCBs in future. It would be sensible to obtain these EMC parameters from measurements according to IC EMC standards. Unfortunately, the results of standard measurements are currently inadequate for such a purpose.

This procedure will become more important for IC development in the future.

These are the reasons why one should consider adapting the test methods of the standard measurement to this task. This will be shown below for ICs by taking conducted emissions as an example.

The interference suppression strategies currently used in electronics development come up against their limits. ICs as potential emission sources are not noticed as troublemakers until the first development sample has been completed. The developer comes across them when taking interference suppression measures in the device or on the PCB. Near-field probes are used to locate RF sources in the electronics. These do not identify the IC itself as the disturbance source but PCB traces into which the IC feeds disturbance currents and disturbance voltages. The electronics will then be modified with additional components, copper foil or other means. Last but not least, EMC measurements are carried out to confirm the success of the interference suppression measures taken after the redesign of the PCB.

This approach is very time-consuming and expensive. One big problem here is that selective EMC measures cannot be taken until the first functional development sample has been completed. Insights, which could be crucial for EMC, are gained when it is too late. Important decisions are taken in the development process without considering the results of the EMC test. Problems are almost inevitable because the EMC test results are obtained at such a relatively late point in time.

However, the industry demands faster and more efficient developments in compliance with EMC. This can only be achieved by taking a completely new approach. This has to begin early on in the development process and delves deep into the emissions' chains of action. Only hands-on knowledge of the emission source allows the developer to follow this path. Once ICs have been described more precisely as potential sources of emissions, appropriate measures can be taken much earlier and more efficiently to stabilize the whole device's EMC.

Appropriate EMC parameters are a prerequisite and are thus subject to high demands. They have to describe the EMC problem zones of the ICs for practical use in industry. This means they must be suitable for the development of PCBs in compliance with EMC requirements. In addition, the IC's EMC parameters must be linked with practical measures and strategies.

This approach should define electronics development in terms of EMC. On account of extreme miniaturisation, a higher susceptibility to electromagnetic disturbances is experienced in the field of device development today. The device manufacturers make increasing efforts to address the problems so as to suppress interference in devices and comply with the corresponding standards.

The problems described in the example above aggravate the situation even more. An important requirement for the Internet of Things in particular is that the devices function properly and reliably in their environment.

The extent to which device manufacturers can continue to master the EMC situation, which is aggravated on account of the miniaturisation, and to suppress interference in devices by spending more time and money on this work remains to be seen. Development in compliance with EMC requirements will represent an increasing share of the costs in device development. It is doubtful whether the EMC objectives will be able to be fulfilled at all. Providing better EMC parameters in the fields of IC research and IC development in future can mitigate this problem. However, this means that more time and money will have to be spent here too. Of course, this relates to the wireless devices. German industry has started to respond to this mounting pressure.

Companies now work together with EMC advisors in solving EMC-related problems in the development of devices and complex systems by using new EMC technologies from the very beginning of the development process.

## MAIN PART

Due to internal functional operations, ICs generate RF voltages, currents and fields. Different physical mechanisms are responsible for these entering cable harnesses in the form of emissions or the surrounding open space in the form of radiation. ICs may have the following effects:

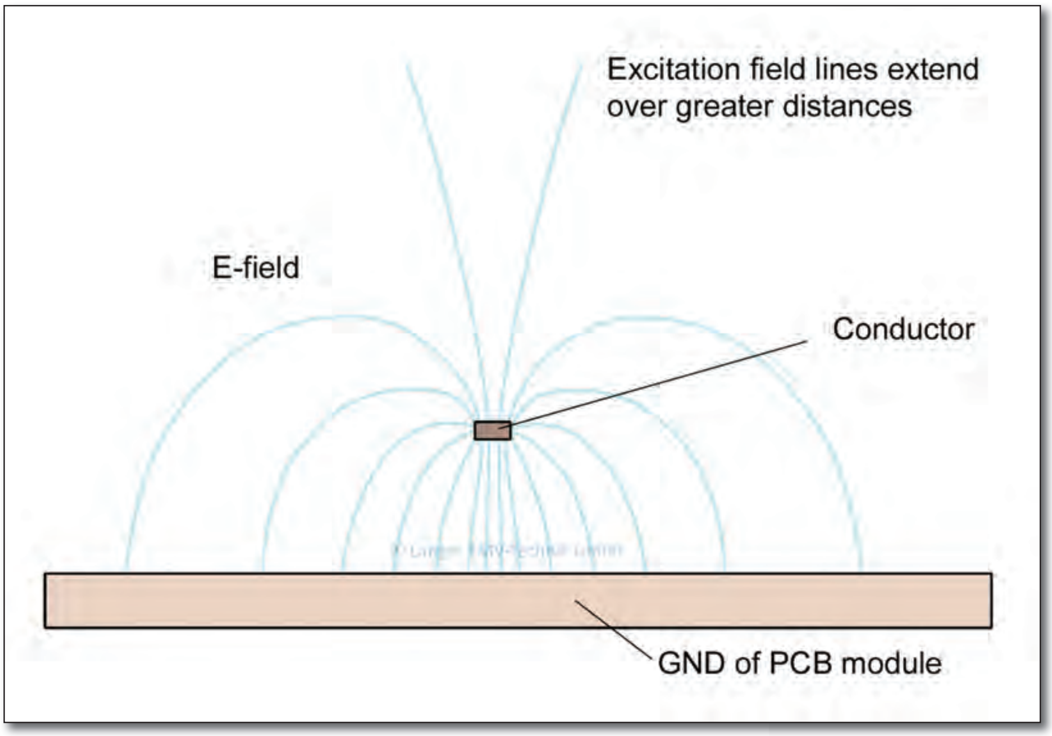



**FIGURE 1:** Electric field of a PCB trace

DESIGN

1. Conductive: Emission of RF currents and voltages via the IC pins into the PCB traces.
2. Capacitive/inductive: Emission of E- and H-near fields from the die or connections of the IC.
3. Radiative: Direct emission of electromagnetic waves. Direct emissions are usually only crucial in the Gigahertz range for ICs with very high clock rates in practice.

The following section describes **Item 1 and 2**: conductive, capacitive and inductive effects in the PCB.

Emissions follow a closed loop. The driving RF-current and RF-voltage sources are located inside the IC. They drive RF into the PCB traces via the bonding wire, lead frame and pin where the current generates magnetic near fields and the voltage generates electric near fields. The electric and magnetic near fields would build up undisturbed if a PCB trace were to be freely positioned in space. The fields are similar to the E-fields and H-fields of an antenna. The electric field is closely coupled to the magnetic field via the antenna element, its current and voltage. This electric field pattern results in the emission of electromagnetic waves. The PCB trace acts as a transmission antenna.

The situation, however, is usually quite different on the PCB. The PCB contains metal surfaces. These metal surfaces usually extend over the entire PCB and have ground or supply voltage potential. The gap between these metal surfaces and the PCB traces is normally < 1 mm. These ground surfaces affect the distribution of the trace's electromagnetic field. The effect can best be described by taking a loop antenna as an example. A loop antenna can emit electromagnetic radiation if positioned freely in space. If the loop antenna is placed on a ground surface, this will prevent the emission of electromagnetic radiation. This is because the corresponding conductive metal surfaces block the magnetic field in the opening of the loop an account of current / field displacement effects (skin effect). The loop antenna's magnetic field can no longer build up around the antenna and is practically no longer present. Radiated emissions from the loop antenna are thus reduced considerably (**Figure 2**).

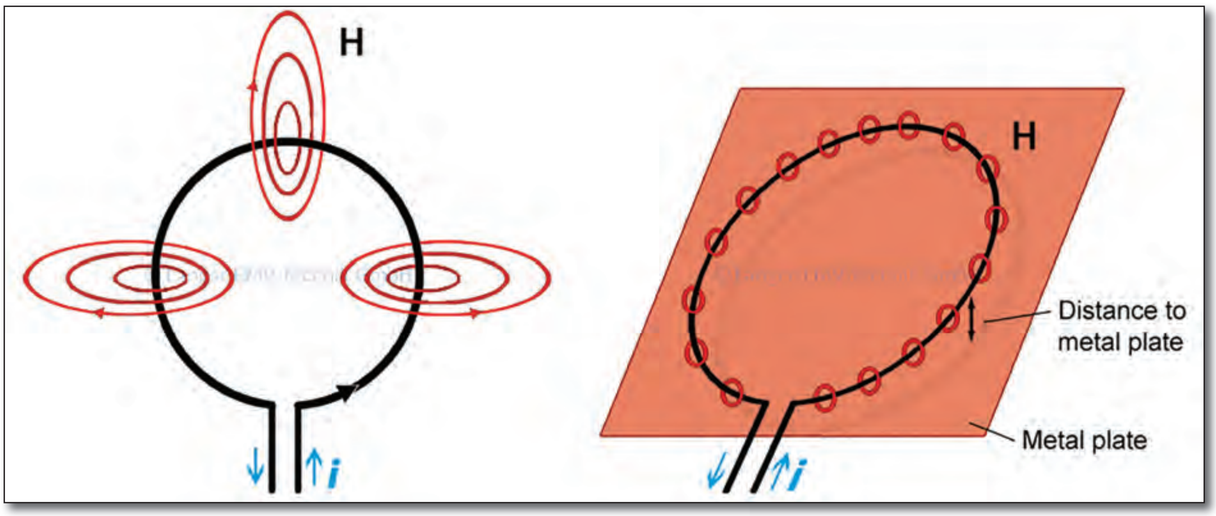



**FIGURE 2:** Blocking of a loop antenna's magnetic field by a metal plate. While the magnetic field is blocked, the loop antenna's near fields can stimulate the metal plate to radiate emissions (other radiation characteristics). If the gap between the loop antenna and metal plate is zero, the H-field is also zero.

The PCB trace reacts in precisely the same way. Direct emissions from the trace are prevented as soon as the ground surfaces in the PCB are large enough. Emissions from the trace will not increase until this is at a certain distance from the ground surface. The required distance depends on the length of the trace. Practical experience shows that the gap must be > 0.5 cm to cause any effective emissions (frequency range < 1 GHz) with a trace length of > 10 cm.

This means that emissions take other ways from a PCB, namely via its near fields.

These near fields cause emissions through interaction with metal parts (Vdd/Vss surfaces, large metal components, cables and lines, metallic structural parts).

## RELATIONSHIP BETWEEN IC VOLTAGE AND EMISSIONS

We refer to the PCB trace in the following text. The traces inside the IC follow the same principles. The statements on the PCB trace can thus be transferred to the traces inside the IC. The pin voltage which is present on the PCB trace or the trace inside the IC builds up an electric field around this trace (**Figure 1**). Most of the field lines lead to the PCB's GND surface. Only a few field lines leave the PCB vertically upwards and penetrate into open space. The closer the trace is to the edge of the GND system, the more field lines penetrate the space.

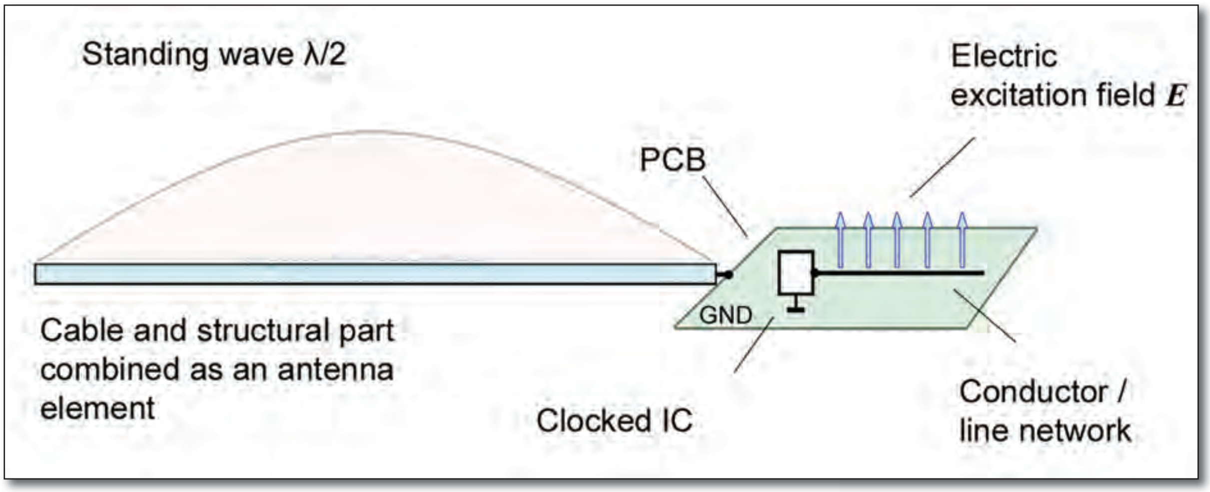



**FIGURE 3:** Stimulation of radiated emissions via electric excitation field lines

These field lines (excitation field lines) leave the PCB's GND system and carry displacement current through space which stimulates the entire metal system (PCB with cables and metallic structural parts) to vibrate electrically (**Figure 3**).

The standing waves on the metal system may cause emissions.

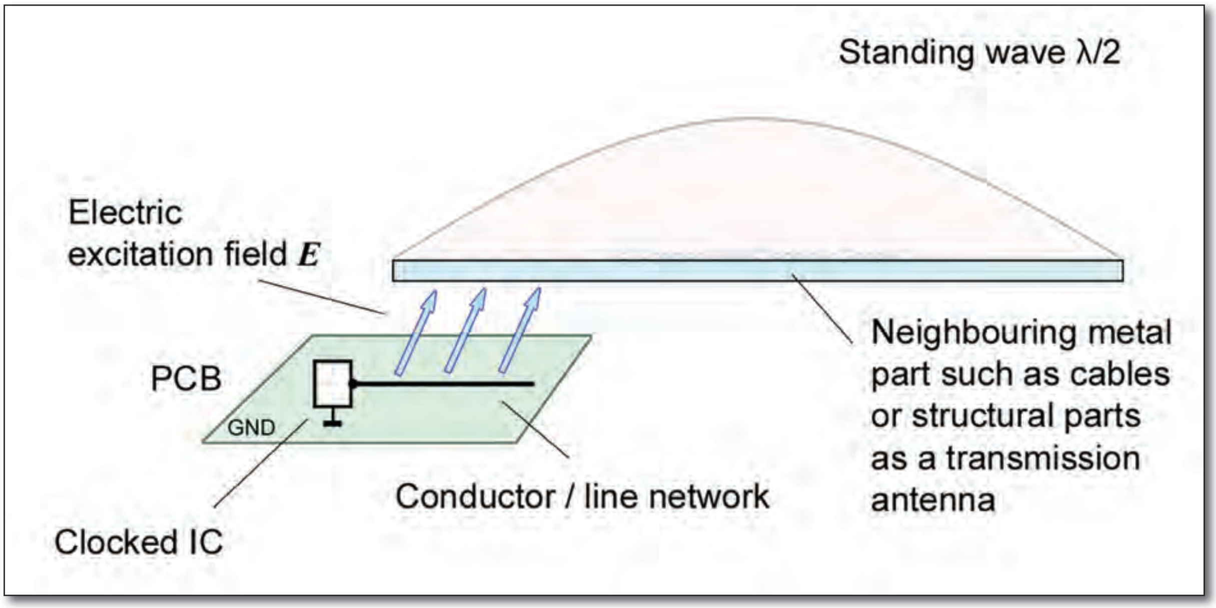



**FIGURE 4:** Overcoupling of excitation field lines to neighbouring metal parts

The electric excitation field may reach metal parts (cables, structural parts, shielding plates, ( **Figure 4**) located opposite the PCB and these may be stimulated to vibrate electrically by the transferred displacement current.

## RELATIONSHIP BETWEEN IC CURRENT AND EMISSIONS

The IC's current loops can either be located inside on the die or loops can be formed by the IC's pins. These loops run through the ground system of the PCB, pin, lead frame, bonding wire and die. This type of loops can be formed via Vdd or Vss pins, for example. The Vdd / Vss loops that penetrate to the outside may be much larger than the loops located inside the die. The larger outer loops can generate a stronger magnetic field and are usually responsible for the highest emissions.

We refer to the PCB trace in the following text. The traces inside the IC follow the same principles. The statements on the PCB trace can thus be transferred to the traces inside the IC.

The pin current, which flows into the PCB trace, builds up a magnetic field H2 (**Figure 5**). The returning pin current also generates a magnetic field H1 in the GND system (). It is assumed that the PCB ground is a metal surface, which extends over the entire PCB. The trace is so close to the ground that it can usually only generate insignificant emissions, as in the loop antenna example above. The field H1 of the returning current induces a self-induction voltage UErr. in the GND plane of the PCB (metal surface). This voltage drives cables and structural parts that are connected to it like an antenna. The cables and structural parts emit electromagnetic waves as a result.

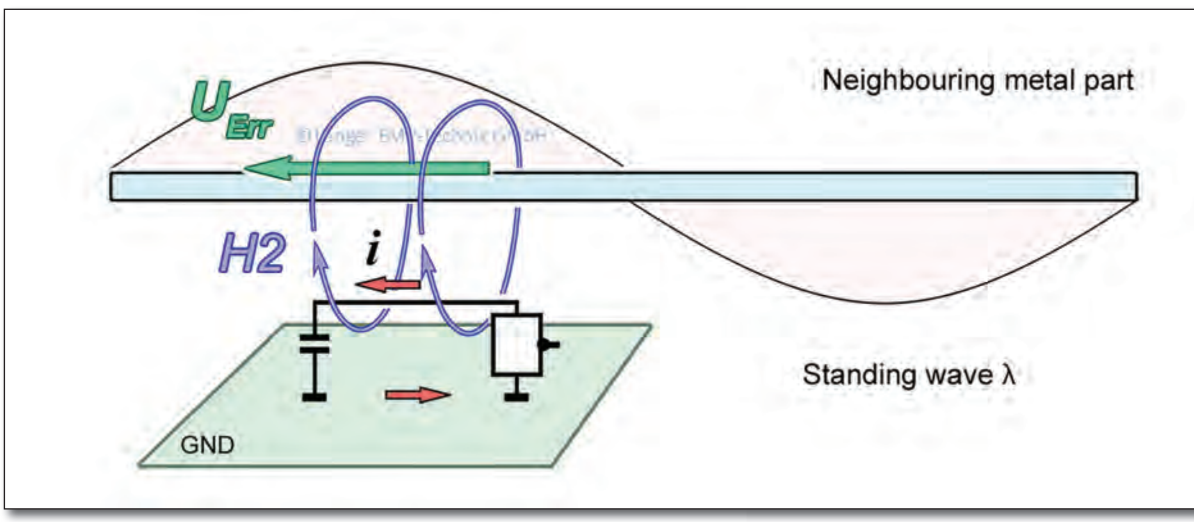



**FIGURE 5:** Stimulation of radiated emissions through mutual induction

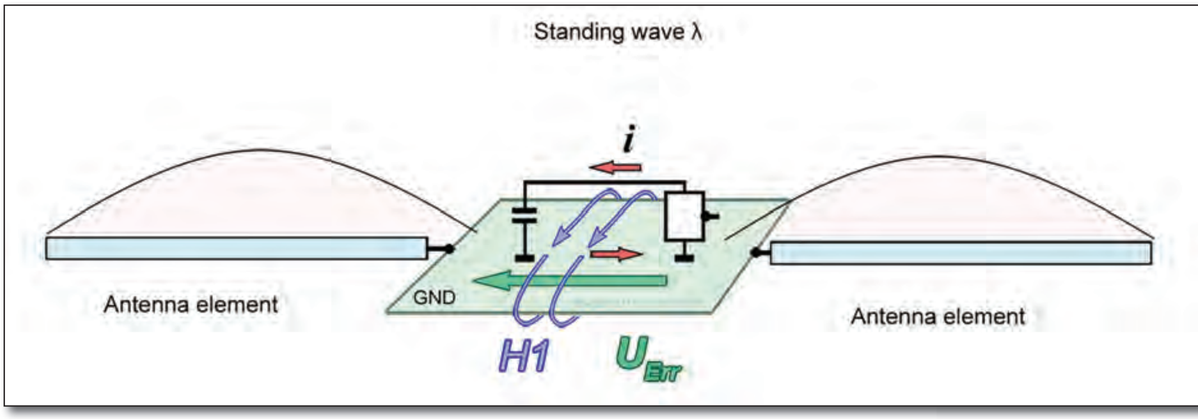



**FIGURE 6:** Stimulation of radiated emissions through mutual induction

The magnetic field H2 (**Figure 5**) of the trace cannot generate any radiated emissions in open space. This is due to the fact that the trace is close to the ground plane, similar to the loop antenna example above, thus preventing emissions. There is another chain of interactions that causes the magnetic field to radiate emissions. This is similar to the one described for the field H1 above. A metal part has to be inserted into the field H2 for this purpose. An excitation voltage is only induced there via mutual induction if the magnetic field encloses a metal part. The excitation voltage stimulates the metal part to act as an antenna. The metal part emits electromagnetic waves. A steering column, a metal strut or a cable in the PCB's neighborhood in a vehicle is taken as an example.

## EMC PARAMETERS FOR IC PINS

The IC pin current and IC pin voltage are the pin-related EMC parameters of an IC. The IC's electric near field and magnetic near field are the field-related EMC parameters of an IC. All four parameters (u, i, E, H) of the IC have to be detected by suitable measuring devices.

The electric near field of the PCB traces is proportional to the pin voltage and the magnetic near field of the conductor loops of the PCB is proportional to the pin current of the IC. The pin current and pin voltage depend on the load to which the pin is subjected through the connected PCB trace.

The values of the cases in which the highest pin voltage and the highest pin current are generated have to be used for the IC parameters.

The current and voltage of the traces depend on the driving voltage in the IC and on the impedance of the load on the PCB traces.

The maximum possible pin current is measured if the pin is operated under short-circuit conditions. The maximum possible pin voltage is measured if the pin is operated under no-load conditions (open circuit). The maximum possible values have therefore been determined and all values from practical operation (determined in a large number of measurements on different PCBs) are equal or smaller.

The voltage, and thus the electric near field, is highest under open-circuit conditions in the PCB traces in special cases. The emission potential is then at its greatest.

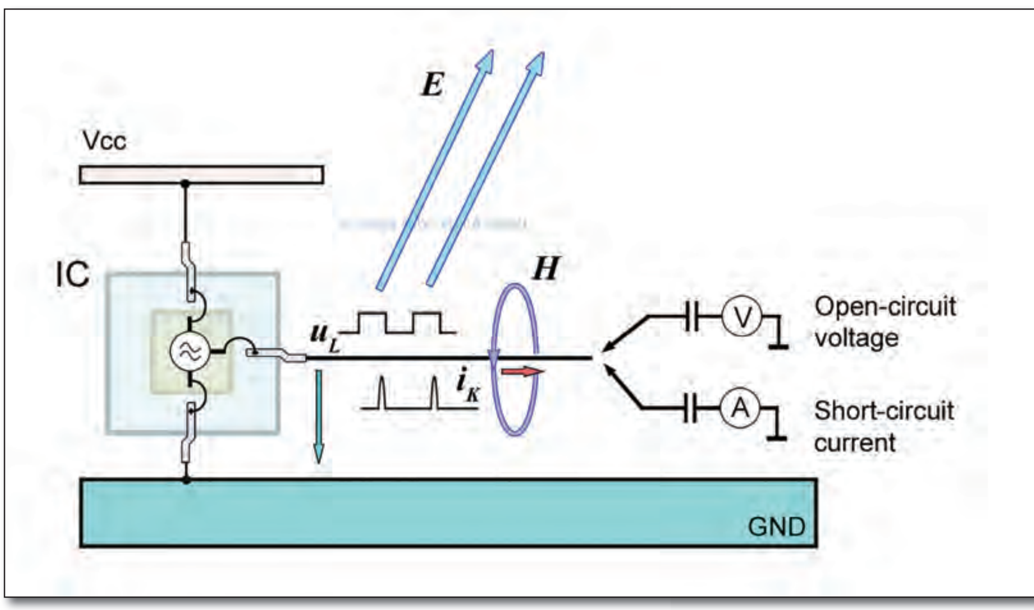



**FIGURE 7:** Measurement of pin parameters close to short-circuit and open-circuit conditions

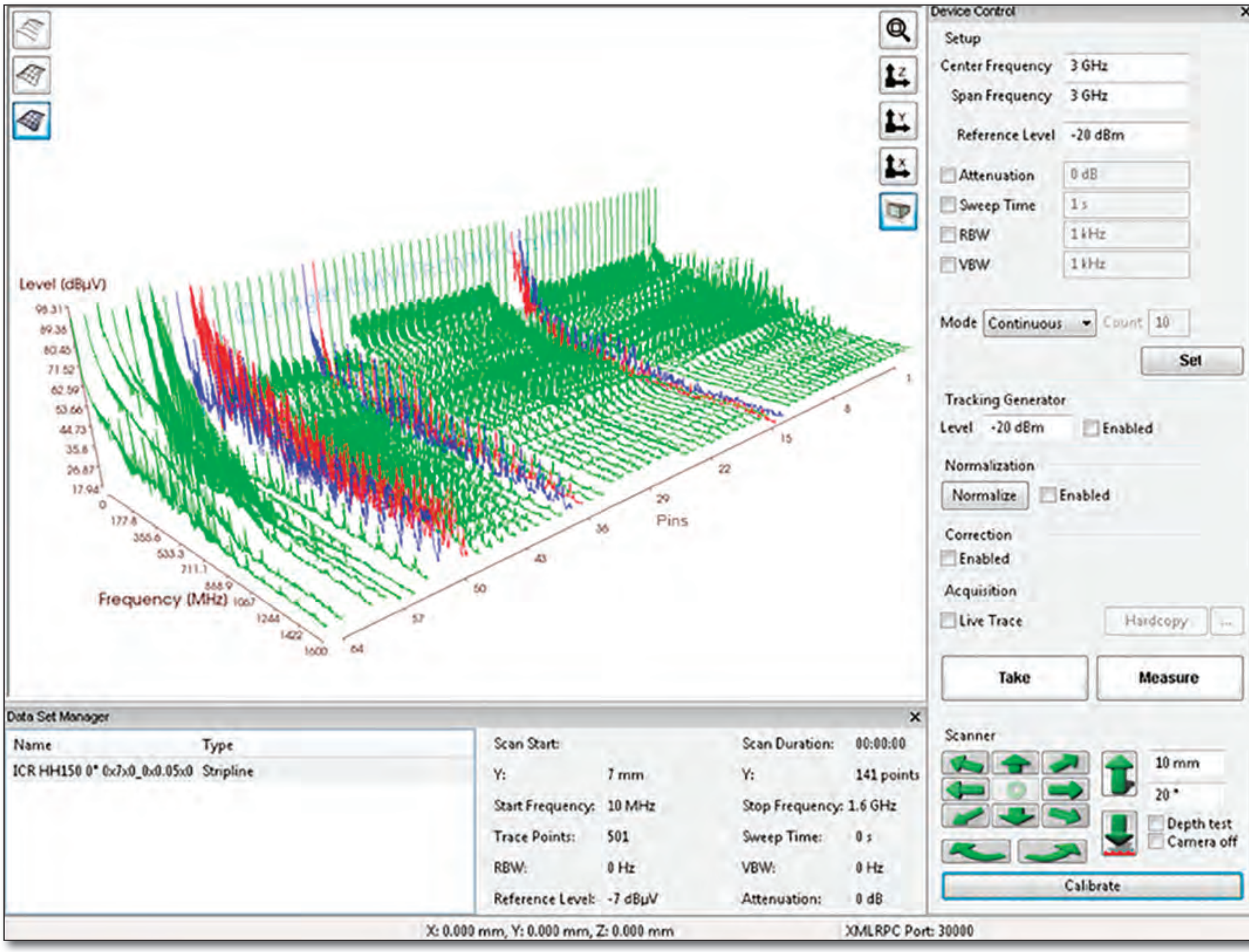



**FIGURE 8:** Open-circuit voltage of the test IC 01

The corresponding EMC parameter of the IC is its open-circuit voltage Ul(f). The magnetic near field is proportional to the current flowing through the trace. The current depends on the IC's driving voltage and the load of the trace. A short circuit may occur in special cases. The current, the magnetic field and thus the emissions are then at their greatest.

The corresponding EMC parameter of the IC is its short-circuit current Ik(f).

The maximum pin current and pin voltage values (Ul(f), Ik(f)) are produced under short-circuit or open-circuit pin conditions. In these cases, the highest emissions are generated via the coupling mechanisms described above.

Hence, it follows that each pin of an IC has its own EMC parameters for conducted emissions. An IC pin's EMC parameters are its open-circuit voltage and its short-circuit current.

The open-circuit voltages and short-circuit currents can be determined for most pins of the IC through measurements under close to open-circuit and short-circuit conditions. Two spectra for each pin result in 128 spectra for a 64-pin IC, for example. Furthermore, the pin can have different switching states (input, output H, L and high-impedance). The internal function may also assume different states (Clk-PLL OFF/ON).

The current in the power supply pins is measured according to the 1 Ohm method. If the resistance of 1 Ohm is too great, a 0.1 Ohm measuring resistor is used. This measurement can be carried out in both the Vdd and Vss. A corresponding high-impedance probe and a decoupling capacitor can be used to measure the RF open-circuit voltage on crystal oscillator pins. The crystal oscillator's filter capacitor may serve as a decoupling capacitor.

The measurements may produce a large amount of data and become difficult to manage. A 3D representation provides a clear overview of the results (**Figure 8**). A custom-developed measurement set-up, with a corresponding software (ChipScan ESA), allows a semi-automatic recording of the pin spectra. The results are visualised in 3D. The representation can be switched over to 2D for selected pins (**Figure 12**).

## USE OF IC PARAMETERS

The 3D spectra clearly reveal the problematic pins for practical applications. Open-circuit voltages in the range of 80 dBμV can lead to limit-exceeding emissions over trace lengths as short as approx. 10 mm (particularly problematic in automobiles). The critical frequency range can be read from the 3D – 2D spectrum. **Figure 12** shows this for the crystal oscillator pin 15. The critical frequency range extends up to 600 MHz. The layout and design can be steered in the right direction on the basis of the EMC parameters of the IC pins to save time and money. There will be ICs where individual pins display high values in terms of conducted EMC parameters of the emissions. These values provide helpful advice on how to use the IC on the PCB in a compatible way. Consequently, these ICs need not be excluded from developments. IC users should determine the IC's EMC parameters before they start developing a PCB.

If ICs are integrated without this information (as it is still common practice today), problems will not arise until the first development sample has been measured. This entails high costs for time-consuming interference suppression measures (layout changes, design modifications, etc.). This approach also permits an IC to be chosen from a range of alternatives because it will most likely cause lower emissions, and hence it will be easier and less costly to make its PCB assembly EMC compliant.

Two new helpful tools can be created for electronics development on the basis of the IC's EMC parameters:

1. Pin-related open-circuit voltage and short-circuit current spectra (3D / 2D)
2. Layout and design tips in conjunction with the EMC parameters of the IC pins

An EMC specialist can derive such design tips (counter-measures) from the pin spectra, interactions (items 1 and 2) and the character of the special application. However, design hints and tips should better be provided in the form of pin information in practice. The EMC parameters Ul(f), Ik(f) of the IC pins can be grouped in frequency-dependent level ranges with different risk potentials. A certain barrier of design measures has to be built up depending on the risk potential. This strategy will be the basis of EMC activities over the years to come.

Examples of pin-selective counter-measures in terms of open-circuit voltage:

The static port pins 16 to 35 (**Figure 8**) show high open-circuit voltages. This leads to emissions via the electric field if several port conductors are connected to PCB traces. As a counter-measure, the traces should be well enclosed by GND and not be located at the edge of the PCB.

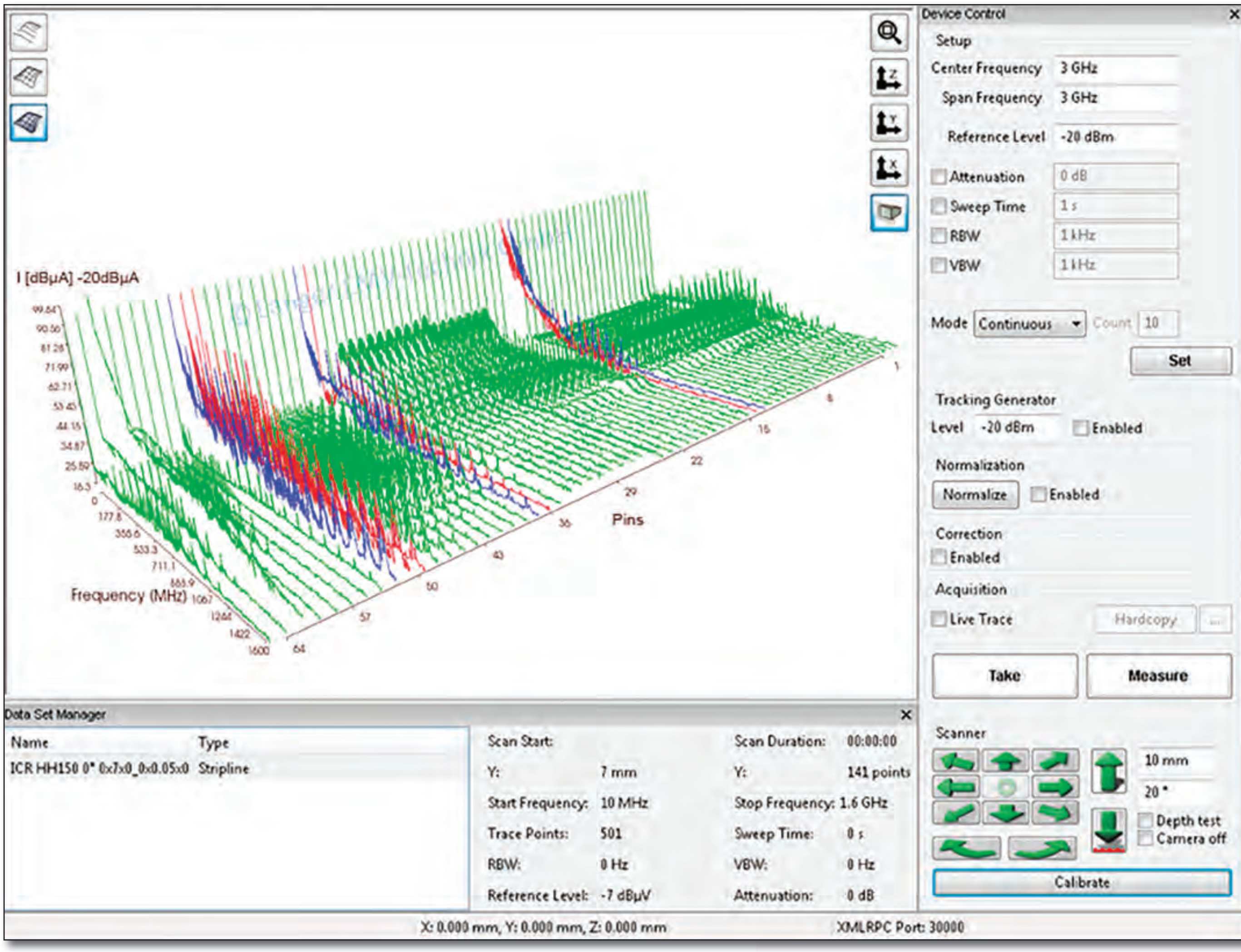



**FIGURE 9:** Short-circuit current of the test IC 01

## EXAMPLES OF PIN-SELECTIVE COUNTER-MEASURES IN TERMS OF SHORT-CIRCUIT CURRENT

The port pins 16 to 35 also provide relatively high short-circuit values (**Figure 9**). Filter capacitors located further away can generate critical current loops. As a counter-measure, the filter capacitors should be located in the vicinity of the IC or series resistors should be inserted.

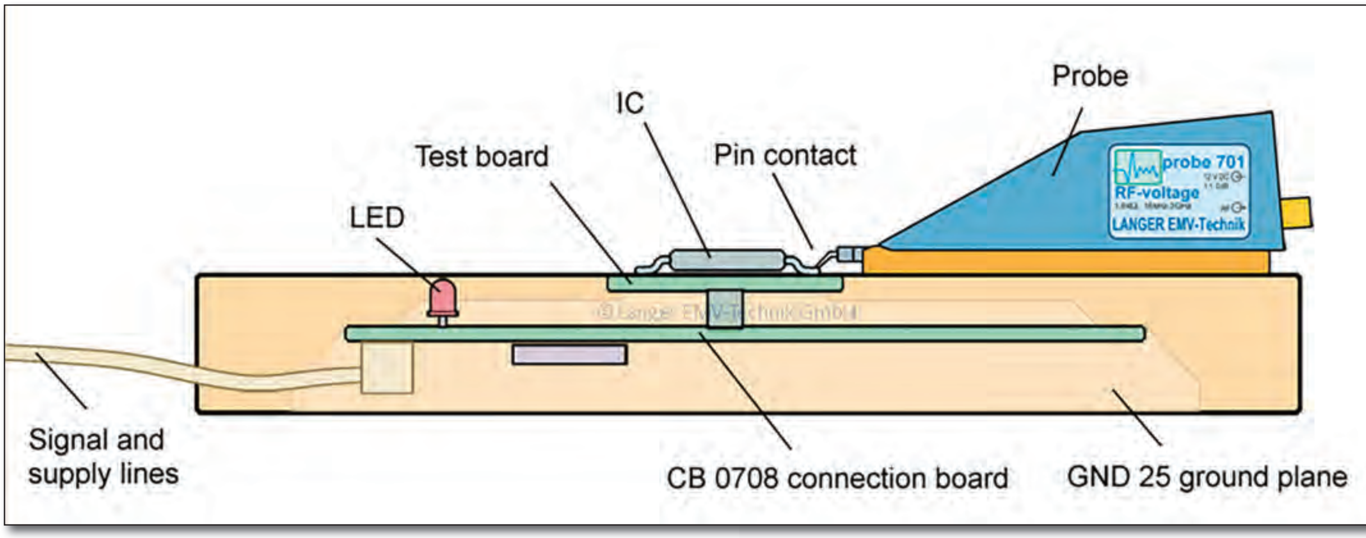
High values are obtained for the supply pins 12, 13 in the lower frequency range (< 100 MHz) and pins 50, 51, 52 in the medium frequency range (around 500 MHz). As a counter-measure, the current loop that passes over the blocking capacitor can be attenuated with a resistor (< 10 Ohm) or a soft ferrite. The blocking capacitors and the IC should not be too close to the edge of the PCB (> 20 mm). The IC should be positioned so that the IC current loop is orthogonal to the PCB's longest axis. This holds particularly true for PCBs that are not wider than 50 mm. The orientation of the IC current loops can be measured with field probes designed for RF field measurements on ICs and provided as IC EMC field parameters.

## MEASUREMENT SYSTEMS FOR EMC PARAMETERS OF IC PINS

**Figure 10** shows the measurement set-up for pin current and pin voltage measurements.

The test IC (DUT) is placed on a test board which is embedded in a ground plane. This provides a continuous GND surface as a prerequisite for measurements up to the GHz range.

A (voltage or current) measuring probe whose tip can be moved easily to contact each pin is placed on the GND plane. The measuring path (IC - pin contact - probe) is only a few millimetres long so that the measurement can be carried out at a short electrical distance. The IC is supplied and controlled by the connection board via filters (**Figure 10**). The connection board is integrated into the ground plane



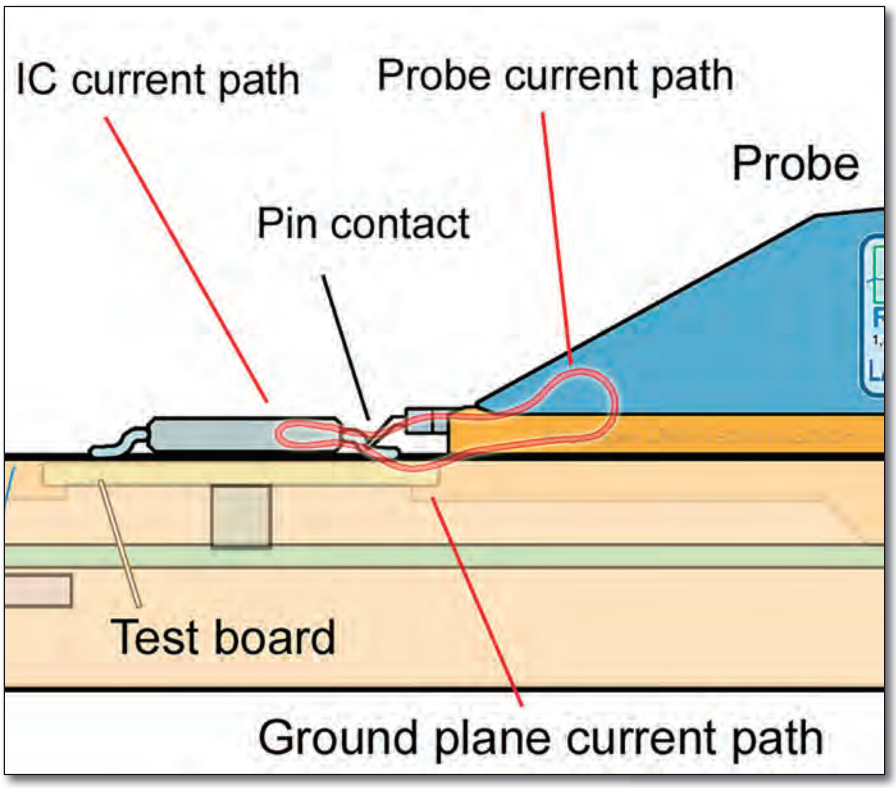




**FIGURE 10:** Measurement system for pin current and pin voltage

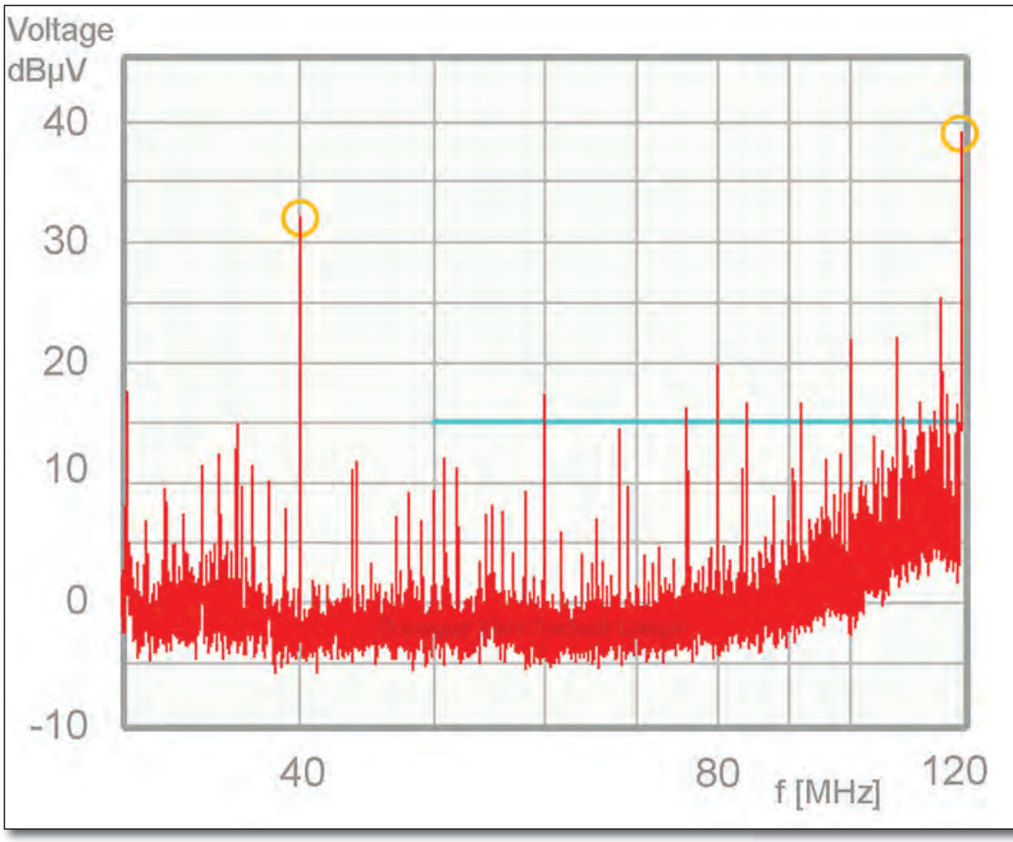



FIGURE 11: Measurement of an IC 02 application with a simulated on-board power system. Limit value violation of 24 dB at 120 MHz. Cause: E-field coupled out of a trace connected to the IC 02



## PRACTICAL EXAMPLE

**Figure 11** summarizes the results of a measurement on vehicle components. The limit value violation of 24 dB occurs at 120 MHz due to an E-field. This problem was not discovered until the development sample was tested. A measurement of the open-circuit voltage Ul(f) of the IC pin as one of the IC EMC parameters reveals the cause.

Exceptionally high voltages (approx. 80 dBµV at 120 MHz) were measured on the IC pins for the crystal oscillator in a 40 MHz grid (shown in black in **Figure 12**).

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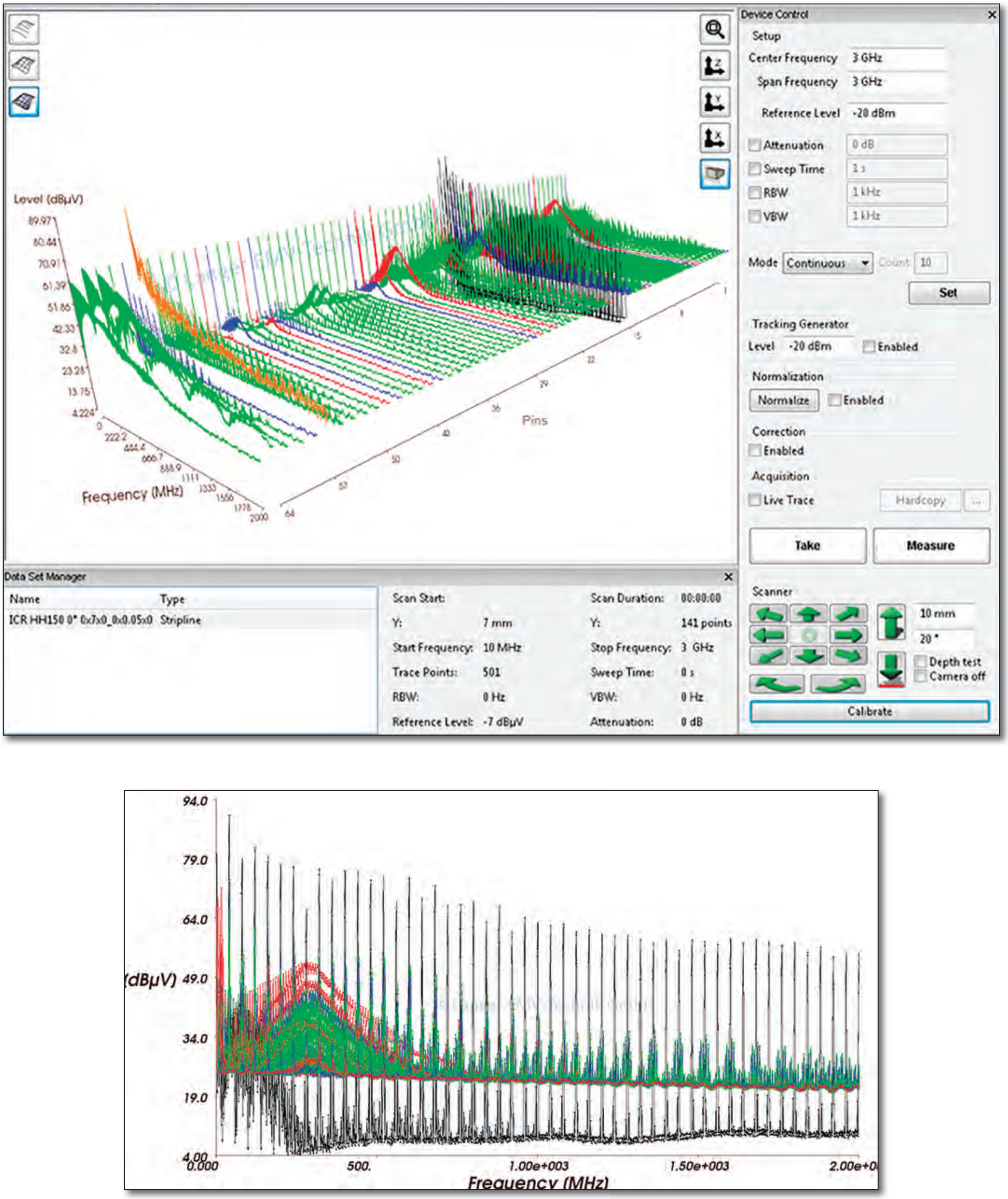


**FIGURE 12:** Open-circuit voltage measurement on IC 02 in 3D and 2D

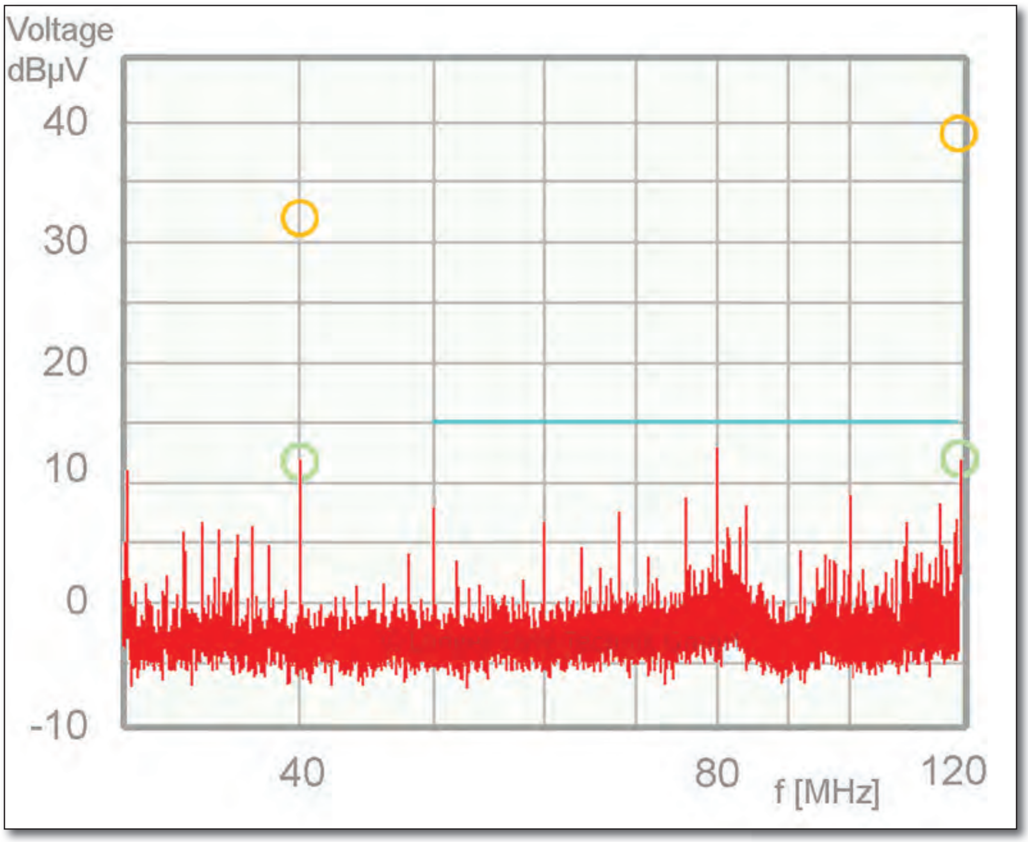


**FIGURE 13:** Verification measurement after the counter-measure was taken: the IC 02 shielding prevents E-field from being coupled out.

All lines and metal parts connected to these pins emit an electric field as described under **Item 1** of the physical mechanisms. The electric field is exceptionally strong and causes the PCB and the cable harness to vibrate electrically.

This means that the field is coupled out via:

- the bonding wires and lead frame of the IC pins that lead to the crystal oscillator,
- the 15 mm PCB traces from the IC to the crystal oscillator,
- the crystal oscillator housing and crystal oscillator wiring 3 x 0603 SMD components.

A suitable remedy in this case is to reduce the surface of these metal parts, i.e. to shorten the traces and embed them in GND, to use smaller crystal oscillator housings. However, these counter-measures are not sufficient in our example. The open-circuit voltage Ul (f) of the pin is so high that the metal surface of the bond wire and lead frame is large enough to cause a limit value violation during the component measurement. Filter capacitors cannot be used to reduce the voltage on the crystal oscillator. An E-field shielding directly above the IC can be used as a final remedy. **Figure 13** shows the positive results achieved thanks to these counter-measures. The limit values are met.

The EMC characteristics of ICs can already be determined today. It is useful if values obtained are entered in product data sheets. This information allows the developer to already plan EMC measures that are necessary for the PCB during the development process, so that in principle they can use any IC. Test methods to determine the IC EMC parameters enable the IC manufacturer to develop ICs more efficiently.

Due to the continued miniaturization of modules and the high number of very complex electronic devices, the EMC assessment of ICs is a valuable prerequisite for the future development of electronic devices. The use of IC EMC parameters will also have a positive effect on the development of the Internet of Things.

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# Multilayer SMD Ferrites Optimized for Peak Current Loads

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## BACKGROUND

**CHIP BEAD FERRITES ARE** inductive surface mount devices (SMDs) used for filtering undesired high frequency signal distortions in printed board assemblies. They are manufactured using a multilayer screen printing process. Optimised for as high as possible losses, these components consist of a nickel-zinc-ferrite body with a very fine embedded silver coil with a thickness of just a few micrometres. This structure makes the conventional SMD ferrite beads vulnerable to current spikes above their maximum rated load, resulting in degenerative or even immediate destruction of the component in some cases.

## APPLICATION

A typical chip bead ferrite application is shown in Figure 1. The multilayer ferrite is used as a longitudinal filter near the input of a circuit. Due to the low charging resistance of the capacitor, a very high pulse current flows for a short time at switch-on. This pulse current temporarily loads the SMD ferrite with a current that can reach many times the component's maximum rated level.

In this example, a multilayer ferrite designated as Multilayer Power Suppression Bead (MPSB) has a rated impedance of 600 Ω for a maximum permissible current load of 2.1 A. The current surge in this constellation reaches a peak value of approx. 19 A and has a pulse length of 0.8 ms before declining to the circuit's rated current.

In general, a SMD ferrite's maximum rated current also defines the component's maximum current amplitude for any given temporary load. However, multilayer ferrites are now available that cater for current surges above their maximum continuous current as rated in their data sheets. Examples of these new components are examined in more detail below.

## TESTING METHOD

Current peaks occur frequently in real life applications, for example at switch-on of switch mode power supplies and electric motors. Windscreen wiper motors in vehicles are a well known example for recurrent current pulses. But discharge lamp ballasts can also produce high current peaks when the light is switched on. The input capacitor in a switch mode power supply can produce a particular high current peak, which the upstream EMC filter needs to withstand. In this context, pulses are understood as temporary current peaks above the circuit's rated DC current level limited to a time span of less than 8 ms.

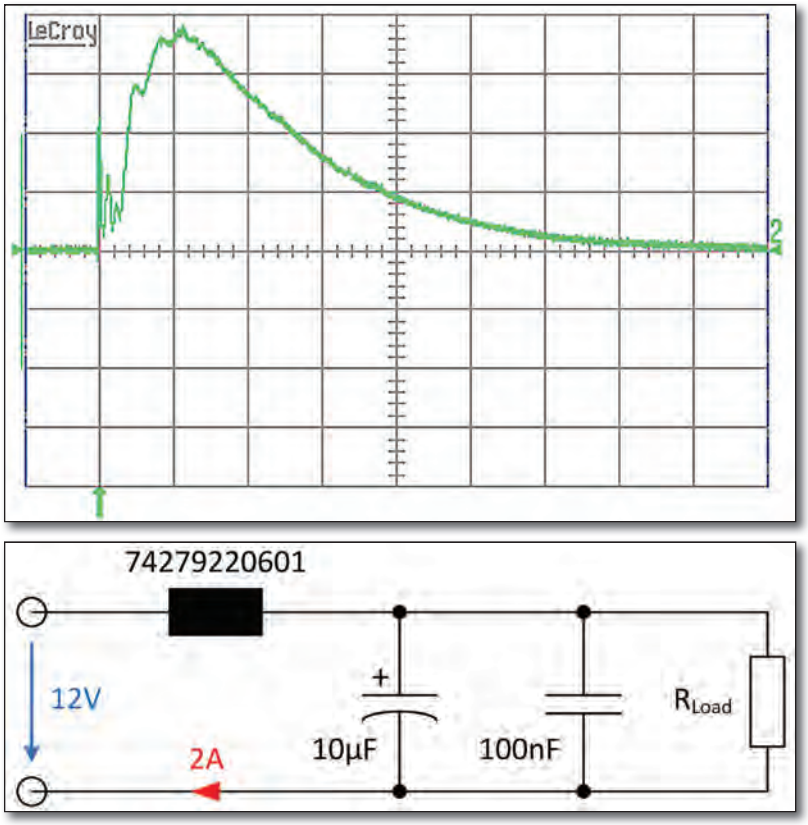


**FIGURE 1:** Application showing current peak at switch-on (5 A/DIV, 100 µs/DIV)

In search of a common standard for measuring the pulse load capacity of SMD ferrites, an appropriate approach was found in the definition of the melting integral for fuses. According to this standard, a pulse of 8 ms duration is applied to the fuse to "give the current time" to heat the fuse to determine its $I^2t$ value. If the fuse withstands a given current pulse, the current is increased and this is repeated until the fuse fails. In this process, pauses of 10 seconds are inserted between pulses to give the component the necessary time to regenerate (cool down).

Würth Elektronik eiSos has developed an adapted test routine for multilayer ferrites based on this fuse testing standard. Using the same 8 ms pulse length, current pulses with increasing strength are applied to the multilayer ferrite up to their destruction. The components are subjected to incrementally increasing pulse currents starting from 1 A.

A rectangle as shown in Figure 2 was selected as pulse shape for all tests as this loads the component with the highest possible energy for a given pulse length although this will only very rarely be applicable in real-life situations.


**FIGURE 2:** Possible switch-on pulse shapes

## PULSE LOAD CAPACITY ANALYSIS

Other than with fuses, multilayer SMD ferrites do not to lend themselves to specifying a generally applicable formula allowing conclusions to be drawn for various current peak values and different pulse lengths by calculating the melt integral. Rather, data sheet values are determined empirically and rely on extended test series with varying parameters.

The following example serves to confirm that the melt integral is unsuitable the multilayer ferrites (using the Würth WE-MPSB ferrite 742 792 206 01 with Z = 600 Ω, IR = 2.1 A, and RDC,typ = 43 mΩ). This component has a maximum peak current load capability of 18 A at a pulse length of 8 ms, which produces an $I^2t$ value of 2.592 $A^2ms$ (18 A @ 8 ms (5 sec pause, 24 °C) $I^2t$ = 2.592 $A^2s$).

The following result is obtained when calculating the current for a pulse length of 2 ms based on the $I^2t$ value for 8 ms:

$$I[A]_{@n[ms]} = \left( \sqrt{\frac{I^2[A]*8[ms]}{n[ms]}} \right)$$

$$I[A]_{@2[ms]} = \left( \sqrt{\frac{2{,}592}{2[ms]}} \right)$$

$$I[A]_{@2[ms]} = 36A$$

However, the data sheet value is specified as max. 24 A as shown in Figure 3. The calculated $I^2t$ value differs significantly from the measured value. This shows that it is not appropriate to apply the known calculation method for the melt integral $I^2t$ to a multilayer ferrite.

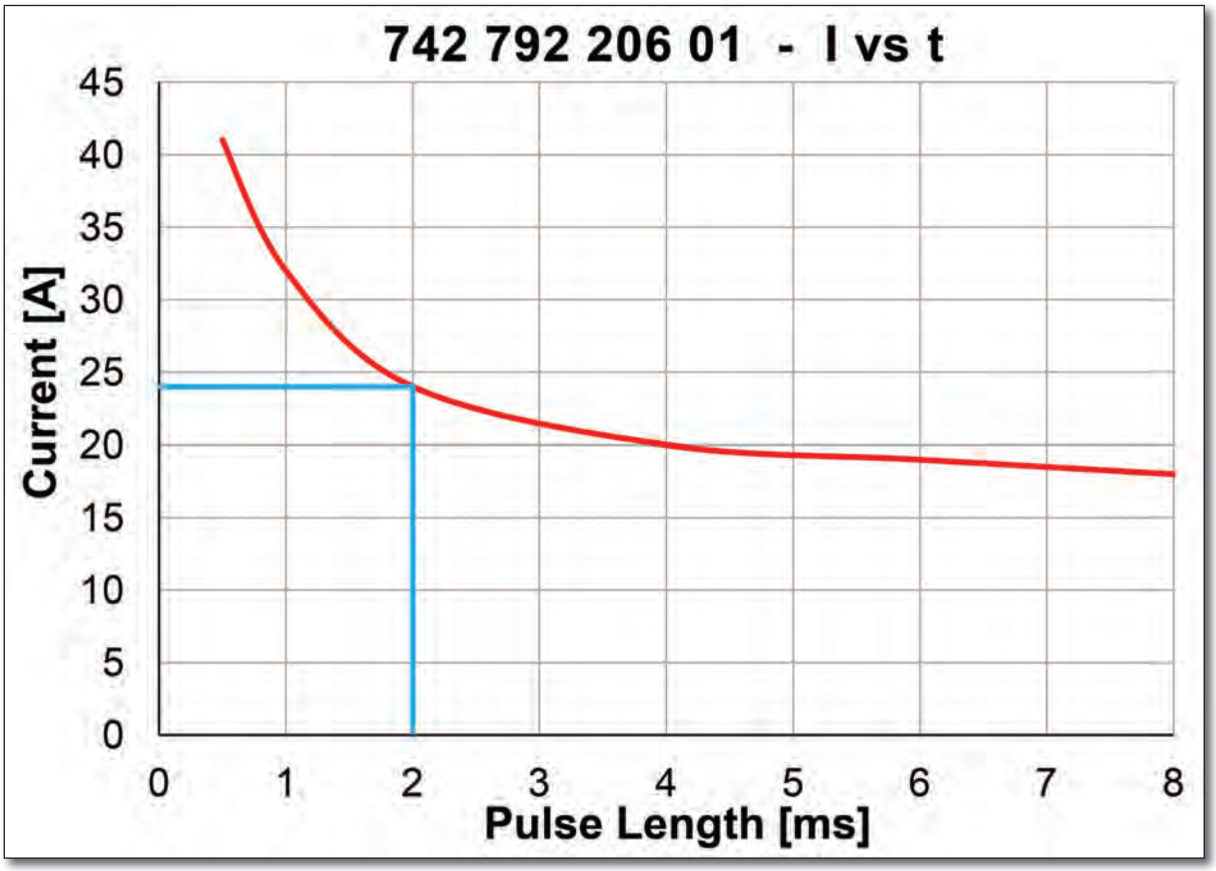


**FIGURE 3:** Specified peak current load capability

## OPTIMISING THE MULTILAYER STRUCTURE

Due to their silver layers with thicknesses of only 8 to 20 µm, multilayer ferrites are not inherently designed for high pulse currents. Würth has developed a new design with a combination of high current tolerance, up to 75% smaller RDC and as high as possible impedance over their complete frequency range. Depending on the desired impedance and peak current level, the design is varied for each individual component type.

## CURRENT PULSE TOLERANCE RELATIONSHIPS

Figure 4 shows the new ferrite bead's current pulse tolerance behaviour in more detail using the 742 792 206 01 bead type as an example. The current vs. pulse length curve on the left side shows the maximum permitted peak current for pulse lengths ranging from 0.5 ms to 8 ms. Each ferrite bead type has an individual curve of this kind and these curves are only applicable for singular current pulses. The right graph

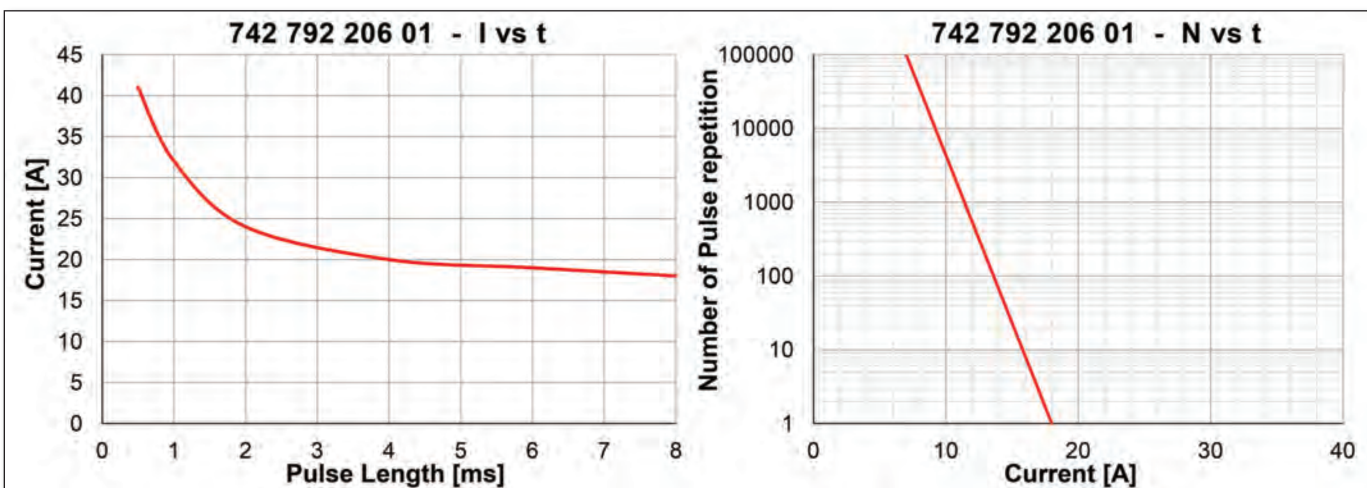


**FIGURE 4:** Permissible peak current by pulse length (left) and pulse number (right)

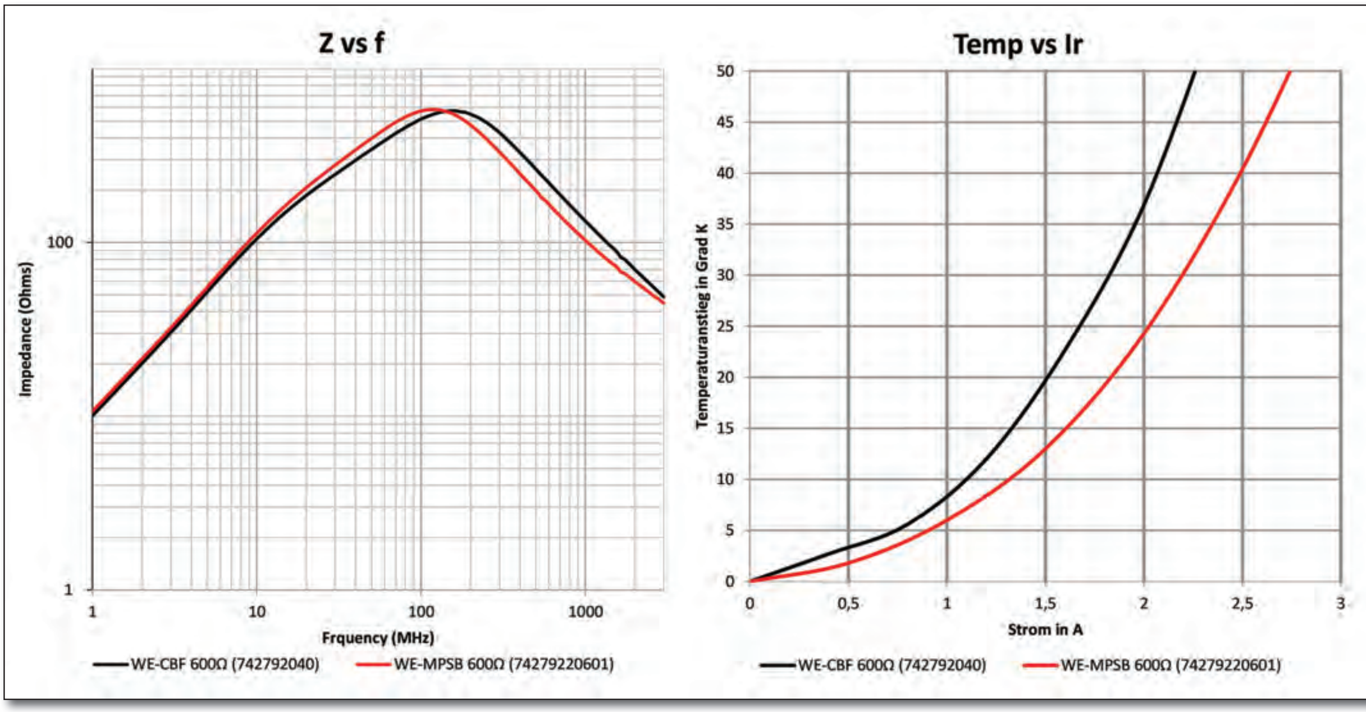


**FIGURE 5:** Impedance and rated current load capability of the 600 Ω WE-CBF and WE-MPSB bead ferrites



shows the maximum permitted pulse current for repeated current pulses. A maximum pulse length of 8 ms was selected to determine these values.

## INFLUENCING FACTORS

The factors influencing the ferrite beads' behavior are:

- The pulse length, with standard test values ranging from 0.5 ms to 8 ms. The longer the pulse, the lower the maximum pulse load capability.
- The number of pulses, which was varied from 10 to 100,000 pulses in the tests (see Figure 4). The maximum permissible current pulse load drops as the pulse frequency increases.
- The temperature should be noted as third reducing influencing factor: As the temperature rises, RDC increases, which results in a further reduction of the maximum permissible current pulse load.

Each of these interlinked factors is affected by the dependency on the pause length between individual pulses. In order to carry out an analysis of the linked system with a smaller pause time, all measurements need to be repeated while varying the influencing factors, temperature [T], pulse repetitions [n] and pulse length [t].

## NEW AND PREVIOUS FERRITE BEAD SERIES COMPARISON

When developing their new ferrite bead series, Würth followed the objective to achieve impedance levels comparable

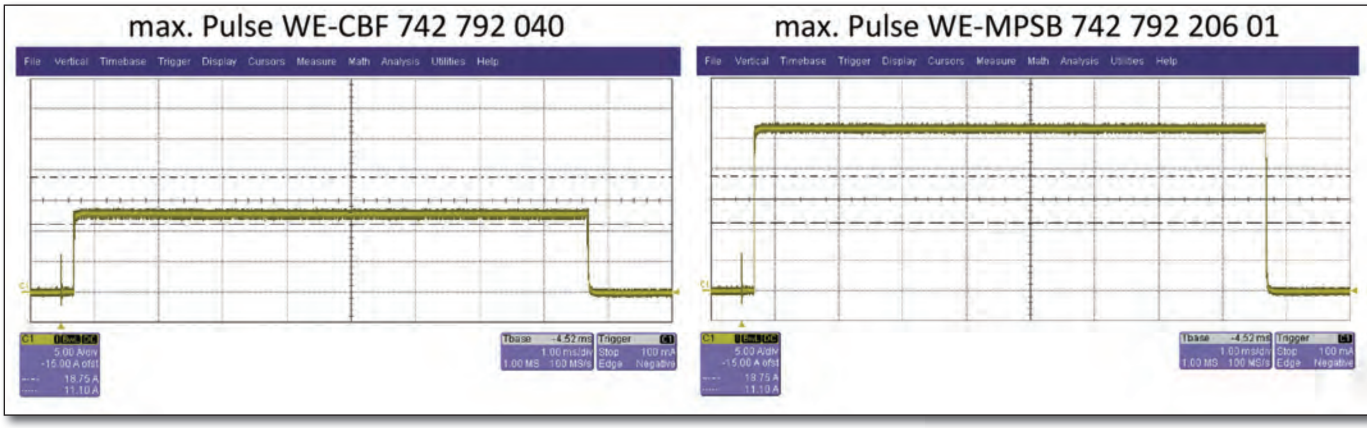


**FIGURE 6:** Comparison of the different pulse load capability of the WE-CBF and WE-MPSB series bead ferrites

with their previous series with additional tolerance to pulse current loads. Using the example of the 600 Ω models in size 0805 as shown in Figure 5, the new series is shown to exhibit almost the same impedance along with a higher rated current pulse tolerance due to its lower resistance.

The new ferrite beads exhibit a significantly higher pulse load capability than the equivalent previous types. Figure 6 shows the maximum pulse level of the older 600 Ω type on the left and the maximum pulse level of the comparable newer 600 Ω model on the right. Moreover, Würth is now able to specify the pulse load capability of SMD ferrites manufactured in the multilayer screen printing process.

## CONCLUSION

Specific chip bead ferrite components can now cater to the requirements of circuits that load multilayer ferrites with temporary peak currents exceeding their rated maximum continuous current. The components' multilayer structures are optimised to enable a higher current load capability by lowering the structure's inherent resistance. The maximum pulse load capabilities of the new multilayer ferrites were determined using empirical measurements as calculations using a formula for the behaviour of fuses proved inappropriate.

## AUTHOR'S BIOGRAPHY:

**Markus Holzbrecher**, born 1983, graduated from Leipzig University of Applied Sciences with a diploma degree in Electrical Engineering. Since 2011, he has been responsible for the product area of EMC components for PCB assembly at Würth Elektronik eiSos.

For more information, contact appnotes@we-online.com.


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# Calendar

## EMC BY YOUR DESIGN

**April 12 – 14, 2016, Northbrook, Illinois**

An EMC Practical Applications three-day Seminar and Workshop by Donald L. Sweeney, Roger Swanberg, and Tim Lusha. Using the latest EMC textbook "Controlling Radiated Emissions by Design, 3rd Edition" by Michel Mardiguian, edited in part by Donald L. Sweeney, and updates of the latest developments in research, standards, regulations, instrumentation and services, participants will study EMC design techniques and the calculations required to design a product to meet compliance regulations.

**http://www.dlsemc.com/emc-class/registration.htm?location=KQ1802444**

## EDI CON 2016

**April 19 – 21 , 2016, Beijing, China**

EDI CON brings together leading RF, microwave, high-speed analog and mixed signal components, semiconductor, test and measurement equipment, materials and packaging, EDA/CAD and system solution providers in the exhibition. EDI CON has industrial and technology leaders delivering most of the technical sessions, workshops and panels so that the exhibition is closely coupled with the conference. This makes the exhibition an extension of the technical conference where attendees can learn first-hand about products and services that offer practical solutions to their problems.

**http://www.ediconchina.com/**

## THREE 1-DAY EMC SHORT COURSES

**April 19 – 21, 2016, Stoughton, Wisconsin**

LearnEMC now offers EMC short courses with a hands-on component, providing a more individualized learning experience for smaller groups of students. These first three classes (The Physics of EMC Measurements, Printed Circuit Board Design for EMC and Signal Integrity, and Computer Modeling Tools for EMC) will be taught by Dr. Todd Hubing. Registration is strictly limited to 15 students.

**http://learnemc.com/emc-classes-in-stoughton**

## EMC LIVE 2016

**April 26 – 28, 2016, Online Event**

EMC Live 2016 is a unique 3-day-event, featuring live webinar presentations, with practical solutions to electromagnetic interference (EMI) challenges. Various electromagnetic compatibility (EMC) topics will be covered including shielding, ground filtering, standards, pre-compliance and testing; and will be applicable to electronics, design and test engineers working in all industries.

**http://www.emclive2016.com/**

## 2016 IEW

**May 17 – 19, 2016, Tutzing, Germany**

The 10th Annual International Electrostatic Discharge Workshop provides a unique environment for participants to meet and engage in discussions about IC EOS/ESD design, verification, test, multichip, and system level ESD topics.

**https://www.esda.org/index.php/events/iew/**

## 7TH ASIAN-PACIFIC INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY (APEMC) 2016

**May 18 – 21, 2016, Shenzhen, China**

The APEMC 2016 will cover both traditional and emerging topics of electromagnetic compatibility, offer a rich scientific program of highest quality with invited speakers from all over the world and provide a broad forum of exchange for both academia and industry.

**http://www.apemc.org/**

## 16TH IEEE CONFERENCE ON ENVIRONMENTAL AND ELECTRONICS ENGINEERING (EEEIC 2016)

**June 7 – 10, 2016, Florence, Italy**

EEEIC is an international forum for the exchange of ideas and information on energy systems both today and in the future. The conference provides a unique opportunity for designers and industrial people in general to interact directly with university researchers, manufacturers and distributors of energy equipment and to discuss a wide variety of topics related to energy systems and environmental questions.

**http://eeeic.eu/**

## ESD DEVICE DESIGN ESSENTIALS SEMINAR

**June 29 – 30, 2016, Santa Clara, California**

This two-day seminar consists of concentrated versions of twelve ESDA tutorials which comprise the ESDA Device Design Certification Program. Instructed by Gianluca Boselli and Michael Khazhinsky.

**https://www.esda.org/events/calendar/**

## EMC WEEK 2016

**August 8 - 12, 2016, Boulder City, Nevada**

5 days of EMC design and test with "*The EMC Century Plus Team*" at the historic Boulder Dam Hotel in Boulder City, NV. Learn from some of the top EMC trainers in the business: Doug Smith, specializing in high frequency measurements, EMC, and ESD; Kenneth Wyatt, specializing in EMC troubleshooting and pre-compliance testing; Derek Walton, who owns a complete test lab and specializes in EMC standards and test; Randy Flinders, specializing in materials compliance, such as RoHS; and Dan Beeker, an application engineer with NXP who will discuss proper PC board design for EMC compliance.

**http://emcesd.com/**

## INNOVATIVE SMART GRID TECHNOLOGIES CONFERENCE (ISTG2016)

**September 6 – 9, 2016, Minneapolis, Minnesota**

The 7th Conference on Innovative Smart Grid Technologies' theme for this year will be "Transformation and Advancements for Grid Modernization," and will include an emphasis on advanced distribution management systems, the integration of distributed energy resources, the seams between distribution and bulk power operations, and the needed approaches for both planning and operations.

**http://sites.ieee.org/isgt-2016/**

## EMC LIVE TEST BOOTCAMP 2016

**November 16, 2016, Online Event**

The EMC Live 2016 Test Bootcamp is a highly focused 1-day event for engineers involved in the development, pre-compliance, testing, and certification of electronic products, systems, and assemblies. Electromagnetic interference (EMI) challenges, and electromagnetic compatibility (EMC) solutions will be addressed across a wide range of applications, covering the latest in standards, test equipment, setups, and techniques.

**http://emclive2016.com**

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# 2015 / 2016
# Standards Review

**Compliance with standards** makes or breaks the launch of any new product. This section recaps new and revised national and international EMC standards over the last 12 months. The information below has been featured in our weekly Interference Technology eNews. Just go to InterferenceTechnology.com, subscribe to the eNews, and you'll be updated on important changes in EMC standards weekly.

## EMC DIRECTIVE 2014/30/EU BECOMES MANDATORY APRIL 2016

***02/23/2016***

Elite Electronic Engineering highlights some of the changes between the current EMC Directive 2004/30/EC and the new EMC Directive 2014/30/EU in a white paper originally published October 14, 2014.

The deadline is almost here. It's time for manufacturers, importers, and distributors to adapt their CE Marking conformity assessment processes to the new directive by April 2016. The new directive will be required for all EMC compliance files, and declarations referencing 2004/108/EC will no longer be valid.

Elite reports, "For the most part, compliance with the new directive 2014/30/EC will not significantly impact conformity assessment. The essential requirements listed in Annex I of the directive remain the same as before and continue to be stated in very general terms. The requirements limit electromagnetic emissions to a level that will not affect telecommunications or other equipment and require products to have immunity to electromagnetic disturbances. For permanently fixed installations, Annex I still specifies applying good engineering practices to assess compliance."

The EN harmonized standards in the Official Journal don't change as a result of the recast directive, so the technical requirements used previously will remain the same going forward. However, all harmonized standards are regularly updated as they evolve to adapt to new technology.

Some of the more significant changes in the recast 2014/30/EU relate to the operations of Notified Bodies and other practices that may not immediately impact manufacturers. Annex VII in the new Directive provides a helpful correlation table that relates requirements in 2004/108/EC to 2014/30/EC.

## CISPR PROVIDES "GUIDE TO EMC IN SMART GRID"

***02/23/2016***

CISPR has prepared a "Guide to EMC in Smart Grid", which gives insight into issues that should be taken into consideration when designing and developing equipment for connection and inter-operation with the Smart Grid.

SmartGrid systems must be immune to sources of interference from a wide array of wanted RF signals and RF disturbances and other events that occur at SmartGrid component installations.

Among the issues that must be addressed is EMC, which is the ability to withstand the electromagnetic (EM) environment (have sufficient immunity) without causing interference (disturbances) primarily to radio reception, but also to other digital/electronic devices.

Electromagnetic disturbances of various types, from a variety of sources, have been reported and have caused performance degradation, outages, shutdowns and even large scale system failure to the power grid. EMC is thus an important factor for consideration in standards relating to the IEC SmartGrid program.

The SmartGrid needs to function properly and have full interoperability, with other electrical and electronic systems. To ensure this these systems and their components must be designed with due consideration for conducted electromagnetic emissions injected into the grid and for immunity to various electromagnetic phenomena originating from the grid. This needs to include devices that will be mounted on the outside of buildings and homes as well as in newly designed "SmartGrid enabled" appliances.

## A2LA AND ANSI RECOGNIZED BY NIST TO ACCREDIT NOTIFIED BODIES

***02/16/2016***

A2LA and ANSI (American National Standards Institute) have been formally recognized by the National Institute of Standards and Technology (NIST) as an Accreditation Body offering Notified Body (NB) accreditation under ISO/IEC 17020:2012, ISO/IEC 17025:2005, and ISO/IEC 17065:2012. Currently, A2LA is the only accreditation body recognized by NIST to offer accreditation to all three conformity assessment standards.

These standards form the basis for NB accreditation based on Section 4 of NIST's Requirements & Application for U.S. Conformity Assessment Bodies Seeking EU Radio Equipment Directive (RED) 2014/53/EU Notified Body Status and Requirements & Application of U.S. Conformity Assessment Bodies Seeking Electromagnetic Compatibility (EMC) Directive 2014/30/EU Notified Body Status. Both state,"The [organization] shall obtain formal accreditation for its Notified Body activities."

The newly published Directives become effective in a relatively short window of time, at which point the NB accreditation requirements come into place –April 20, 2016 for the EMC Directive, and June 13, 2016 for the RED.

## ACMA RELEASES PRODUCT COMPLIANCE GUIDANCE FOR EMC

***02/10/2016***

The electromagnetic compatibility (EMC) regulatory arrangements impose compliance labeling and record-keeping requirements for the supply of an extensive range of electrical and electronic products, vehicles and products with internal combustion engines. The requirements are detailed in the:

Radiocommunications Labeling (Electromagnetic Compatibility) Notice 2008 (the EMC LN) made under section 182 of the *Radiocommunications Act 1992*.

The objective of the arrangements is to minimize the risk of unintentional electromagnetic interference from products that may affect the performance of other electrical products or disrupt radiocommunications services.

The EMC LN specifies, among other things, the form and placement of the compliance label, the compliance level, the applicable EMC testing and record-keeping requirements. The Radiocommunications (Electromagnetic Compatibility) Standard 2008 (the EMC Standard) specifies the technical standards that apply to a device.

The EMC regulatory arrangements require that, prior to supplying a product to the Australian market, a supplier must:

- **Assess applicability** – establish whether the product is subject to the EMC regulatory arrangement (refer to Part 2 in the EMC LN).
- **Identify the applicable standards** – identify the applicable EMC standards as listed on the ACMA website.
- **Demonstrate compliance** – ensure the product complies with the applicable standard/s at the specified compliance level (refer to section 4.3 of the EMC LN). Compliance can be demonstrated through testing and/or assessment of supporting documentation.
- **Complete a Declaration of Conformity (DoC) and maintain compliance records** – The DoC is a declaration made by, or on behalf of the supplier that all products comply with the applicable standard/s. A compliance record is a collection of documents (and may include the DoC and test reports) that support the supplier's claim the product complies with the standard/s (refer to section 4.3A and Part 5 of the EMC LN).
- **Register on the national database** – a supplier must register on the national database before affixing a compliance label to a compliant product (refer to sections 4.2 and 4.2A of the EMC LN).
- **Apply a compliance label** – a compliance label indicates the device complies with the applicable standards (refer to Part 3 of the EMC LN). The compliance label consists of the Regulatory Compliance Mark (RCM).

The EMC LN and its associated explanatory statement are available on the Federal Register of Legislative Instruments through the ComLaw website.

## RELEASE OF ICES-003 ISSUE 6

***02/01/2016***

Industry Canada released ICES-003 Issue 6, which clarifies several definitions for "interference-causing equipment" for information technology equipment (ITE) and other digital apparatus.

The document became effective January 19, 2016, but there is a three month transition period, where either Issue 5 or 6 may be accepted. After that transition period, compliance to Issue 6 becomes mandatory.

The following are the list of changes from Issue 5: updated Section 2.1 to clarify the definition of an ITE device; updated Section 2.3 to include storage media; updated Section 2.4 to clarify applicability of broadcasting equipment; updated Section 3(b) to reference the latest version of ANSI C63.4-2014.

## FCC TO CHANGE EMC APPROVALS PROCESS

***02/01/2016***

Ghery Pettit Consulting reports a change in the FCC approvals process starting July 13, 2016.

Until now, manufacturers have had the choice of using "FCC Listed" test labs or "FCC Recognized Accredited Test Laboratories." After that date, only the latter test labs – and ONLY those located in countries with mutual recognition agreements (MRAs) with the FCC may be used for the "Certification" approval process.

Countries with current MRAs include Australia, Canada, the EU, Hong Kong, Israel, Japan, South Korea, Singapore, and Taiwan. The country with the biggest impact will be those test labs in China, where an MRA does not yet exist.

These test labs (and others located in countries lacking an FCC MRA) will only be able to test products to the FCC's "Verification" process.

## FUNCTIONAL SAFETY STANDARD IEC 61508

***01/26/2016***

With more electronic systems controlling human-machinery interfaces, functional safety for EMC is becoming an important consideration.

IEC 61508 addresses functional safety for industrial-process measurement, control and automation.

This standard was developed by IEC SC 65A and includes various comments and changes by leading experts.

## KOREAN PRA KN32 AND KN35 RECOGNITION

***01/13/2016***

TÜV Rheinland is among the first Nationally Recognized Testing Laboratories to be granted accreditation from Korea's National Radio Research Agency to "test and certify IT and multimedia equipment to the recently enacted KN32/KN35 standards," as reported by the company. This recognition was received on January 8, 2016.

This recognition applies to products scheduled for testing after January 1, 2016.

"The new KN32/KN35 standards have added new requirements regarding radiated immunity, conducted immunity and surge I/O (for outdoor cables). Any new audio, IT, and multimedia products bound for the Korean market will need to meet the new standards," stated the company.

Products certified to the old standards will still be market eligible through 2017, according to the company.

TÜV Rheinland is a global leader in testing, inspection and certification.

## C63 COMMITTEE STANDARDS INCORPORATED BY FCC

***01/11/2016***

IEEE, the world's largest professional organization dedicated to advancing technology for humanity, today announced that two Accredited Standards Committee on Electromagnetic Compatibility (ASC-C63®) standards have been 'incorporated by reference' into the updated U.S. Federal Communications Commission (FCC) rules by which telecommunications certification bodies (TCBs) authorize radio-frequency (RF) equipment. The FCC's reference of the two ASC C63® standards impacts the work of wireless-device manufacturers, test laboratories, and trade associations globally.

The two ASC C63® standards referenced in FCC 14-208, 'Authorization of Radiofrequency Equipment', propose procedures for testing the compliance of a wide variety of wireless transmitters. ANSI C63.4-2014, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz, defines measurement procedures for unintentional radiators such as computers and various digital electronic devices. ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices, covers intentional radiators such as remote controls, cordless phones, hands-free microphones, some medical devices, security devices, and other unlicensed wireless devices.

'The rules we are adopting will facilitate the continued rapid introduction of new and innovative products to the market while ensuring that these products do not cause harmful interference to each other or to other communications devices and services,' as taken from FCC 14-208, which became effective July 13, 2015. Its rules in July 2016 will become mandatory for RF devices used in the United States.

## MIL-STD-461G - REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF SUBSYSTEMS AND EQUIPMENT

***01/11/2016***

The most recent version of MIL-STD-461 has been released as the "G" revision December 11, 2015. There are a number of changes from the "F" revision.

This standard establishes interface and associated verification requirements for the control of the electromagnetic interference (EMI) emission and susceptibility characteristics of electronic, electrical, and electromechanical equipment and subsystems designed or procured for use by activities and agencies of the Department of Defense (DoD). Such equipment and subsystems may be used independently or as an integral part of other subsystems or systems. This standard is best suited for items that have the following features: electronic enclosures that are no larger than an equipment rack, electrical interconnections that are discrete wiring harnesses between enclosures, and electrical power input derived from prime power sources. This standard should not be directly applied to items such as modules located inside electronic enclosures or entire platforms. The principles in this standard may be useful as a basis for developing suitable requirements for those applications. Data item requirements are also included.

## P802.22.3 - STANDARD FOR SPECTRUM CHARACTERIZATION AND OCCUPANCY SENSING

***01/06/2016***

The IEEE has initiated a new standards working group, P802.22.3, whose purpose is to specify the operating characteristics of the components of a system to characterize and sense the occupancy of the radio spectrum.

The purpose is to specify operating characteristics of the components of the Spectrum Characterization and Occupancy Sensing System. This Standard defines a Spectrum Characterization and Occupancy Sensing (SCOS) System. It specifies measurement parameters and device behaviors. It includes protocols for reporting measurement information – protocols that enable coalescing the results from multiple such devices. The standard leverages interfaces and primitives that are derived from IEEE Std. 802.22-2011, and uses any on-line transport mechanism available to achieve the control and management of the system. Interfaces and primitives are provided for conveying value added sensing information to various spectrum sharing database services. This standard specifies a device operating in the bands below 1 GHz and a second device operating from 2.7 GHz to 3.7 GHz.

## IEC 62132-1:2015 - INTEGRATED CIRCUITS – MEASUREMENT OF ELECTROMAGNETIC IMMUNITY – PART 1: GENERAL CONDITIONS AND DEFINITIONS

***11/24/2015***

IEC 62132-1:2015 provides general information and definitions about measurement of electromagnetic immunity of integrated circuits (ICs) to conducted and radiated disturbances. It also defines general test conditions, test equipment and setup, as well as the test procedures and content of the test reports for all parts of the IEC 62132 series.

## IEC 61000-4-24:2015 - ELECTROMAGNETIC COMPATIBILITY (EMC) - PART 4-24: TESTING AND MEASUREMENT TECHNIQUES - TEST METHODS FOR PROTECTIVE DEVICES FOR HEMP CONDUCTED DISTURBANCE

***11/24/2015***

IEC 61000-4-24:2015 deals with methods for testing protective devices for HEMP conducted disturbance. It includes two-terminal elements, such as gas discharge tubes, varistors, and two-port SPDs, such as HEMP combination filters. It covers testing of voltage breakdown and voltage-limiting characteristics but also methods to measure the residual voltage and/or the residual current, peak rate of rise and root action for the case of very fast changes of voltage and current as a function of time.

## IEC 60424-3:2015 - FERRITE CORES – GUIDELINES ON THE LIMITS OF SURFACE IRREGULARITIES – PART 3: ETD-CORES, EER-CORES, EC-CORES AND E-CORES

***11/04/2015***

IEC 60424-3:2015 gives guidelines on allowable limits of surface irregularities applicable to ETD-cores, EER-cores, EC-cores and E-cores in accordance with the relevant general specification. This standard is a specification useful in the negotiations between ferrite core manufacturers and customers about surface irregularities.

## IEC 60364-4-44:2007+AMD1:2015 CSV - LOW-VOLTAGE ELECTRICAL INSTALLATIONS – PART 4-44: PROTECTION FOR SAFETY – PROTECTION AGAINST VOLTAGE DISTURBANCES AND ELECTROMAGNETIC DISTURBANCES

***10/20/2015***

IEC 60364-4-44:2007+A1:2015 are intended to provide requirements for the safety of electrical installations in the event of voltage disturbances and electromagnetic disturbances generated for different specified reasons. This consolidated version consists of the second edition (2007) and its amendment 1 (2015). Therefore, no need to order amendment in addition to this publication.

## EN 60512-29-100:2015 - CONNECTORS FOR ELECTRONIC EQUIPMENT – TESTS AND MEASUREMENTS – PART 29-100: SIGNAL INTEGRITY TESTS UP TO 500 MHZ ON M12 STYLE CONNECTORS – TESTS 29A TO 29G

***10/12/2015***

IEC 60512-29-100:2015 specifies the test methods for transmission performance for M12-style connectors up to 500 MHz. It is also suitable for testing lower frequency connectors if they meet the requirements of the detail specifications and the standard. The test methods provided are: – insertion loss, test 29a; – return loss, test 29b; – near-end crosstalk (NEXT) test 29c; – far-end crosstalk (FEXT), test 29d; – transverse conversion loss (TCL), test 29f; – transverse conversion transfer loss (TCTL), test 29g. For the transfer impedance (ZT) test, see IEC 60512-26-100, test 26e. For the coupling attenuation see ISO/IEC 11801. All test methods apply for two and four pair connectors.

## CISPR 16-1-1:2015 - SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS – PART 1-1: RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS – MEASURING APPARATUS

***09/29/2015***

CISPR 16-1-1:2015 is available as CISPR 16-1-1:2015 RLV and contains the International Standard and its Redline version, showing all changes of the technical content compared to the previous edition.

CISPR 16-1-1:2015 specifies the characteristics and performance of equipment for the measurement of radio disturbance in the frequency range 9 kHz to 18 GHz. In addition, requirements are provided for specialized equipment for discontinuous disturbance measurements. This fourth edition cancels and replaces the third edition published in 2010, Amendment 1:2010 and Amendment 2:2014. This edition constitutes a technical revision.

## IEC 61000-4-13:2002/AMD2:2015 - AMENDMENT 2 – ELECTROMAGNETIC COMPATIBILITY (EMC) – PART 4-13: TESTING AND MEASUREMENT TECHNIQUES – HARMONICS AND INTERHARMONICS INCLUDING MAINS SIGNALLING AT A.C. POWER PORT, LOW FREQUENCY IMMUNITY TESTS

***09/11/2015***

IEC 61000-4-13:2002+A1:2009+A2:2015 define the immunity test methods and range of recommended basic test levels for electrical and electronic equipment with rated current up to 16 A per phase at disturbance frequencies up to and including 2 kHz (for 50 Hz mains) and 2,4 kHz (for 60 Hz mains) for harmonics and interharmonics on low voltage power networks. The standards establish a common reference for evaluating the functional immunity of electrical and electronic equipment when subjected to harmonics and inter-harmonics and mains signaling frequencies. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon. This consolidated version consists of the first edition (2002), its amendment 1 (2009) and its amendment 2 (2015). Therefore, no need to order amendments in addition to this publication.

## IEC 60533:2015 RLV - ELECTRICAL AND ELECTRONIC INSTALLATIONS IN SHIPS – ELECTROMAGNETIC COMPATIBILITY (EMC) – SHIPS WITH A METALLIC HULL

***09/08/2015***

IEC 60533:2015 RLV contains the International Standard and its Redline version. The Redline version is available in English only. The Redline version provides a quick and easy way to compare all the changes between this standard and its previous edition. The Redline version is not an official IEC Standard; only the current version of the standard is to be considered the official document.

IEC 60533:2015(E) specifies minimum requirements for emission, immunity and performance criteria regarding electromagnetic compatibility (EMC) of electrical and electronic equipment for ships with metallic hull. This International Standard assists in meeting the relevant EMC requirements as stated in SOLAS 74, Chapter IV, Regulation 6 and Chapter V, Regulation 17. Reference to this International Standard is made in IMO Resolution A.813(19).

This edition includes the following significant technical changes with respect to the previous edition:

- Introduction has been supplemented;
- Scope and title have been modified to limit the application of the standard to installations in ships with metallic hulls only;
- The normative references have been updated;
- Further explanation for in-situ testing has been given in 5.1;
- Numbering of CISPR-Standards in Tables 1, 2 and 3 has been updated;
- Title of Annex B has been changed;
- Requirements on cable routing in Annex B have been amended;
- New Annex C EMC test report has been added.

## IEC TR 61000-4-38:2015 - ELECTROMAGNETIC COMPATIBILITY (EMC) – PART 4-38: TESTING AND MEASUREMENT TECHNIQUES – TEST, VERIFICATION AND CALIBRATION PROTOCOL FOR VOLTAGE FLUCTUATION AND FLICKER COMPLIANCE TEST SYSTEMS

***09/01/2015***

IEC TR 61000-4-38:2015(E) defines a test protocol for flicker test systems designed to perform compliance tests in accordance with IEC 61000-3-3 and IEC 61000-3-11. It is intended to provide test system manufacturers and testing laboratories with systematic methods to determine if the flicker test system meets the IEC design specifications for a wide range of voltage fluctuations and fluctuation frequencies, as specified in IEC 61000-4-15:2010, Table 5, that have been observed in product testing. It has the status of a basic EMC publication in accordance with IEC Guide 107.

## IEC 60384-20:2015 - FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT – PART 20: SECTIONAL SPECIFICATION – FIXED METALIZED POLYPHENYLENE SULFIDE FILM DIELECTRIC SURFACE MOUNT D.C. CAPACITORS

***08/10/2015***

IEC 60384-20:2015 applies to fixed surface mount capacitors for direct current, with metalized electrodes and polyphenylene sulfide dielectric for use in electronic equipment. These capacitors have metalized connecting pads or soldering strips and are intended to be mounted directly onto substrates for hybrid circuits or onto printed boards. They may have “self healing properties” depending on conditions of use and are primarily intended for applications where the a.c. component is small with respect to the rated voltage.

This edition includes the following significant technical changes with respect to the previous edition:

a) Revision of the structure in accordance with ISO/IEC Directives, Part 2:2011 (sixth edition) to the extent practicable, and harmonization between other similar kinds of documents.
b) In addition, Clause 4 and all the tables have been reviewed in order to prevent duplications and contradictions.

## IEC 61000-4-24:2015 - ELECTROMAGNETIC COMPATIBILITY (EMC) – PART 4-24: TESTING AND MEASUREMENT TECHNIQUES – TEST METHODS FOR PROTECTIVE DEVICES FOR HEMP CONDUCTED DISTURBANCE

***08/05/2015***

IEC 61000-4-24:2015 deals with methods for testing protective devices for HEMP conducted disturbance. It includes two-terminal elements, such as gas discharge tubes, varistors, and two-port SPDs, such as HEMP combination filters. It covers testing of voltage breakdown and voltage-limiting characteristics but also covers methods to measure the residual voltage and/or the residual current, peak rate of rise and root action for the case of very fast changes of voltage and current as a function of time. It has the status of a basic EMC publication in accordance with IEC Guide 107. This second edition cancels and replaces the first edition published in 1997. This edition constitutes a technical revision.

## IEC 60384-24:2015 RELEASED - FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT – PART 24: SECTIONAL SPECIFICATION – FIXED TANTALUM ELECTROLYTIC SURFACE MOUNT CAPACITORS WITH CONDUCTIVE POLYMER SOLID ELECTROLYTE

***07/28/2015***

IEC 60384-24:2015 applies to fixed tantalum electrolytic surface mount capacitors with conductive polymer solid electrolyte primarily intended for d.c. applications for use in electronic equipment.

This edition includes the following significant technical changes with respect to the previous edition:

a) Revision of the structure in accordance with ISO/IEC Directives, Part 2:2011 (sixth edition) to the extent practicable, and harmonization between other similar kinds of documents.
b) In addition, Clause 4 and all the tables have been reviewed in order to prevent duplications and contradictions.

## IEC 60143-1:2015 - SERIES CAPACITORS FOR POWER SYSTEMS – PART 1: GENERAL

***07/14/2015***

IEC 60143-1:2015 applies both to capacitor units and capacitor banks intended to be used connected in series with an a.c. transmission or distribution line or circuit forming part of an a.c. power system having a frequency of 15 Hz to 60 Hz. The primary focus of this standard is on transmission application. The series capacitor units and banks are usually intended for high-voltage power systems. This standard is applicable to the complete voltage range. This standard does not apply to capacitors of the self-healing metalized dielectric type.

The following capacitors, even if connected in series with a circuit, are excluded from this standard:

– capacitors for inductive heat-generating plants (IEC 60110-1);
– capacitors for motor applications and the like (IEC 60252 (all parts));
– capacitors to be used in power electronics circuits (IEC 61071);
– capacitors for discharge lamps (IEC 61048 and IEC 61049). For standard types of accessories such as insulators, switches, instrument transformers, external fuses, etc. see the pertinent IEC standard.

The object of this standard is:

– to formulate uniform rules regarding performance, testing and rating;
– to formulate specific safety rules;
– to serve as a guide for installation and operation.

This fifth edition cancels and replaces the fourth edition, published in 2004. This edition constitutes a technical revision. The main change with respect to the previous edition is that the endurance test has been replaced by an aging test because voltage cycling is already performed in the cold duty test. The guide section has been expanded regarding long line correction and altitude correction. In addition, the insulation tables and references to other standards have been updated.

## IEEE 1547.1A-2015 - IEEE STANDARD CONFORMANCE TEST PROCEDURES FOR EQUIPMENT INTERCONNECTING DISTRIBUTED RESOURCES WITH ELECTRIC POWER SYSTEMS – AMENDMENT 1

***07/02/2015***

Interconnection equipment that connects distributed resources (DR) to an electric power system (EPS) must meet the requirements specified in IEEE 1547. Standardized test procedures are necessary to establish and verify compliance with those requirements, so this is IEEE P1547.

1a Amendment 1 establishes test regimens to verify interconnection systems conformance to IEEE 1547 Amendment 1 for voltage regulation, and response to area EPS abnormal conditions of voltage and frequency. It may also consider other testing changes that may be necessary in response to updates under the 1547 Amendment 1.

## IEC 61338-1-5:2015 - WAVEGUIDE TYPE DIELECTRIC RESONATORS – PART 1-5: GENERAL INFORMATION AND TEST CONDITIONS – MEASUREMENT METHOD OF CONDUCTIVITY AT INTERFACE BETWEEN CONDUCTOR LAYER AND DIELECTRIC SUBSTRATE AT MICROWAVE FREQUENCY

***06/29/2015***

IEC 61338-1-5:2015 describes a measurement method for resistance and effective conductivity at the interface between conductor layer and dielectric substrate, which are called interface resistance and interface conductivity.

This first edition cancels and replaces IEC PAS 61338-1-5 published in 2010. This edition includes the following significant technical changes with respect to the previous edition:

1. Description of technical content related to patents (Japanese patent numbers JP3634966, JP3735501) in the Introduction;
2. Changes to normative references;
3. Addition to bibliography.

## IEC 60143-3:2015 - SERIES CAPACITORS FOR POWER SYSTEMS – PART 3: INTERNAL FUSES

***06/25/2015***

IEC 60143-3:2015 applies to internal fuses designed to isolate faulty capacitor elements, to allow operation of the remaining parts of that capacitor unit, and the bank in which the capacitor unit is connected. Such fuses are not a substitute for a switching device such as a circuit-breaker, or for external protection of the capacitor bank, or any part thereof.

The object of this part of IEC 60143 is:

– to formulate requirements regarding performance and testing;
– to provide a guide for coordination of fuse and bank protection.

This second edition cancels and replaces the first edition published in 1998. This edition constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition: The test procedure has been largely simplified.

## CISPR 11:2015 - INDUSTRIAL, SCIENTIFIC AND MEDICAL EQUIPMENT – RADIO-FREQUENCY DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT

***06/16/2015***

CISPR 11:2015 is available as CISPR 11:2015 RLV and contains the International Standard and its Redline version, showing all changes of the technical content compared to the previous edition.

CISPR 11:2015 applies to industrial, scientific and medical electrical equipment operating in the frequency range 0 Hz to 400 GHz and to domestic and similar appliances designed to generate and/or use locally radio-frequency energy. This standard covers emission requirements related to radio-frequency (RF) disturbances in the frequency range of 9 kHz to 400 GHz. Measurements need only be performed in frequency ranges where limits are specified in Clause 6.

For ISM RF applications in the meaning of the definition found in the ITU Radio Regulations (see Definition 3.13), this standard covers emission requirements related to radio-frequency disturbances in the frequency range of 9 kHz to 18 GHz. Requirements for ISM RF lighting equipment and UV irradiators operating at frequencies within the ISM frequency bands defined by the ITU Radio Regulations are contained in this standard. Equipment covered by other CISPR product and product family emission standards are excluded from the scope of this standard.

This sixth edition cancels and replaces the fifth edition published in 2009 and its Amendment 1 published in 2010. It constitutes a technical revision. It introduces and permits type testing on components of power electronic equipment, systems and installations. Its emission limits apply now to low voltage (LV) a.c. and d.c. power ports, irrespective of the direction of power transmission. Several limits were adapted to the practical test conditions found at test sites. They are also applicable now to power electronic ISM RF equipment used for wireless power transfer (WPT), for instant power supply and charging purposes. The limits in the range 1 GHz to 18 GHz apply now to CW-type disturbances and to fluctuating disturbances in a similar, uniform and technology-neutral way.

For these measurements, two alternative methods of measurement are available, the traditional log-AV method and the new APD method. It has the status of a Product Family EMC standard in accordance with IEC Guide 107, Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications (2014).

## IEC 60384-23:2015 - FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT – PART 23: SECTIONAL SPECIFICATION – FIXED METALIZED POLYETHYLENE NAPHTHALATE FILM DIELECTRIC SURFACE MOUNT D.C. CAPACITORS

***05/27/2015***

IEC 60384-23:2015 is applicable to fixed surface mount capacitors for direct current, with metalized electrodes and polyethylene naphthalate dielectric for use in electronic equipment. These capacitors have metalized connecting pads or soldering strips and are intended to be mounted directly onto substrates for hybrid circuits or onto printed boards. These capacitors may have "self healing properties" depending on conditions of use. They are primarily intended for applications where the a.c. component is small with respect to the rated voltage.

This edition includes the following significant technical changes with respect to the previous edition:

a) Revised all parts of the document based on the ISO/IEC Directives, Part 2:2011 (sixth edition) and harmonization between other similar kinds of documents.
b) Revised tables and Clause 4 so as to prevent duplications and contradictions.

## IEC 62153-4-4:2015 - METALLIC COMMUNICATION CABLE TEST METHODS – PART 4-4: ELECTROMAGNETIC COMPATIBILITY (EMC) – TEST METHOD FOR MEASURING OF THE SCREENING ATTENUATION AS UP TO AND ABOVE 3 GHZ, TRIAXIAL METHOD

***05/04/2015***

IEC 62153-4-4:2015(E) describes a test method to determine the screening attenuation as of metallic communication cable screens. Because of the concentric outer tube, measurements are independent of irregularities on the circumference and outer electromagnetic field. A wide dynamic frequency range can be applied to test even super-screened cables with normal instrumentation from low frequencies up to the limit of defined transversal waves in the outer circuit at approximately 4 GHz. This second edition cancels and replaces the first edition, published in 2006 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– Impedance matching adapters are no longer required when measuring devices have a characteristic impedance different from the characteristic impedance of the test equipment;
– The reflection loss due to a mismatch is taken into account by a (calculated) correction factor.

## CISPR 24 ED2.1 CONSOL. WITH AM1 - INFORMATION TECHNOLOGY EQUIPMENT – IMMUNITY CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT

***04/22/2015***

CISPR 24:2010+A1:2015 applies to information technology equipment (ITE) as defined in CISPR 22. The object of this publication is to establish requirements that will provide an adequate level of intrinsic immunity so that the equipment will operate as intended in its environment. The publication defines the immunity test requirements for equipment within its scope in relation to continuous and transient conducted and radiated disturbances, including electrostatic discharges (ESD). The publication also defines procedures for the measurement of ITE and specifies limits developed for ITE within the frequency range from 0 Hz to 400 GHz. For exceptional environmental conditions, special mitigation measures may be required. Owing to testing and performance assessment considerations, some tests are specified in defined frequency bands or at selected frequencies. Equipment that fulfills the requirements at these frequencies is deemed to fulfill the requirements in the entire frequency range from 0 Hz to 400 GHz for electromagnetic phenomena. The test requirements are specified for each port considered. This second edition cancels and replaces the first edition published in 1997, and its Amendments 1(2001) and 2(2002). It is a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– dated references updated;
– option of using a 4 % step size for continuous conducted immunity test deleted;
– revision of Annex A for telephony equipment including methodology for measuring the demodulation from a speaker/hands free device;
– inclusion of new annex related to DSL equipment. The contents of the corrigendum of June 2011 have been included in this copy.

This consolidated version consists of the second edition (2010) and its amendment 1 (2015). Therefore, no need to order amendment in addition to this publication.

## CISPR 15 ED8.1 CONSOL. WITH AM1 - LIMITS AND METHODS OF MEASUREMENT OF RADIO DISTURBANCE CHARACTERISTICS OF ELECTRICAL LIGHTING AND SIMILAR EQUIPMENT

***04/15/2015***

CISPR 15:2013+A1:2015 apply to the emission (radiated and conducted) of radiofrequency disturbances from:

– all lighting equipment with a primary function of generating and/or distributing light intended for illumination purposes, and intended either for connection to the low voltage electricity supply or for battery operation;
– the lighting part of multi-function equipment where one of the primary functions of this is illumination;
– independent auxiliaries exclusively for use with lighting equipment;
– UV and IR radiation equipment;
– neon advertising signs;
– street/flood lighting intended for outdoor use;
– and transport lighting (installed in buses and trains). Excluded from the scope of this standard are:
– lighting equipment operating in the ISM frequency bands (as defined in Resolution 63 (1979) of the ITU Radio Regulation);
– lighting equipment for aircraft and airports;
– and apparatus for which the electromagnetic compatibility requirements in the radio-frequency range are explicitly formulated in other CISPR standards. The frequency range covered is 9 kHz to 400 GHz. This eighth edition cancels and replaces the seventh edition published in 2005, its Amendment 1 (2006) and Amendment 2 (2008). It is a technical revision. This edition includes the following significant technical changes with respect to the previous edition:
– inclusion of LED light sources and luminaires, clarification of test supply voltage and frequency, and improvements to clause 5 relating to the application of limits to the various types of lighting equipment covered under the scope of CISPR 15;
– introduction of requirements for flashing type emergency lighting luminaires utilizing xenon lamps;
– introduction of requirements for neon and other advertising signs;
– and clarification of the requirement for radiated disturbances between 30 MHz and 300 MHz in case the operating frequency of the light source is below 100 Hz. The contents of the interpretation sheet 1 and 2 of June 2013 have been included in this copy.

**WANT TO KNOW MORE?**

For more information on EMC standards and regulations, visit:

**http://www.interferencetechnology.com/category/standards/**

# Professional Societies

## IEEE ELECTROMAGNETIC COMPATIBILITY SOCIETY (S-27)

**IEEE Operations Center**
**445 Hoes Lane, P.O. Box 6804**
**Piscataway, NJ 08855-1331**
**Phone: 732-981-0060**
**Website: www.emcs.org**

The Institute of Electrical & Electronics Engineers (IEEE), the world's largest professional engineering society, is a global organization of individuals dedicated to improving the understanding of electrical and electronics engineering and its applications to the needs of society. The parent organization has over 360,000 members, approximately 70 percent of whom belong to technical groups such as the EMC Society.

The EMC Society, which enjoys a membership of over 5000, functions through a Board of Directors elected by the Society membership. The Board includes 20 members-at-large who serve staggered 3-year terms. The Executive Board consists of the President, President-Elect, Immediate Past President, Secretary, Treasurer, and five Vice Presidents, who oversee the activities of standing and technical committees. The officers are elected by the Board of Directors. The annual IEEE International Symposium on Electromagnetic Compatibility is sponsored by the Board of Directors, which also coordinates activities of standing technical and ad hoc committees.

EMC Society publications include Transactions on EMC, a quarterly journal which features state-of-the-art papers on interference technology and EMC, and the EMC Society Newsletter, a quarterly newsletter of society activities, industry developments, practical papers, and notices of meetings, regulations, and new publications.

The EMC Society also has a group of distinguished lecturers who are available to present talks to IEEE and other organizations. The society subsidizes the lecturers' expenses, and organizations are encouraged to contact the society for further details.

The IEEE Symposium on Electromagnetic Compatibility - US was held March 15-20, 2015 in Silicon Valley, Calif., USA. The IEEE Symposium on Electromagnetic Compatibility - Germany will be held in Dresden, Germany August 16-22, 2015. Visit the Symposium website at www.emc2015.org.

The EMC Society has published a number of standards. For information on EMC Society and other IEEE standards, contact the IEEE Operations Center.

## IEEE PRODUCT SAFETY ENGINEERING SOCIETY

While product safety had been addressed in various committees over the years, there was never a professional society or symposium solely devoted to product safety engineering as a discipline until recently. The IEEE Product Safety Engineering Society (PSES) began operation on 1 January 2004.

The field of interest of the Society is the theory, design, development and implementation of product safety engineering for electronic and electro-mechanical equipment and devices. This includes the theoretical study and practical application of analysis techniques, testing methodologies, conformity assessments, and hazard evaluations.

The society's mission is to strive for the advancement of the theory and practice of applied electrical and electronic engineering as applied to product safety and of the allied arts and sciences.

The society provides a focus for cooperative activities, both internal and external to IEEE, including the promotion and coordination of product safety engineering activities among IEEE entities. In addition, the Society will provide a forum for product safety engineering professionals and design engineers to discuss and disseminate technical information, to enhance personal product safety engineering skills, and to provide product safety engineering outreach to engineers, students and others with an interest in the field. The Society is accepting members at any time during the calendar year, both full IEEE members and affiliate members. Membership is available at www.ieee.org/services/join/.

The IEEE Product Safety Engineering Society works closely with various IEEE Societies and Councils that also include product safety engineering as a technical specialty.

Every year, the PSES hosts a Symposium on Product Compliance Engineering. The next conference will be in Chicago, Illinois, USA on May 18-20, 2015. The Symposium will consist of Technical Sessions, Workshops, Tutorials and Demonstrations specifically targeted to the compliance engineering professional. Attendees will have the opportunity to discuss problems with vendors displaying the latest regulatory compliance products and services. For more information, visit www.psessymposium.org. Past papers from the Symposia are available in IEEE Xplore or on CD (for a fee).

In addition to hosting an annual conference, the PSES provides the opportunity for product safety engineers to publish technical papers in a newsletter. See http://www.ieee-pses.org/newsletters.html.

**For further information visit www.ieee-pses.org.**

## dB SOCIETY

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This unique, interesting, and exclusive fraternity of EMC engineers was founded in 1975 by 10 eminent EMC engineers. The purpose of the dB Society is to open doors within the EMC community. Its primary objectives are to greet and to welcome new engineers, suppliers, vendors, and manufacturers to the EMC community and to assist them in establishing contacts in the EMC field.

The following membership requirements are unique and rigidly enforced:

- Ten years of service to the EMC community,
- Five years of service to a recognized professional, EMC organization,
- Sponsorship by two Duo-Decade members,
- Favorable recommendations by three other recognized individuals in the EMC community, and
- Acceptance by the Admissions Board.

Business meetings and informal, relaxed get-togethers take place during major EMC functions. A formal evening social function is the highlight of each year and is usually conducted during the IEEE EMC Symposium. All meetings are for members only.

U.S. membership is limited to 100 EMC engineers. There are society affiliates in the United Kingdom, India, and Israel.

## ESD ASSOCIATION

**ESD Association**
**7900 Turin Road, Building 3**
**Rome, NY 13440-2069**
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**Email: info@esda.org**
**Website: www.esda.org**

Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the association has broadened its horizons to include areas such as textiles, plastics, web processing, cleanrooms, and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness through standards development, educational programs, local chapters, publications, tutorials, certification, and symposia.

### ELECTROSTATIC DISCHARGE (ESD) TECHNOLOGY ROADMAP

In the late 1970s, electrostatic discharge, or ESD, became a problem in the electronics industry. Low-level ESD events from people were causing device failures and yield losses. As the industry learned about this phenomenon, both device design improvements and process changes were made to make the devices more robust and processes more capable of handling these devices. With devices becoming more sensitive through the year 2010, it is imperative that companies begin to determine the ESD capabilities of their handling processes. The ESD Technology Roadmap can be downloaded at: **www.esda.org**

### ANSI/ESD S20.20 CONTROL PROGRAM STANDARD AND CERTIFICATION

A primary direction for the association is the continued implementation of a facility certification program in conjunction with ISO registrars. With the association's ESD control program standard, ANSI/ESD S20.20: Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), the Association offers a means of independently assessing a company's ESD control program and of issuing a formal ANSI/ESD S20.20 certification.

The ANSI/ESD S20.20 standard covers the requirements necessary to design, establish, implement, and maintain an ESD control program to protect electrical or electronic parts, assemblies and equipment susceptible to ESD damage from Human Body Model (HBM) discharges greater than or equal to 100 volts. Developed in response to the Military Standardization Reform Act, ANSI/ESD S20.20 has been formally adopted for use by the U.S. Department of Defense.

### SYMPOSIA, TUTORIALS, AND PUBLICATIONS

As part of its commitment to education and technology, the association holds the annual EOS/ESD Symposium, which places major emphasis on providing the knowledge and tools needed to meet the challenges of ESD. Scheduled for June 30-July 3, 2015, at the Conference Center, COEX in Seoul, KOREA, the annual Symposium attracts attendees and contributors from around the world. Technical sessions, workshops, authors' corners, seminars, tutorials, and technical exhibits provide a myriad of opportunities for attendees to expand their knowledge of ESD.

In addition to tutorials and seminars, the association offers a number of publications and reference materials for sale. These range from proceedings of past EOS/ESD Symposia to textbooks written by experts in the field of ESD.

## TECHAMERICA ELECTROMAGNETIC COMPATIBILITY COMMITTEE

**1401 Wilson Blvd., Suite 1100**
**Arlington, VA 22209**
**Phone: 703-284-5344**
**Website: www.geia.org**

TechAmerica is the association that was created by the merger of AeA and ITAA. Earlier in 2008, ITAA and GEIA merged. The result of these mergers is an organization that is the leading voice for the U.S. technology industry, which is the driving force behind productivity growth and jobs creation in the United States. TechAmerica is the technology industry's only grassroots-to-global advocacy network. With nearly 1200 member companies, 20 regional councils and offices in Beijing and Brussels, the association represents the full spectrum of the technology industry.

TechAmerica is the technology industry's only grassroots-to-global advocacy network. The organization has expanded initiatives in areas such as information Assurance / Information Security, Identity Management, Cloud Computing, Global Sourcing / Globalization, Intelligence agencies, Department of Defense & NASA, and State & Local programs and public policy advocacy.

TechAmerica provides programs for business development, networking and market intelligence in the Federal arena, dealing with government entities such as Department of Defense, Homeland Security, Federal Communications Commission, Federal Trade Commission, Congress, as well as with state and local governments.

TechAmerica has a team of public policy professionals at state, federal and international levels that allow the organization to successfully influence legislative and regulatory issues that affect member companies.

In addition, TechAmerica offers an active standards development program to provide industry with proven solutions to business process challenges. The program is nationally and internationally recognized for its leadership and expertise in the development of standards. Configuration Management, Systems Engineering, Systems Safety, Earned Value Management, Logistics, Reliability and Electromagnetic Compatibility (EMC) area where TechAmerica is involved in standard.

The Electromagnetic Compatibility (EMC) Committee (formally known as G-46) deals with the system-oriented discipline that ensures electromagnetic compatibility in electronics design. The Committee develops technical criteria and procedures to guide the design engineer. Its work also includes spectrum management and conservation; secure communications; and electromagnetic emissions, susceptibility, control, and characterization.

The EMC Committee was established to provide an industry/user position on government specifications, regulations, and standards. Participation has expanded to include G-46 representation on the various committees drafting government specifications and standards. For example, G-46 participated on the working committees for MIL-STD-464A and MIL-STD-461E and provided update recommendations to MIL-STD-461F. The scope of G-46 activities has expanded to foster and facilitate the EMC discipline for the benefit of TechAmerica member companies.

Additional information on TechAmerica and the EMC Committee (G-46) can be obtained at (703) 284-5315, phyllis.call@techamerica.org, or via the GEIA website at http://www.geia.org.

## SOCIETY OF AUTOMOTIVE ENGINEERS

**400 Commonwealth Drive**
**Warrendale, PA 15096-0001**
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SAE International is a professional society of engineers dedicated to a broad spectrum of engineering disciplines within the aerospace and automotive fields. Under the SAE Aerospace Council, technical standards committees address disciplines ranging from electrical power to multiplex signal characteristics — and from fiber optic data transmission to electromagnetic compatibility. The many elements of EMC are handled by SAE Committee AE-4, Electromagnetic Compatibility, which was organized in 1942 under the Aerospace Council. The committee is composed of technically qualified members, liaison members, and consultants —all of whom are responsible for writing standards on electromagnetic compatibility.

Committee AE-4 provides assistance to the technical community through standardization, improved design and testing methodology, and technical forums for the resolution of mutual problems. Engineering standards, specifications, and technical reports are developed by the Committee and are issued by the Society for industry and governments worldwide. Objectives of Committee AE-4 are to advance the state of technology, to stabilize existing technology, to obtain a uniformity of EMC requirements among government agencies, and to further the interests of the EMC technical community. The theme of "design before the fact" for EMC is a guiding concept. Special attention is given to maintenance of EMI control requirements consistent with the rapidly advancing state-of-the-art.

The following is a partial list of documents that have been issued to assist in implementing SAE objectives. For a complete list, visit the SAE website at www.sae.org or call SAE Customer Service at 724-776-4841.

### AEROSPACE RECOMMENDED PRACTICES (ARPS)

| | | |
|---|---|---|
| ARP | 935A | Control Plan/Technical Construction File |
| ARP | 936A | Capacitor, 10 mF for EMI Measurements |
| ARP | 958C | Electromagnetic Interference Measurement Antennas, Standard Calibration Method |
| ARP | 958D | Electromagnetic Interference Measurement Antennas, Standard Calibration Method |
| ARP | 1172 | Filters, Conventional, EMI Reduction, Specifications |



SOCIETIES

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| **ARP** | **1173** | Test Methods for EMI Gasketing |
| **ARP** | **1267** | EMI Measurement of Impulse Generators, Standard Calibration Requirements and Techniques |
| **ARP** | **1481A** | Corrosion Control and Electrical Conductivity in Enclosure Design |
| **ARP** | **1705** | Coaxial Test Procedure to Measure the RF Shielding Characteristics of EMC Gasket Materials |
| **ARP** | **1870** | Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety |
| **ARP** | **1972** | Recommended Practices and Procedures for EMC Testing |
| **ARP** | **4043A** | Flightline Bonding and Grounding of Aircraft |
| **ARP** | **4242** | Electromagnetic Compatibility Control Requirements, Systems |
| **ARP** | **4244** | Recommended Insertion Loss Test Methods for EMI Power Line Filters |
| **ARP** | **5416A** | Aircraft Lightning Test Methods |

**AEROSPACE INFORMATION REPORTS (AIRS)**

| | | |
|---|---|---|
| **AIR** | **1147** | EMI on Aircraft from Jet Engine Charging |
| **AIR** | **1209** | Construction and Calibration of Parallel-Plate Transmission Lines for EMI Susceptibility Testing |
| **AIR** | **1221** | EMC System Design Checklist |
| **AIR** | **1255** | Spectrum Analyzers for EMI Measurements |
| **AIR** | **1394A** | Cabling Guidelines for Electromagnetic Compatibility |
| **AIR** | **1404** | DC Resistivity vs. RF Impedance of EMI Gaskets |
| **AIR** | **1423** | EMC on Gas Turbine Engines for Aircraft Propulsion |
| **AIR** | **1425A** | Methods of Achieving EMC of Gas Turbine Engine Accessories, for Self-Propelled Vehicles |
| **AIR** | **1499** | Recommendations for Commercial EMC Susceptibility Requirements |
| **AIR** | **1662** | Minimization of Electrostatic Hazards in Aircraft Fuel Systems |
| **AIR** | **1700A** | Upper Frequency Measurement Boundary for Evaluation of Shielding Effectiveness in Cylindrical Systems |
| **AIR** | **4079** | Procedure for Digitized Method of Spark Energy Measurement |

**SAE AE-4 ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E3 OR EMC) COMMITTEE**

The SAE AE-4 E3 Committee provides a technical, coordinating, and advisory function in the field of E3. The focus is on problem areas in which committee expertise can be effectively applied at the national and international levels. Electrical and electronic accessories are studied for compatibility within systems and with various communications media. Engineering standards, specifications, and technical reports are developed and are issued for the general information of industry and government.

In the past, subcommittees have included AE-4R, Aircraft Radiated Environments, and AE-4H, High Power RF Simulators and Effects. AE-4 E3 holds national meetings in conjunction with the IEEE EMC Society Symposium, usually held in August at various locations. Additional information about meetings or more specific information on the activities of the committee can be obtained by contacting the world headquarters at 1-724-776-4841. Visit the SAE's Technical Standards Committee Forum website at **http://forums@sae.org**.

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iNARTE, Inc. (The International Association for Radio, and Telecommunications and Electromagnetics, Inc.) was founded as a non-profit membership/certification organization in 1982. With the advent of deregulation and the Federal Communications Commission's "encouragement/urging" private industry to establish certification standards to fill the licensing void, iNARTE initiated and developed a comprehensive certification program for telecommunications engineers and technicians.

In 1988, a Command of the United States Navy, seeking a credible and respected certification entity, selected iNARTE as the administrative agent for the certification of engineers and technicians in the field of electromagnetic compatibility (EMC).

## ACIL—THE AMERICAN COUNCIL OF INDEPENDENT LABORATORIES

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The American Council of Independent Laboratories (ACIL) is the trade association representing independent, commercial engineering, and scientific laboratory, testing, consulting, product certifying and R&D firms; manufacturers' laboratories; related non-profit organizations; and consultants and suppliers to the industry. The organization was founded in 1937. All ACIL activities focus on its mission: to enhance members' success by providing advocacy, education, services, and mutual support and by promoting ethics, objectivity, independence, and free enterprise.

ACIL is a voluntary, non-profit membership organization. Programs are determined by members, administered by an elected Board of Directors, and supported by a professional staff operating from headquarters in Washington, D.C.

**ACIL'S CONFORMITY ASSESSMENT SECTION**

ACIL's Conformity Assessment Section consists of firms with wide and varied interests, all performing testing, listing, or labeling in accordance with applicable safety and performance standards, and/or materials testing and resolution of product and structural problems. Several committees have evolved within the Section to meet the needs of its diverse membership, including the EMC Committee, the U.S. Council of EMC Laboratories, and the Third-Party Product Certifiers Committee. In January 2005, the section sponsored a booth at the Consumer Electronics Show that advocated the advantages of independent third-party testing and the capabilities of ACIL member EMC laboratories.

**ACIL'S EMC COMMITTEE**

ACIL's EMC Committee was established in 1996 to address the common concerns of the ACIL EMC community. The Committee sponsors educational sessions at ACIL meetings that include both technical and policy issues such as mutual recognition agreements (MRAs). The Committee updates members on the latest developments, upcoming requirements, and activities in the field—both domestic and international.

In January 2002, ACIL published a 143-page document, Technical Criteria for the Accreditation of Electromagnetic Compatibility (EMC) and Radio Testing Laboratories, a checklist to assist both assessors and laboratories.

The Committee also formed the U.S. Council of EMC Laboratories (USCEL) in an effort to aid U.S. laboratories in addressing technical issues arising from the U.S./EU MRA and other global concerns. As the USCEL Secretariat, ACIL provides staff and supports volunteers active in this important area.

**U.S. PRODUCT CERTIFIERS**

Key U.S. product certifiers are ACIL members and are reaping many benefits, such as participation in the ACIL Third-Party Product Certifiers Committee ($3P^2C^2$). This Committee provides a forum for members to discuss and to act upon various issues of common interest. This committee formed the American Council for Electrical Safety to serve as a forum among testing laboratories, regulators, and electrical inspectors.

interference technology

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The following is a list of the principal government personnel involved in EMC/EMI. Additions, deletions and corrections for any facility may be updated at any time by e-mailing your changes to geoff@item.media.

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Director: Mr. D. Mark Johnson ................703-601-1414

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### U.S. Environmental Protection Agency (EPA)

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Fax: 202-343-3204
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