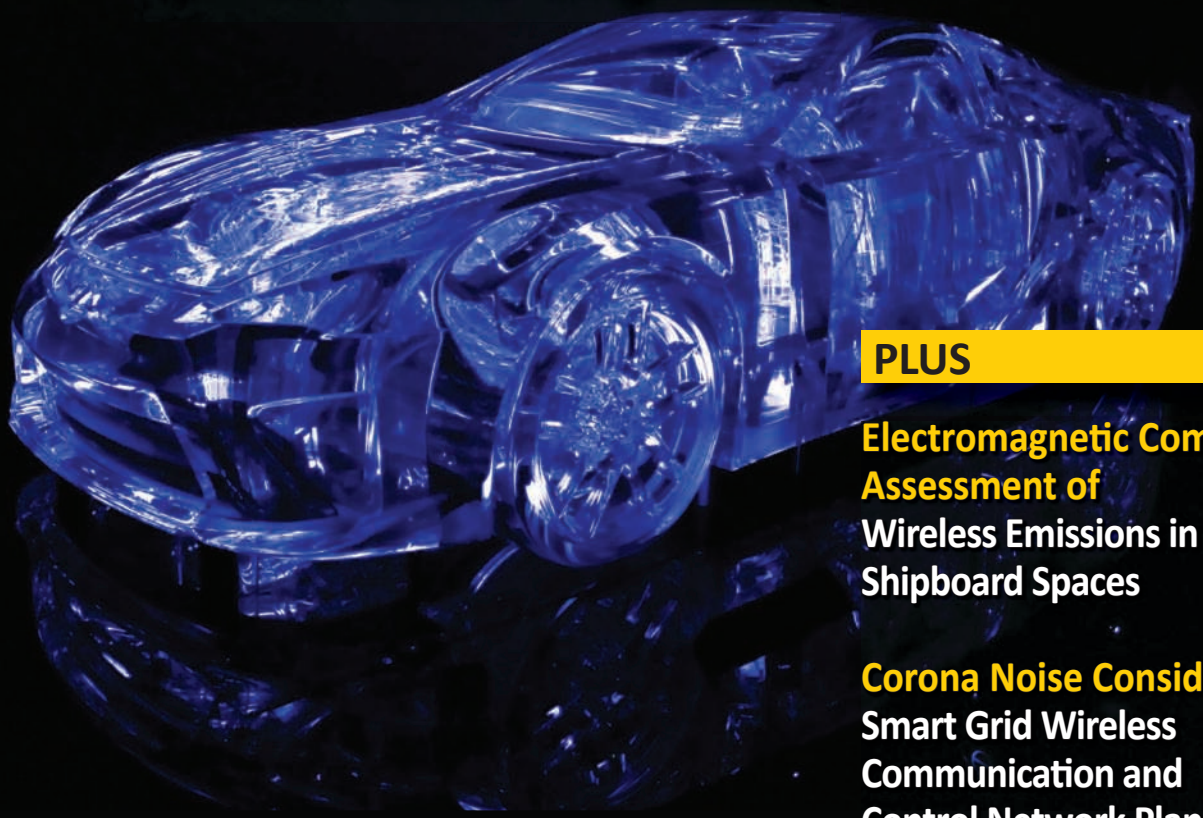
JUNE 2013

IN COMPLIANCE™

THE COMPLIANCE INFORMATION RESOURCE FOR ELECTRICAL ENGINEERS

A Primer on Automotive EMC

for Non-EMC Engineers



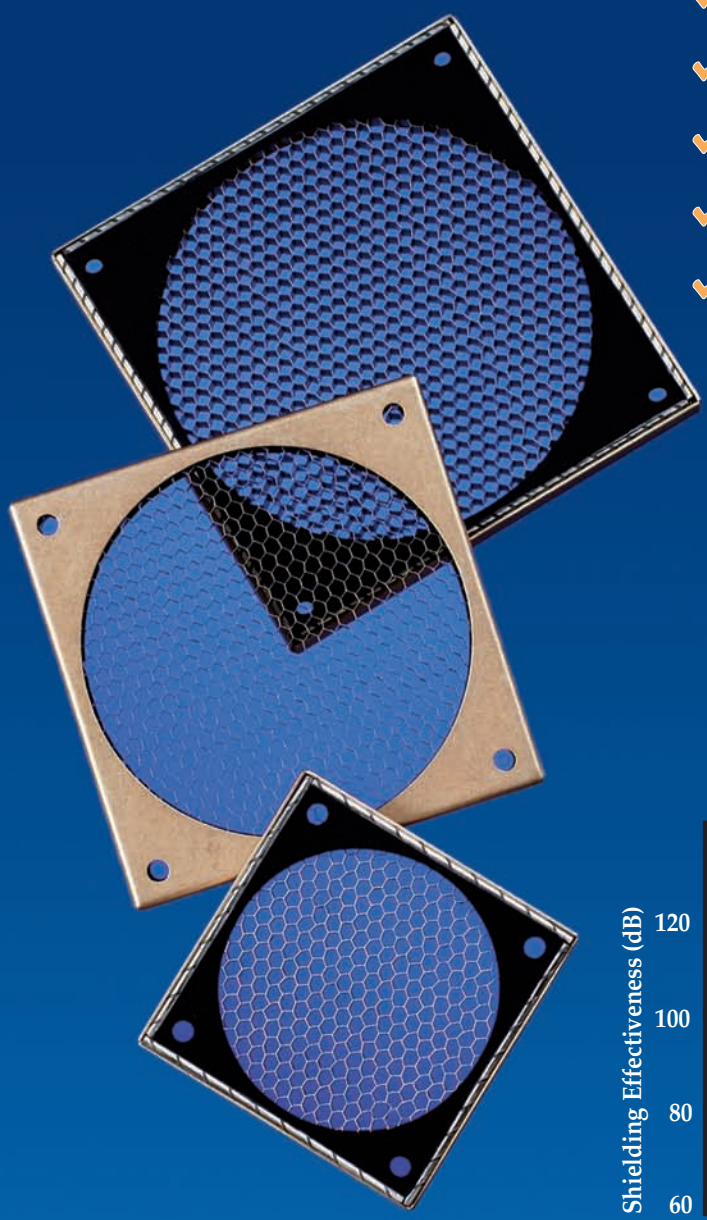
PLUS

Electromagnetic Compatibility Assessment of Wireless Emissions in Shipboard Spaces

Corona Noise Considerations for Smart Grid Wireless Communication and Control Network Planning

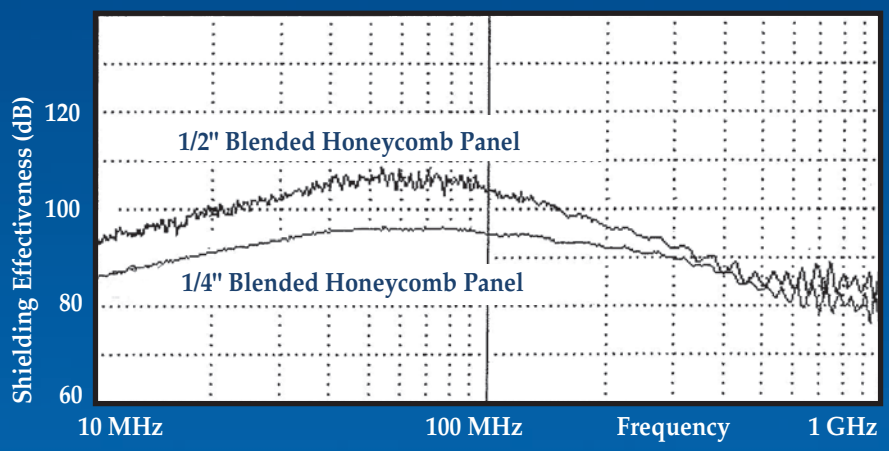
ESD Standards: An Annual Progress Report

Newest Inspiration in Shielded Fan Filters!



- ✔ *New Innovative & Cost-Effective Design!*
- ✔ *Patented Honeycomb "Blending" Process*
- ✔ *Up to 80dB of Shielding at 1GHz*
- ✔ *Includes Spira's Patented EMI Gasket*
- ✔ *Compatible with 40, 60, 80, 92 and 120mm fans or custom sizes*

Spira's Shielded Fan Fllter is the newest addition to our family of exceptional shielded honeycomb filters. The Shielded Fan Filters provide high and reliable levels of shielding at a great price. They include our patented "blending" process of the aluminum panel and patented spiral gasket to provide an exceptional EM bond. The Shielded Fan Filters are compatible with 40, 60, 80, 92 and 120mm fans or can be made in custom sizes with no additional design fees. Available in 1/8" cell by 1/4" or 1/2" thick honeycomb panels.



Typical Shielding Effectiveness Test Data of Spira Honeycomb Fan Filters

All Spira Filters & EMI Gaskets are Available in RoHS Compliant Versions

Contact Us or Visit our Website for Product and Design Information

www.spira-emi.com

sales@spira-emi.com

(818) 764-8222

Spira products are protected under U.S. patents 3,502,784, 5,895, 885 and 5,910,639.

AS9100
ISO9001

Certified System

COMMITMENT. COMMUNITY. COMPLIANCE.

OUT and ABOUT in the COMMUNITY

In Compliance is **COMMITTED** *to the* **COMMUNITY** *of* **COMPLIANCE** *engineering professionals who make up our readership. We actively participate in community events throughout the year.*

As a leader in the compliance community, we turn to you to tell us what you need. These events give us a chance to talk to you face-to-face. We encourage you to stop by and tell us your ideas, feedback and suggestions.

You can turn to us as your #1 source for all your compliance news - in our magazine, at events and online.

INCOMPLIANCE

INCOMPLIANCE

In Compliance Magazine
ISSN 1948-8254 (print)
ISSN 1948-8262 (online)
is published by

Same Page Publishing Inc.
531 King Street, Suite 5
Littleton, MA 01460-1279
tel: (978) 486-4684
fax: (978) 486-4691

editorial staff

editor/publisher Lorie Nichols
lorie.nichols@incompliancemag.com
(978) 873-7777

production director Erin Feeney
erin.feeney@incompliancemag.com
(978) 873-7756

contributing editor Mary Ann Kahl
maryann.kahl@incompliancemag.com

publishing staff

director of sales Sharon Smith
sharon.smith@incompliancemag.com
(978) 873-7722

national sales manager Shellie Johnson
shellie.johnson@incompliancemag.com
(404) 991-8695

marketing communications specialist Heather Stehman
heather.stehman@incompliancemag.com
(978) 873-7710

circulation manager Alexis Harrington
alexis.harrington@incompliancemag.com
(978) 873-7745

subscriptions

In Compliance Magazine subscriptions are free to qualified subscribers in North America.

Subscriptions outside North America are $129 for 12 issues.
The digital edition is free.

Please contact our circulation department at circulation@incompliancemag.com

advertising

For information about advertising contact:
Sharon Smith at 978-873-7722
sharon.smith@incompliancemag.com

CONTENTS

June 2013
Volume 4 • Number 6

A Primer on Automotive EMC for Non-EMC Engineers

The automotive industry has changed drastically in recent years. Advancements in technology paired with tighter federal fuel and emissions regulations have resulted in the need to place more electrical systems into vehicles. This in turn places a greater emphasis on keeping the Electromagnetic Interference (EMI) of these systems from interfering with each other through radiated and conducted emissions, as well as crosstalk between the multitudes of on-board systems.

Gary Fenical

DEPARTMENTS

6 **News in Compliance**

10 **Product Showcase**

12 **The iNARTE Informer**

14 **Mr. Static**
Abatement of Static Electricity
Part I: Conductors

18 **Reality Engineering**
The Scale of Shaky Things

54 **Business News**

58 **Authors**

58 **Advertisers**

FEATURES

28 **Electromagnetic Compatibility Assessment of Wireless Emissions in Shipboard Spaces**
Electromagnetic compatibility of wireless communications and sensor networks with mission critical electronic equipments is assessed for below-deck spaces on ships and submarines.
Gregory Tait and Paul Opperman

36 **Corona Noise Considerations for Smart Grid Wireless Communication and Control Network Planning**
As the wireless receiver sensitivity levels surpass thermal noise levels, reliable operation of smart grid Distributed Generating System (DGS) wireless communication and control devices demands consideration of the power line produced noise spectrum.
Dheena Moongilan

44 **ESD Standards: An Annual Progress Report**
Industry standards play a major role in providing meaningful metrics and common procedures that allow various manufacturers, customers, and suppliers to communicate from facility to facility around the world. Standards are increasingly important in our global economy.
The ESD Association

News in Compliance

FCC News

FCC Proposes Fine for Company Using Cellphone Jammers

The U.S. Federal Communications Commission (FCC) has proposed a fine of nearly $150,000 against an Alabama company that used signal jamming devices to prevent the company's employees from using their cellphones during working hours.

According to a *Notice of Apparent Liability for Forfeiture* issued in April 2013, the company, The Supply Room, Inc. of Oxford Alabama, operated multiple cellular phone jammers in the company's warehouse for than two years. The illegal jammers were discovered as a result of an investigation by the FCC Enforcement Bureau's Atlanta Field Office of strong wideband emissions emanating from the company's warehouse. In a subsequent inspection of the facility, the company's general manager told an FCC agent that the warehouse was outfitted with four separate jammers to prevent employees from using their phones at work. The jammers were identified and removed by the agent from the warehouse.

The use of any device that interferes with authorized radio communications is a violation of Sections 201, 302(b) and 333 of the Communications Act, and sections 2.803(g) and 15.1(c) of the Commission's rules. Further, the use of so-called jamming devices in public places could prevent a user from contacting fire or police personnel in the event of an emergency. Continued violation regarding the use of jamming devices can lead to monetary penalties starting at $16,000 for each violation or for each day of continuing violations, up to $112,500 for any single act. The Commission also has the authority to impose separate monetary penalties for each signal jammer used.

The complete text of the Commission's *Notice* is available at incompliancemag.com/news/1306_01.

FCC Issues Receiver Performance White Paper, Seeks Comments

The Technical Advisory Council (TAC) of the U.S. Federal Communications Commission (FCC) has issued a white paper on how to address the role of signal receivers as part of the overall effort to increase wireless spectrum utilization.

The white paper, "Interference Limits Policy—The use of harm claim thresholds to improve the interference tolerance of wireless systems," argues that receiver technology can be included in spectrum policy efforts by establishing ceilings for interference limits. These "harm claim thresholds" are in-band and out-of-band interfering signal levels that must be exceeded before a radio system can contend that it is experiencing harmful interference. According to the paper, this approach would allow the Commission to offer guidance on optimizing receiver performance without dictating specific technical approaches or remedies.

The FCC's Office of Engineering and Technology has requested comments on the white paper in order to determine the next steps that can be taken to implement the paper's recommendations. Comments are due by June 21, 2013. The complete text of the white paper is available at incompliancemag.com/news/1306_02.

FCC Examines Changes to RF Exposure Limits

As part of its ongoing review of its rules and regulations, the Federal Communications Commission (FCC) has recently launch an important re-evaluation of its requirements regarding the safety of radiofrequency (RF) emissions from radio transmitters, signaling possible future changes in current RF exposure limits.

FCC News

In an extensive communication issued in March 2013, the Commission has initiated three separate actions related to its rules regarding human RF exposure, as follows:

- ***First Report and Order***—In the *First Report and Order*, the Commission clarifies evaluation procedures and references to determine compliance with its RF limits, and reaffirms its use of specific absorption rate (SAR) as the primary metric for assessing compliance with its RF exposure requirements. The *Report and Order* also provides additional information on labeling and other mitigation procedures that can be used to ensure compliance with the Commission's limits.
- ***Further Notice of Proposed Rulemaking***—In the *Further Notice of Proposed Rulemaking*, the Commission proposes to update and revise its criteria for determining those devices that are subject to its RF exposure limits and those that are exempt from evaluation. The *Further Notice* also proposes clarifications regarding the evaluation of portable medical devices, as well as new requirements for signs and barriers at fixed transmitter sites to better address public and occupation-related RF exposure.
- ***Notice of Inquiry***—In the *Notice of Inquiry*, the Commission requests comments on whether its current RF exposure limits and policies, originally established in 1996, should be reassessed. Specifically, it seeks input on the appropriateness of existing standards, possible options for exposure reduction, and potential improvements in the equipment authorization process as it relates to RF exposure.

The complete text of the Commission's March 2013 communication on its human RF exposure requirements is available at incompliancemag.com/news/1306_03.

News in Compliance

European Union News

EU Releases Recent RAPEX Stats on Unsafe Consumer Products

The Commission of the European Union (EU) has released statistics for March 2013 on notices of unsafe consumer products that have been processed through the EU's rapid information system (RAPEX).

According to the Commission's report, 132 notifications of products posing serious risks to consumers were received through the RAPEX system during the month. This is down from the number of notifications received one year ago in March 2012, when the RAPEX system recorded 159 notifications.

Of the notifications received, 53 were related to the product category of clothing, textiles and fashion items (40%), and 30 were related to toys (23%). There were also 10 notifications related to unsafe electrical appliances and equipment, accounting for 8% of the total notifications of products posing serious risks.

Regarding the country of origin identified in connection with products posing serious risks, more than half (74 notifications, or 56%) of all notifications were related to products originating from China, including Hong Kong. Another 21 notifications (16%) related to unsafe products originated in EU Member States. Eleven notifications (8%) failed to identify any country of origin.

To view the complete text of the EU Commission's most recent report on RAPEX statistics, go to incompliancemag.com/news/1306_04.

New List of Standards Issued for EU's Machinery Directive

The Commission of the European Union (EU) has issued an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 2006/42/EC, also known as the Machinery Directive.

The EU's Machinery Directive defines the essential health and safety requirements for a wide range of products, including: machinery and partly completed machinery; lifting accessories; chains, ropes and webbing; interchangeable equipment; removable mechanical transmission devices; and safety components.

The Directive's scope specifically excludes electrical and electronic products covered under Directive 2006/95/EC (the EU's so-called Electrical Safety Directive), including household appliances, audio and video equipment, informational technology equipment and ordinary office machinery.

The extensive list of CEN and Cenelec standards for the Machinery Directive was published in April 2013 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards can be viewed at incompliancemag.com/news/1306_05.

EU Commission Expands REACH Regulations

The Commission of the European Union (EU) has amended its regulations covering the registration, evaluation, authorization and restriction of chemicals (REACH), adding to its list of restricted chemicals a number of substances deemed carcinogenic, mutagenic or toxic for reproduction.

The Regulation, published in the *Official Journal of the European Union* in April 2013, covers an additional seven chemicals, including trichloroethylene, chromium trioxide, sodium dichromate, potassium dichromate, ammonium dichromate, potassium chromate and sodium chromate. The Regulation also adds acids generated from chromium trioxide to the list of restricted substances.

The changes, which reflect recommendations made by the European Chemicals Agency in December 2011, affect the list of chemicals identified in Annex XIV of the REACH Regulation (EC) No 1907/2006. Restrictions against the use of these newly added chemicals begin as early as October 2014.

The Commission of the European Union (EU) has released RAPEX statistics on unsafe consumer products and expanded its REACH regulations. The EU has also updated standards lists for the Machinery Directive and the ATEX Directive.

European Union News

The complete text of the amended REACH regulations is available at incompliancemag.com/news/1306_06.

EU Commission Updates Standards List for ATEX Directive

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the essential requirements of its directive concerning equipment and protective systems intended for use in potentially explosive atmospheres.

The directive, 94/9/EC, which is also known as the ATEX Directive, applies to "machines, apparatus, fixed or mobile devices, control components and instrumentation…and detection or prevention systems which…are intended for the generation, transfer, storage, measurement, control and conversion of energy and/or the processing of material," and "which are capable of causing an explosion through their own potential sources of ignition."

The updated list of standards was published in May 2013 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the ATEX Directive.

The complete list of standards can be viewed at incompliancemag.com/news/1306_07.

News in Compliance

CPSC News

Riser Cable Recalled for Fire Hazard

Home Depot, U.S.A., Inc. of Atlanta, GA has initiated a recall of about 11,300 boxes of 1000 foot lengths of data cable manufactured in China.

In a filing with the U.S. Consumer Product Safety Commission (CPSC), Home Depot reports that the recalled riser cable does not meet fire resistance standards, posing a fire hazard. The company says that it has not received any reports of incidents or injuries related to the riser cable, but has initiated the recall to prevent future incidents.

The recalled riser cable was sold exclusively at Home Depot stores nationwide in January and February 2013 for about $100.

More information about this product recall is available at incompliancemag.com/news/1306_08.

Heated Jacket Liners Linked to Burns Are Recalled

Gerbings, LLC of Stoneville, NC has recalled about 9900 of its 12-volt heated jacket liners manufactured in China.

According to the company, the recalled jacket liners contain a defective wire connector that can cause the jacket liner to overheat, thereby posing a burn hazard to consumers. Gerbings reports that it has received two reports of jacket liners overheating, causing minor burns and resulting in blisters.

The heated jacket liners were sold through Harley-Davidson dealerships, Eagle Leather and other sporting goods, retail stores and motorcycle shops nationwide from April 2011 through December 2012 for between $200 and $240.

Additional information about this recall is available at incompliancemag.com/news/1306_09.

Chandeliers Recalled Due to Shock Hazard

Currey & Company of Chico, CA has announced the recall of about 2100 of chandelier fixtures manufactured in China.

According to Currey & Company, the recalled chandeliers incorporate defective wiring that can conduct electricity to the fixture's metal parts, posing an electric shock hazard to consumers as a result. The company says that it has not received any reports of incidents or injuries related to the recalled chandeliers, but has initiated the recall to prevent future incidents.

The recalled chandeliers include 10 crystal or metal models imported by Currey & Company. The fixtures were sold through home furnishing stores, lighting centers, and interior decorators nationwide, as well as at www.lightingdirect.com and at Amazon.com, from January 2010 through February 2013 for between $500 and $3250.

Further details about this recall are available at incompliancemag.com/news/1306_10.

Recalls have been issued for riser cables, heated jacket liners and chandeliers. Visit the Consumer Product Safety Commission's site, www.cpsc.org, for more information.

Product Spotlight

We've Bent The Rules.

AR's Bent-Element Approach Provides A Size Reduction Of Up To 75%, Along With Great Performance.

Our family of Radiant Arrow bent element antennas – for fields from 26 MHz to 6,000 MHz – up to 75% smaller, lighter, and more compact than standard log periodic antennas. Yet they cover broad frequency ranges, offer up to 6dBi gain, and produce high fields for the toughest applications. The smaller size not only makes them more portable, it minimizes field loss from "room loading."

With these innovative antennas, AR has advanced the science of log periodic antennas. The design is so revolutionary, we had to patent it to protect it.

Our newest Radiant Arrow antenna pushes the boundaries even farther. The ATR26M6G-1 (26 to 6,000 MHz / 5,000 watts input power) goes beyond existing susceptibility requirements, so it's ready for future developments. And the robust design accommodates the high power levels needed to generate significant E-fields.

All the Radiant Arrow antennas are frequency and power-matched to AR amplifiers. And they can be calibrated for emissions testing. No wonder these little antennas are getting such a big reception!

To learn more, visit www.arworld.us/bentRules or call us at 215-723-8181.

ISO 9001:2008
Certified

rf/microwave instrumentation

Other ar divisions: modular rf • receiver systems • ar europe

USA 215-723-8181. For an applications engineer, call 800-933-8181.
In Europe, call ar United Kingdom +44 1908 282766 • ar France +33 147 917530 • ar GmbH +49 69 53054310 • ar Benelux +31 172 423000

www.arworld.us

The iNARTE Informer

BY RABQSA STAFF

INARTE ADVISORY COMMITTEE (INAC) UPDATES

Members of the iNARTE Advisory Committee (iNAC) met on May 9, 2013 to discuss the current state of iNARTE as a product offering of RABQSA International. In attendance were members of the RABQSA Executive team, Peter Holtmann (CEO), Sal Agnello, and Adam Maxwell, and members of the newly formed iNAC, Elya Joffe (iNAC Chair), Kimball Williams, Terry Welsher, Mike Violette, Michael Hayden, and L Behr.

One responsibility of the iNAC is to serve as the Certification Review Committee, reviewing completed iNARTE application files for the various iNARTE certification programs. This review process provides an important step in the certification approval process to ensure that those achieving certification not only meet the knowledge requirements by passing the necessary examination, but also that their education and work experience are appropriate for meeting the certification requirements.

The iNAC also provides valuable input to the RABQSA Executive team regarding the global issues and trends for the various iNARTE certifications and the industries that these programs serve. It was the iNAC that assisted RABQSA in understanding how the newly developed Wireless Device Certification Professional (WDCP) certification program may move

(from left to right) Jay Baron, Sal Agnello, Vipin Sahni, Prakash Sathe (back), Jenny Lewis (front), Mary Rehm, Elya Joffe, Monique Inman, Cindy McHenry, Adam Maxwell, Andrew Baines, Mike Violette, Paul Borowski, and Peter Holtmann

forward in the future and how Product Safety may be updated to reflect its important aspect within many industries.

RABQSA BOARD OF DIRECTORS MEET TO DISCUSS THE 2013-14 STRATEGIC PLAN

Members of the RABQSA Board of Directors and the RABQSA Management Team met on May 10, 2013 to review the activities of RABQSA and iNARTE in 2012-13 and look forward to the strategies for the upcoming 2013-14 business plan year.

In attendance were Jay Baron, Sal Agnello, Vipin Sahni, Prakash Sathe, Jenny Lewis, Mary Rehm, Elya Joffe, Monique Inman, Cindy McHenry, Adam Maxwell, Andrew Baines, Mike Violette, Paul Borowski, and Peter Holtmann.

RABQSA IS SEEKING TEST CENTERS TO ADMINISTER EXAMINATIONS

RABQSA is proud to announce that we now have several Individual Proctors on military bases overseas who are proctoring the FCC examinations for military personnel. RABQSA would like to thank these individuals for their military service and for becoming iNARTE Proctors who have chosen to assist our service men and women in obtaining their FCC licenses.

In an effort to accommodate our iNARTE customers to ensure they travel fewer miles from their home, RABQSA is recruiting test centers and individual proctors to administer the iNARTE and FCC examinations. If you are interested in becoming an iNARTE Authorized Test Center or iNARTE Individual Test Proctor, please fill out the application form located at http://narte.com/h/tchome.asp#TC.

RABQSA ONLINE PORTAL

To ensure you receive access to your iNARTE records via the RABQSA Online Portal when it is made available, send your name, certificate number, and current email address to Laura Funk, RABQSA Office Assistant, Certification Services, at lfunk@rabqsa.com.

iNARTE (International Association of Radio and Telecommunications Engineers) is a product of RABQSA (Registrar Accreditation Board and Quality Society of Australasia) International, Inc.

RABQSA's mission is to provide world-class products and services that add value to professionals in industry through competency-based certification. RABQSA creates value for you and your customers. We design, develop, and deliver personnel and training certification services relevant to your industry. Our certification services are designed to be efficient, consistent and relevant to Industry's needs. We create and maintain value to industry, our certified professionals, and training providers by ensuring that our certification remains relevant and also compliant to international standards. RABQSA International certification delivers the right people, with the right abilities, to achieve the right outcomes.

RABQSA's principal offices are located in Sydney, Australia, Milwaukee, USA and Seoul, Korea and international offices located throughout the world.

To learn more about the iNARTE certification programs, visit www.narte.org. To learn more about RABQSA, visit www.rabqsa.com.

QUESTION OF THE MONTH

Last month's question was from the EMC Design Engineer pool:

In Automotive EMC testing according to CISPR 25, what value of series capacitance is in the LISN (Artificial Network) between the power supply and equipment under test (EUT)?

A) 500 μF
B) 50 μF
C) 5 μF
D) A series capacitor is not used.

The correct answer is D) A series capacitor is not used.

This month's question is from the Product Safety Engineer pool:

An Information Technology Equipment rack mount power distribution unit connects to the AC mains via a NEMA L5-30P attachment plug. It has a series of NEMA 5-15R panel mount AC output receptacles and incorporates UL Listed panel mounted circuit breakers in the front panel protecting the outlets. What is the required current rating for each of these circuit breakers?

A) 30 A
B) 20 A
C) 15 A
D) The current rating of each circuit breaker shall be greater than the maximum rated current to be delivered by each series of outlets.

See the next iNARTE Informer for the correct answer to this month's question.

MR. Static

Abatement of Static Electricity

Part I: Conductors

BY NIELS JONASSEN, sponsored by the ESD Association

Several methods enable reduction or negation of the damaging effects of static charges on conductors.

INTRODUCTION

Associate Professor Neils Jonassen authored a bi-monthly static column that appeared in *Compliance Engineering Magazine*. The series explored charging, ionization, explosions, and other ESD related topics. The ESD Association, working with *In Compliance Magazine* is re-publishing this series as the articles offer timeless insight into the field of electrostatics.

Professor Jonassen was a member of the ESD Association from 1983-2006. He received the ESD Association *Outstanding Contribution Award* in 1989 and authored technical papers, books and technical reports. He is remembered for his contributions to the understanding of Electrostatic control, and in his memory we reprise "Mr. Static".

~ The ESD Association

A previous article ("How Fast Does a Charge Decay?" *In Compliance Magazine*, July 2012) argued that, from a physicist's point of view, it does not make sense to talk about removing static electricity. It was demonstrated that the rate of charge neutralization, usually called charge decay, depends on the resistivity and permittivity of the materials involved. This article discusses the practical principles used in abating the nuisances and risks of static charge distributions on conductors, as well as the differences between charged conductors and charged insulators.

The first thought that comes to mind in this context is, "Isn't it possible to avoid static charges altogether (i.e., prevent charges from being separated)?" In situations in which friction between two solid materials is essential for charging, a reduction in the degree of friction reduces the rate of charge separation. In the case of charging by flow of insulative liquids, a reduction in the flow rate also reduces the charging. In addition, because spraying of almost any kind of liquid often results in charge separation, free jets of liquids should be avoided whenever possible (for instance, by keeping the flow rate low when filling containers until the tip of the filling tube is immersed in the liquid). However, these are probably the only examples in which the actual magnitude of the charges separated can be affected.

Nevertheless, there are quite a few remedies and procedures on the market that claim to reduce or remove static electric problems by reducing charging. It is likely, however, that the efficiency of these methods depends on an increased rate of neutralization or recombination of the charges separated, rather than on an actual reduction of the charging rate.

CHARGE NEUTRALIZATION

Most static charge removal processes do not involve actual removal of an electric charge from the charged object. The exception is charged conductors. If a negatively charged metallic conductor is connected to ground by another metallic conductor, the excess charge (electrons) may flow to ground through the metallic connection. In all other situations, the neutralization consists of oppositely charged carriers, either ions or electrons, being drawn to the excess charge. The field from the neutralizing charge superimposes the original field, and the resulting reduced field is then interpreted as a reduction or removal of the charge.

CONDUCTOR GROUNDING

The basic rule for fighting the unwanted effects of static electric charges is to ground all conductors that might become charged or exposed to induction from other charged objects. Ungrounded charged conductors can produce discharges ranging from weak

current pulses that may harm only the most sensitive electronic components to energetic sparks that may cause explosions and fires. Direct (i.e., very low impedance) grounding is rarely necessary.

CHARGING OF PERSONS

The charging of persons walking on an insulative floor covering was treated in detail in "Charging by Walking" (*CE*, March/April 2001). It was demonstrated that the theoretical maximum charge separated in one step, Δq_{max}, is about $4 \cdot 10^{-7}$ C, leading to a mean value of the maximum charging current, i_m, of about 1 μA. Experimental results, however, suggest that more reasonable values would be $q_{max} \approx 3 \cdot 10^{-8}$ C and $i_m \approx 6 \cdot 10^{-8}$ A.

If a person has a total decay resistance (from floor and shoes) of R, the person's maximum voltage can be written as

$$V_m = i_m \cdot R \qquad (1)$$

Equation 1 assumes uniform charge separation. However, the charge Δq is separated in the time it takes to lift the foot from the floor. During this time, Δt, the body voltage grows to a value ΔV that can be written as

$$\Delta V = \frac{\Delta q}{C} \cdot \frac{RC}{\Delta t}\left(1 - e^{-\frac{\Delta t}{RC}}\right) \qquad (2)$$

In Figure 1, V_m and ΔV are plotted as a function of R for $i_m = 6 \cdot 10^{-8}$ A, $\Delta t = 0.1$ second, and C (one foot) = 100 pF. It therefore appears that at a decay resistance of 1 GΩ the mean maximum voltage V_m may be as high as 60 V, while the one-step voltage ΔV is about 180 V.

MR. Static

BULK CHARGING

The constant value of ΔV (see Figure 1) for $R >$ (approximately) $10^{10}\,\Omega$ is a case of bulk charging, a process in which a capacitive system receives a charge Δq in a time that is short compared to the time constant RC of the system. In addition to walking, examples of bulk charging of people include rising from a chair with an insulative cover and sliding across a car seat.

Bulk charging results in a sudden rise ΔV in the voltage of the system, given by

$$\Delta V = \frac{\Delta q}{C} \qquad (3)$$

It follows from equation 2 and Figure 1 that ΔV decreases with the decay resistance R for given values of charging time Δt and capacitance C. In many cases and in many industries, ΔV and V_m can be kept at sufficiently low levels with sufficient reliability by choosing floor coverings and footwear to yield decay resistances in the range of 10–100 MΩ.

WRIST STRAPS

In the electronics industry, grounding through footwear and a floor covering may prove inadequate. This is especially true when dealing with MOSFETs and similarly sensitive components in which a current pulse from a person charged to, say, 100 V can be destructive.

Although the idea of keeping a person at zero voltage by tying him physically to a ground point with a conductive wire may seem odd and impractical, this is nevertheless an accepted procedure in many areas of the electronics industry. The gadget employed for this purpose is a wrist strap, which consists of a band or chain, similar to an expandable watchband and made of metal and conductive plastic or conductive fibers, and a strap that connects the band to ground. The strap is made of either solid conductive plastic or multistrand wire. Normally, the strap includes a series safety resistor of 1 MΩ for minimizing the shock from accidentally touching a live wire while being tied to ground via the strap. For the normal household peak voltage of 160–170 V, the maximum current through the person would be less than 0.2 μA, well below fatal values.

Although wrist straps appear to be simple devices, their use involves a series of problems to be considered, including intermittent skin contact with loose-fitting bands, bad skin contact caused by excessively dry skin or too much body hair, and sloughing of the band material resulting in contamination of electronic components. In addition, the strap should be grounded carefully to a separate ground terminal; the grounding should not be left to a chance

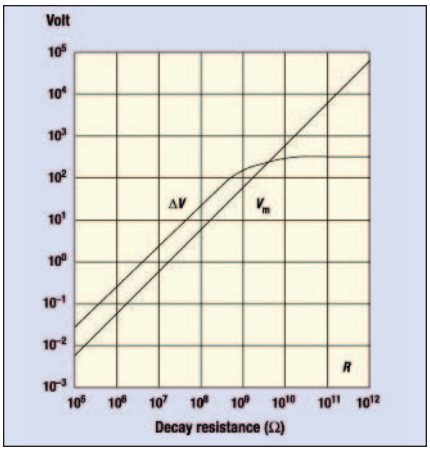


Figure 1: Maximum voltage, V_m, and one-step voltage, ΔV, as a function of the decay resistance R.

connection through an alligator clip hooked onto a potentially suitable point.

OTHER MOVABLE CONDUCTORS

While the grounding of stationary conductors like machinery and metallic tube systems is a straightforward and usually simple problem, movable conductors like trolleys and chairs constitute the same type of scenario as do mobile persons. The solution is also similar. Just as people are kept at a safe low voltage by a combination of footwear and floor covering, so are movable conductors kept at a safe low voltage by the use of conductive wheels.

CHARGED INSULATORS

There are two distinct differences in the electrostatic behavior of conductors and insulators. The first difference is that a charged conductor can dissipate all the energy stored in its field in a single discharge or current pulse, neutralizing its entire charge. The second is that a charged conductor needs only to be connected to ground from a single point of its surface through a suitably conductive path to have its charge eventually neutralized.

A discharge from a charged insulator, on the other hand, neutralizes only part of the charge and hence dissipates only part of the energy stored in the field. Furthermore, charges on an insulator cannot be removed by connecting the surface of an insulator to ground.

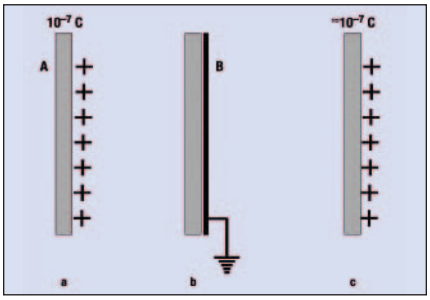


Figure 2: Results of charged plane insulator A being brought in contact with grounded conductor B.

Figure 2a shows a charged plane insulator A with a charge of 10^{-7} C. In Figure 2b, the insulator is brought in contact with a grounded conductor B. When conductor B is removed in Figure 2c, insulator A turns out to have retained most of its charge. If the charge in Figure 2c is less than that of Figure 2a, it is because the approach of the grounded conductor B may have caused ionization between B and A. (See "Charges are Forever," *In Compliance Magazine*, February 2012.)[3]

CONCLUSION

This article, the first of two in a series, discussed different techniques for abating the damaging effects of static electricity on conductors. The next article will discuss several methods used with insulators, along with the pros and cons of the individual methods.

(the author)

NIELS JONASSEN, MSC, DSC, worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. After retiring, he divided his time among the laboratory, his home, and Thailand, writing on static electricity topics and pursuing cooking classes. Mr. Jonassen passed away in 2006.

The Scale of Shaky Things

BY MIKE VIOLETTE

We examine the size of things that move and shake, from the whisper of a lover to the crunch of tectonics.

Barely audible, a whisper at the threshold of human hearing produces a "zero dB" sound pressure level (SPL), according to convention.

At the lowest levels of perception, nominal levels are some 10^{-12} watt/m^2, or 10^{-16}W/cm^2—an amount of acoustic power density inconceivably small to consider: one trillionth of a watt spread out over an area that is ten thousand the size of the human eardrum. Small, like the breath of a hummingbird.

On the upper end of the scale of human hearing, attending a WHO concert back in the day, the acoustic power density may get up to 10 W/m^2, especially if one were to stand in front of the amp stack. This would be the "ear bleed" position and may induce irreversible damage. From the lowest audio sensitivity to the threshold of pain is about 130 dB or 10^{13} power, a fantastic dynamic range.

Sound pressure is also defined in terms of Newtons-per-square-meter (N/m^2) or Pascals (Pa) after the extraordinary French philosopher-mathematician Blaise Pascal. (By the way, if you want a scientific unit named after you, it's helpful if you're Caucasian, have invented some new theories—and are dead. Witness: Newton, Pascal, Watt, Hertz, Faraday and their ilk). The threshold of human hearing, in Pa, is on the order of 10^{-5} Pa at 1 kHz, the nominal middle of the frequency of human speech.

An acoustic wave is longitudinal, akin to energy propagating along a stretched-out Slinky™. The peaks and crests of the wave (pressure maxima and minima) flex the eardrum in-and-out. The eardrum responds to the change in air pressure by vibrating. Consider that the eardrum is around 1cm in size, a crude calculation of the "received power" is, then, about 10^{-16} watts (assuming 100% conversion of the acoustic wave to the vibrations on the ear drum).

The ear performs a remarkable acoustic to electrical conversion in the inner ear and the sound signal travels into the brain. The displacement of the "tympanic membrane" as the eardrum is more correctly called, at the most sensitive levels of normal hearing, is about 10^{-3} nanometers or about 10^{-12} meters. Considering that the size of human cells is on the order of 10^{-6} meters, the negligible amount of mechanical movement that brings Mozart back to life is an astonishing testament to the design of these features of the body.

The conversion from vibration to neural signal involves the action of cilia hairs in the cochlea; these fine hairs vibrate against their host cells, releasing a flow of ions that convert the mechanical motion to a change in charge. This fine movement can be measured in terms of chemical reactions, which are really electron transfer.

A few years back, I was doing some RF measurements in a Texas research lab. There was a tub of live frogs on the floor. A lab technician in a white coat and splotched black sneakers was arranging a slide on a microscope.

"What's with the frogs?" I asked.

The technician replied with a nonchalant "The frogs? Yeah, they're to be vivi-sectioned." At which time he reached into the tub, grabbed a croaker and promptly snipped its head off. "The inner ear of frogs have cilia similar to humans, so we study them, but they have to be alive. Using fine electrodes we can measure the flow of ions that are transferred when the cilia move." Digging into the greenish head, he extracted a whitish mass about the size of a small pea from the amphibian, he continued. "In addition to providing signals for hearing, it's the function of these cilia to give us a sense of balance so we can keep upright, sort of like a gyroscope. The inertia of the fluid in the ear makes it tend to stay in place, the cilia sense motion and give signals to the brain that help keep your physical orientation." He put the white gooey mass on the microscope and looked into the eyepiece. "When you get a head cold, sometimes your sense of balance can be compromised."

I never thought much about frogs' ears before, but his point stuck with me. The fine displacement of those very special cilia is necessary for grooving to Herb Alpert on your ear buds while standing upright on a moving subway train.

On the opposite end of the displacement scale: consider the shaking of the Earth when a fault slips and jiggling seismographs record the movement. Rock structures transmit and echo the energy and the severity depending on a multitude of factors, especially proximity to the epicenter. The effect also depends on the structure of the Earth which may focus energy at certain locations or cause soil "liquefaction," as it did to the city of Christchurch, New Zealand on February 22, 2011 when a magnitude 6.3 destroyed a good portion of the historical city center and downtown.

The Richter scale has been used since 1935 to measure the intensity of the shaking of the planet's plates and associated fault lines. The "moment magnitude scale" MMS has replaced the Richter scale, the Richter scale is 'burned into' popular reporting. The Richter scale is logarithmic, such that each change in one unit is equal to a 10X change in intensity, so a magnitude 7 earthquake is 10 times stronger than a magnitude 6.

The earthquake that rocked Japan in April 2011 and sent a wall of water at Miyagi prefecture moved the country 4 meters closer to North America, shifted the Earth's axis by 17 cm and shortened the day by 1.8 microseconds. (I knew I was waking up less refreshed lately—I'm obviously missing that extra sleep.)

The Fukushima quake measured about 7.3 on the Richter scale, which "released" the equivalent of about one megaton of TNT energy or just over 4 Pentajoules where 1 PJ=10^{12} Joules (after James Prescott Joule, BTW).

The largest quake recorded occurred in Chile (Valdivia) and measured 9.5 on the Richter scale!—a monster that released 11,000 PJ or the equivalent of 100 teratons of TNT. This amounts to 1000 times the yield of the largest thermonuclear bomb ever devised, the Soviet Union's "Tsar Bomba" that was heralded at the UN by Nikita Krushchev's eardrum-vibrating declaration: "We'll show YOU a mother!"

The scale of vibration and displacement energy, from the barely audible whisper of a lover across the room to the terrifying fury of mother Earth, is terrific, extending across a range from 10^{-12} to 10^{15} Joules. Even in decibel form, that's big (270 dB!). There are bigger "displacements" that occur, of course, something like an asteroid hitting the planet, for example, would be "off the scales" (not to mention ruin your day) and events called *Starquakes* (great album name!) have been recorded that crank out something called *yottatons* of energy. 'That's a yotta energy!'

We like whispers and quiet music and hope we never experience those other extreme kinds of "displacements".

(the author)
MIKE VIOLETTE
is President of Washington Labs and Director of American Certification Body (mikev@wll.com).

A Primer on Automotive EMC for Non-EMC Engineers

BY GARY FENICAL

The automotive industry has changed drastically in recent years. Advancements in technology paired with tighter federal fuel and emissions regulations have resulted in the need to place more electrical systems into vehicles. This in turn places a greater emphasis on keeping the Electromagnetic Interference (EMI) of these systems from interfering with each other through radiated and conducted emissions, as well as crosstalk between the multitudes of on-board systems.

In addition to the sources within the vehicle, there are external sources of EMI that could interfere with vehicle electronic systems. These sources include, but are not limited to, cell phone towers, commercial broadcast signals of all sorts, remote entry devices as well as RADAR near airports and other such places. There are devices brought on board by passengers such as Bluetooth® devices, DVD players, video games and pretty much anything else you or your children can think of that must also be taken into consideration by automakers.

Before discussing the best solutions for common EMI issues, it is helpful to understand EMI; its influences on vehicle EMC (Electromagnetic Compatibility) and where EMI shielding is often used in automobiles. Once engineers have all the information and have considered all of the factors affecting EMI, then they can choose the proper shielding material for their need.

WHAT IS EMI?

EMI is a process by which disruptive electromagnetic energy is transmitted from one electronic component or device to another via radiated or conducted paths, or both. There are always both paths there but many times one is more prevalent than the other. In

Consumers have become more interested in the optional convenience and entertainment systems available in vehicles today. These options include rear-view cameras, back-up radar and complicated infotainment systems.

an automotive electronic system, EMI can adversely affect the performance of an integrated circuit internally, as well as that of other electronic components in close proximity.

There is a root cause to most EMI noise. In a digital system, clock pulses are generated to operate the logic. As these clock pulses are developed, they have a given rise time. The rise time, as it gets shorter, has a tendency to create a broadband energy pulse on the leading edge. This is commonly known as overshoot and/or ringing.

The energy present in the overshoot and ringing is the basis for generating other higher frequencies called harmonics. These higher frequencies are multiples of the clock frequency. Both odd and even multiples (harmonics) exist. In most cases, the odd harmonics (observed at 3, 5, 7, and 9 etc. times the fundamental of the clock frequency) create most of the EMI noise problems. However, even harmonics do exist and must not be ignored.

Placing more and more electronic systems into the confined spaces of vehicles poses a potential EMI problem. If not properly addressed, the interference can cause each system to malfunction or even fail. Current trends and technology advancements are introducing new electronic systems, and with that, new potential EMI issues into vehicles at a rapid pace. And, of course, every new device or system must meet all mandatory EMC requirements that give a reasonable assurance that the device or system will operate as intended and will not cause any other devices or systems to not operate as intended. This is especially critical where safety is concerned.

CURRENT TRENDS INFLUENCING VEHICLE EMI

As the automotive industry has progressed, there have been several factors external to the business which have influenced the evolution of today's vehicle. Between increased fuel and emissions standards by the federal government to the consumer's interest in additional convenience and entertainment options, the automotive industry must address these trends and the additional potential sources for EMI.

With the new fuel efficiency standards issued by the Transportation Department and Environmental Protection Agency stating vehicles must get an average of 35.5 miles per gallon by 2016, automakers are increasing the use of electronic engine controls. These electronic controls allow more precise control of the engine and therefore, fuel use, helping to achieve the increased fuel efficiency standards. The use of these controls also means additional electronics introduced into the car, resulting in potential EMI issues.

As fuel efficient automobiles become a focus, hybrid and electric vehicles are gaining popularity with consumers. These types of vehicles feature some degree of electronic drive systems, introducing new EMI issues for engineers, which must be dealt with to maintain the "mission critical" systems. These types of drives are high current devices. As current increases in a circuit, emissions increase. Therefore it becomes more difficult to meet radiated emission standards.

Additionally, consumers have become more interested in the optional convenience and entertainment systems available in vehicles today. These options include rear-view cameras, back-up radar and complicated infotainment systems. As more electronic applications are added to vehicles, additional EMI shielding for these systems is necessary to ensure the safety and functionality of the automobile. And let us not forget the PEDs (Portable Electronic Devices) many of us like to bring into the vehicle. Although the PEDs must meet FCC radiated and conducted emissions, these devices have not been specifically tested for use in an automotive system. Generally, conducted emission will not matter because there are only requirements for conducted emission on the AC mains.

SHIELDING

Shielding is the practice of reducing the electromagnetic field in an environment by blocking it, or isolating it from the "outside world" with some type of conductive or magnetic material. The amount of reduction depends on the material used, thickness of the shield, amplitude and the frequency of the fields. Shielding is noninvasive and does not affect high-speed operation of components and systems. Other solutions such as filters, ferrites and/or absorbers can change the signal characteristics and affect circuit operation. Shielding can be a stand-alone solution, but is more cost effective when combined with other suppression techniques such as filtering, absorbers, grounding and,

As more electronic applications are added to vehicles, additional EMI shielding for these systems is necessary to ensure the safety and functionality of the automobile. And let us not forget the portable electronic devices many of us like to bring into the vehicle.

most importantly, proper design. The use of shielding can take many forms, from RF gaskets to board level shielding (BLS) and there are several factors to consider when choosing shielding material.

SELECTING PROPER MATERIALS

There are many factors that affect the proper selection of RF gasket materials. The following list identifies some of the key issues that must be considered when choosing a material.

- Operating frequency
- Materials compatibility
- Corrosive considerations
- EMC compliance specification
- Operating environment (In the passenger compartment, under the hood, etc.)
- Load and forces
- Cost
- Attenuation performance
- Storage environment
- Oil and fuel resistance
- Cycle life
- Electrical requirements
- Materials thickness/alloy
- Space and weight considerations
- Product safety
- Recyclability

WHERE IS EMI SHIELDING USED ON A VEHICLE?

As stated previously, there are both internal and external sources of EMI to vehicles. The automotive

electromagnetic environment is very complex, requiring automakers to consider both these external and internal sources prior to production of vehicles.

Internal EMI problems can range from simple static on the radio to a loss of control of the vehicle. Internal electrical systems that can affect the vehicle function include:

- Collision avoidance radar
- Navigation-radio combination
- Power steering module
- Airbag inflator
- Adaptive cruise control
- Infotainment systems
- Tire pressure monitor, etc.

Vehicles' electronics can be affected by harsh external EMI environments. EMI can be generated from power transients, radio frequency interference, electrostatic discharge and power line electric and magnetic fields. These external sources can include:

- Garage door openers
- Remote entry devices
- Cell phones
- Bluetooth devices
- Third party navigation
- DVD players
- Pretty much anything that uses electricity but especially digital devices

Vehicle electronics must be designed for extremely high reliability at the lowest possible cost. If EMI is not considered at the beginning stages of the design process, it becomes more difficult and expensive to deal with later. All these issues have to be overcome through optimal electromagnetic compliance (EMC) design and the correct EMI shielding materials selection.

EXAMPLES OF EMI SHIELDING USED IN VEHICLES

EMI shielding can be found in virtually any electronic system in a vehicle. Because of the confined space and the number of electronic systems within a vehicle, engineers often use EMI shielding as an efficient and cost-effective means of addressing interference issues.

Audio Systems – Audio and entertainment systems can be one of the largest sources of EMI in vehicles due to AM/FM radios and additional electronics including GPS and navigation or satellite radio. Other considerations include in-car entertainment options such as televisions and DVD players and the convenience of after-market items including multi-programmable wireless controls. Common shielding solutions used in these systems include board-level shielding, metal fingerstock, conductive Fabric-over-Foam and spring gaskets.

Interior Systems – These systems include the lighting (which is only a problem during turn-on and turn-off unless it is electronic lighting), power modules, rearview mirrors and display screens found in most cars today. These electronics are more vital to the function of the vehicle and EMI issues should be carefully considered. Typical solutions used in these systems include board-level shields, metal fingerstock, spring gaskets, Form-in-Place gaskets and conductive elastomers. For example, in a rearview mirror with a camera, a board-level shield could be used to prevent crosstalk among components on the circuit board. For a system that is exposed to the elements, conductive elastomers are a good choice as it is an environmental seal as well as an EMI gasket.

Safety and Security Systems – These systems, often considered "mission critical", include cruise control, driver information systems, tire pressure monitors, blind spot detectors and nigh vision systems. If these systems fail, then the safety of passengers is immediately at risk. Often engineers will use board-level shields, fingerstock, spring gaskets and microwave absorbers to mitigate the EMI in these systems. Microwave absorbers are used in some blind-spot detectors and side-view radar to help alleviate cavity resonance and reduce crosstalk between boards and elements. As frequencies get higher, absorbers become a more efficient solution. It is difficult to put a number on just when to rely on absorbers as opposed the shielding but in the low gigahertz region is a good rule of thumb.

EMI SHIELDING OPTIONS FOR AUTOMAKERS

There is a wide variety of solutions available to automakers to help solve EMI issues. The following discusses the shielding options most often used in vehicles. It is important to remember that considering EMI early in the design process is not only more cost-effective, but also more efficient. Automakers and design engineers should consider all factors when choosing the proper EMI material for their needs.

Fingerstock and Spring Contacts

Metal RF gaskets are made from various materials. The standard product is offered in Beryllium Copper (BeCu), but phosphor bronze and stainless steel are also available.

The metal must be conductive and have good spring properties. The metal RF gaskets generally have the largest physical compression range and high shielding effectiveness holding steady across a wide frequency range. BeCu is the most conductive and has the best spring properties.

Fingerstock and spring contact products are ideal for high cycling applications requiring frequent access. Hundreds of standard shapes are available, as well as cut-to-length and modified standards. Fingerstock and spring contacts offer superior performance at elevated temperatures, often a concern in automotive applications. Metal fingerstock can be used from as low as 20% to 90%or more depending upon the geometry and material.

Fabric-over-Foam (FoF)

FoF EMI gaskets offer high conductivity and shielding attenuation and are ideal for applications requiring low compression force. The FoF profiles are available in a UL 94V0 flame retardant version and offer high abrasion and shear resistance. Typical FoF EMI gasket applications include shielding or grounding of automotive electronic equipment seams and apertures.

There are a wide range of shapes and thickness to meet any design need. Compression of the gasket from 30% to as high as 75% can be allowed depending on the geometry and FoF material, thereby accommodating the tolerances of many systems.

Form-in-Place (FiP)

Form-in-Place (FiP) EMI gaskets can be dispensed onto any conductive painted, plated, or metallic surface of an electronics enclosure that requires environmental sealing. It can be applied on complex or rounded surfaces as well as miniature devices requiring a precision gasket. In return FiP gaskets protect the enclosure against internally and externally radiated interference and environmental elements.

These EMI gaskets save costs in the form of raw materials, labor and assembly time. FiP gaskets allow for more critical packaging space for board-level components. Room temperature curing gasket materials eliminate the need for costly heat curing systems because single-component compounds eliminate ingredient mixing, thus shortening production cycles. They have shielding effectiveness in excess of 70-100 dB to 18 GHz and beyond.

Electrically Conductive Elastomers

Conductive elastomers are ideal for automotive applications requiring both environmental sealing and EMI shielding. Compounds can be supplied in molded or extruded shapes, sheet stock, and custom extruded or die-cut shapes to meet a wide variety of applications. Conductive elastomers

Automakers must take into consideration a number of factors when choosing materials for their EMI needs, including internal and external sources of EMI and cost.

provide shielding effectiveness up to 120dB at 18GHz and beyond and come with many different material choices for both the conductive filler and elastomer compound.

Conductive Foam

Conductive foam (CF) offers unlimited compression performance while providing a relatively soft Compression Load Deflection (CLD) curve. Lower CLD properties further reduce the potential distortion in the application. CF can be die cut into or supplies as gaskets or in sheet stock.

Board-Level Shielding (BLS)

When electrical and electronic circuits are in nonconductive enclosures, or when it is difficult or impossible to use RF gasketing, BLS provides the best option for EMI suppression. It is well known that the closer you are to the source of an EMI problem, the more efficient and less expensive it is to fix, and using a board-level shield is as close as you can get to the problem.

If done well, PCB level shielding can be the most cost-efficient means of resolving EMI issues. The approaches involve proper shield selection and optimal circuit design including partitioning, board stack-up, as well as high-frequency grounding of the board and filtering techniques. Generally, shielding on a PCB is some form of conductive cover mounted over one or more components. In some applications, a shielding barrier separates board components to prevent crosstalk.

Heat can be an issue when using PCB shields. Ventilation holes are usually an adequate way to address this problem. However, if ventilation holes do not provide enough heat dissipation, PCB shields are available with integral heat sinks or other thermal dissipation systems.

For extremely high frequency applications board level shields are available for use in conjunction with microwave absorbers.

As a low cost and common shielding method, a variety of board-level metal can-type shields have been used to eliminate EMI radiation from entering or exiting sections of a PCB. This method has primarily employed solder-attached perforated metal cans being attached and soldered to the ground trace on a PCB directly over the electrical components that need to be shielded. The can-type-shields are often installed in a fully automated fashion via a surface mount technology process at the same time the components themselves are installed onto the PCB using wave soldering, or solder paste and a reflow process. Such cans offer very high levels of shielding effectiveness, are typically very reliable, and are widely used in the industry. But remember that a board level shield is only five sides. The manufacture (PCB designer) must provide the sixth side in the form of a solid layer within the board with properly spaced vias to attach the BLS.

There are detailed articles available on BLS usage.

CONCLUSION

With the advancements in technology and the increased emphasis on fuel efficiency, the automotive industry has placed more and more electrical systems into cars than ever before. These electrical systems present a greater need to control the EMI issues they often present in the vehicle environment. If EMI issues are not addressed, automakers risk the proper functionality of basic and complex systems within the car, and even passenger safety.

Automakers must take into consideration a number of factors when choosing materials for their EMI needs, including internal and external sources of EMI and cost. Engineers should always consider the potential EMI issues in the beginning phases of the design process, as it will be more efficient and more cost-effective.

There are a number of potential EMI shielding solutions for the automotive industry. With a variety of shapes, sizes, material options and mechanical factors, however, there is a product that will fit virtually any need.

(the author)

GARY FENICAL

Senior EMC Engineer and NARTE Certified EMC Engineer, Gary has been with Laird Technologies for 30 years. He is a specialist in RF shielded enclosures and has been responsible for the design and/or measurement and quality control of hundreds of large-scale shielded enclosures, as well as a number of shielded equipment cabinets and housings. He was instrumental in the design and construction of Laird Technologies' state-of-the-art World Compliance Centers and has authored many articles on EMC requirements for medical devices, mutual recognition agreements and guidelines to meet the essential requirements if the EU EMC Directive. He has also authored several seminars, presented worldwide, on the EU EMC Directive, international compliance, and designing for EMC and EMC requirements for medical devices. He holds the patent for the invention of heat-treated beryllium-copper knitted wire mesh gasket. Other patents are pending.

2013 IEEE International Symposium on Electromagnetic Compatibility

WINDS OF CHANGE

August 5 - 9, 2013 • Denver, Colorado

Technology is advancing at a MILE HIGH pace and EMC testing is necessary to the success of this progress. No longer are the boundaries of EMC testing relegated to open area test sites, laboratories and text books; they are becoming part of our daily lives. The electric and hybrid vehicles and the Smart Grid, are two big arenas where EMC plays a major role.

The EMC 2013 Symposium will include many topics to enhance your understanding of EMC, sharpen your design skills, and perfect your skills in dealing with EM phenomena. Join us in the Mile High City for a week of learning, collaboration and connecting with industry peers and start your path into the world of EMC green.

Learn the Leading Edge Info on:

- EM Interference and Environments
- Shielding, Grounding, Bonding
- EMP, Lightning, ESD
- Transient Suppression
- EMC Measurement
- Signal Integrity
- EMC Management
- Nanotechnology
- Spectrum Management
- EM Product Safety

For Event Details Visit: **www.emc2013.org**

IEEE EMC SOCIETY®

Electromagnetic Compatibility Assessment of Wireless Emissions in Shipboard Spaces

Electromagnetic compatibility of wireless communications and sensor networks with mission critical electronic equipments is assessed for below-deck spaces on ships and submarines. With intentional wireless emission of radio-frequency (RF) energy into the reverberant spaces, it is necessary to measure and characterize the statistical electromagnetic environment (EME) and to predict maximum electric field strengths to a specified confidence level.

BY GREGORY TAIT AND PAUL OPPERMAN

A random-walk test technique has been developed and applied to measurements conducted in these reverberant spaces. Maximum electric field strengths versus input power in several submarine spaces, ranging from high to low reverberant properties, are demonstrated. EMI risk mitigation in below-deck spaces is based on alignment with a 10-V/m electric field radiated susceptibility requirement of MIL-STD-461F and requirements from MIL-STD-464C for shipboard internal EME.

INTRODUCTION

With the proliferation of RF wireless technologies currently being deployed in enclosed, reflective spaces, such as found in aircraft, ships and buildings, it is critical to assess the resultant EME in these spaces, especially where potentially disruptive effects to critical electronic equipment systems may exist. Examples of these spaces include below-deck compartments in ships and submarines, and in aircraft cabins and bays [1]-[3]. Of particular note is the introduction of wireless communications and sensor network systems into ship and submarine below-deck spaces. In assessing the potential impact associated with using intentional emitters in reverberant spaces, we must address the cumulative build-up of the RF energy.

Below-deck spaces have very complex shapes and loading, particularly in submarines. Such complex cavities are characterized by a chaotic electric field standing wave pattern of maximums and minimums whose locations are very sensitive to small changes in boundary conditions, such as occur from changes in physical structure (mechanical stirring), frequency (frequency stirring), and loading (material, personnel, equipment) over a period of time. The dominant multi-path nature of such coupled reflective spaces creates a significant Rayleigh amplitude fading of signals in the communications channel. Therefore, it is vitally important to characterize the full statistical properties of the electromagnetic environment in assessing compatibility.

RANDOM-WALK TEST TECHNIQUE

Reverberation chamber test methods and their associated statistical analyses are well established [4],[5]. It was necessary to modify and adapt these techniques to address the special circumstances of field-operational spaces. A random-walk test technique, dubbed the "walk-around" method, has been developed and applied to measurements in below-deck spaces on Navy ships and submarines [6].

Figure 1: Execution of the random-walk test technique

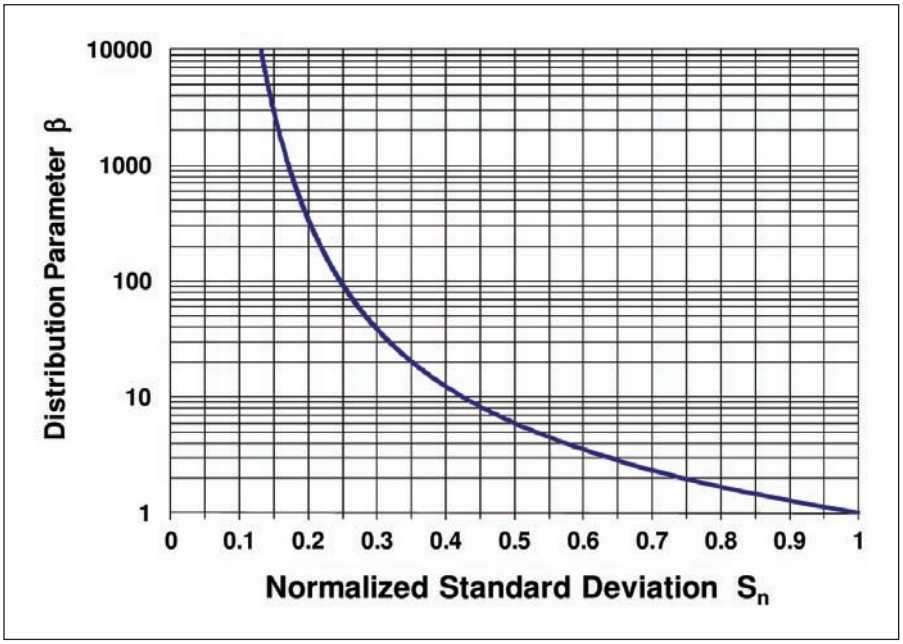


Figure 2: Estimation of maximum power distribution parameter β from the normalized standard deviation S_n of measured maximum power data samples.

Figure 1 shows measurements being taken in a reverberation chamber.

For the walk-around method, which utilizes tracking generator/spectrum analyzer Max Hold measurements, the results are a collection of maximum received power values across the swept frequency band. A full walk-around measurement is conducted a total of 12 times in the space. Hence, at a given frequency, there are 12 maximum received power data points. This number can be augmented by including maximum power data points at adjacent frequencies, a process associated with frequency stirring of the field distribution. The independence of these samples is established by the following arguments. First, the 12 maximum power data points at any given frequency are spatially uncorrelated, as it is virtually impossible that any two maximum data points will originate under identical transmit and receive antenna positioning given the 6 degrees of freedom for orienting the antenna mounting pole in the space during the 12 random walk-arounds. Secondly, the maximum power data points at two frequencies are further uncorrelated since their frequency difference Δf exceeds the Q-bandwidth of the overmoded cavity [5], i.e.,

$$\Delta f > \frac{f}{Q(f)} \qquad (1)$$

For Q values on the order of 1000 in a submarine below-deck space at 2.4 GHz, Δf is on the order of 2-3 MHz. The maximum fractional bandwidth around the center frequency f that can be utilized for frequency stirring is limited by the fact that insertion loss (and hence Q) is frequency dependent, and insertion loss bias in the data must be avoided. For the statistical analysis of this paper, 108 maximum power data points are utilized – 12 maximum values at each of 9 adjacent frequencies (10 MHz separation) centered at 2.437 GHz.

The 80-MHz bandwidth yields a 3.3 % fractional bandwidth.

The statistical analysis of data obtained from the random-walk measurement technique essentially works "backward" from maximum received power data towards determining the well-known complex-cavity exponential (chi-squared X_2^2) probability density function (pdf) for the random variable of received power from a linearly polarized antenna in the space [6]. The walk-around process exploits both source stirring and volume sampling as the transmit and receive antennas are moved throughout the space. At a given frequency, the spectrum analyzer Max Hold measurement will retain the largest value w of received power P_i from N frequency sweeps executed during the random walk session,

$$w \equiv \max_N \{P_i\} \tag{2}$$

A sufficiently large sample of measured maximum received power values is collected over a given frequency bandwidth from each random-walk trial. The cumulative distribution function for the random variable w is given by,

$$F_{Max}(w;\ \alpha, \beta) = [1 - e^{-\alpha w}]^{\beta} \tag{3}$$

This cumulative distribution function is derived from the extreme value theory of statistics for an underlying (parent) exponential probability density function (X^2_2). α and β are, respectively, location and shape parameters of the distribution function. These distribution parameters are estimated from the mean μ_w and standard deviation σ_w of the measured values of w. The mean-normalized standard deviation of the maximum power data samples is given by,

$$S_n = \frac{\sigma_w}{\mu_w} \tag{4}$$

The shape parameter β is estimated from the following constraint,

$$I(\beta) \equiv \frac{\int_0^\infty z^2 f_\beta(z)\, dz}{\left[\int_0^\infty z\ f_\beta(z)\, dz\right]^2} = 1 + S_n^2 \tag{5}$$

where,

$$f_\beta(z) = \beta\, e^{-z}\, [1 - e^{-z}]^{\beta - 1} \tag{6}$$

The integral quotient $I(\beta)$ is a monotonically decreasing function with increasing β. Therefore, the solution of (5) for β is unique and globally convergent for any initial guess for β in the nonlinear root solver. The solution of (5) for β as a function of S_n is provided in Figure 2.

Once β has been estimated, the following estimate for the location parameter α is obtained as,

$$\frac{1}{\alpha} = \frac{\mu_w}{\ln(\beta) + \gamma + \frac{1}{2\beta}} \quad (7)$$

where $\gamma = 0.577$

is Euler's constant. The maximum power distribution function (3) with parameters β and α estimated by (5) and (7) respectively has proven to yield remarkably good fits to measured maximum power data samples in ship and submarine below-decks spaces.

A confidence level can now be established from the probability function in (3) such that the maximum received power w_x for a given input power P_{input} is not expected to exceed the value on the right-hand-side of (8),

$$w_x \leq -\frac{1}{\alpha} \ln\left(1 - x^{1/\beta}\right) \quad (8)$$

where x is the one-sided confidence level, e.g., x = 0.95 [7]. A cavity calibration factor (*CCF*), or normalized electric field in V/m/√W, characterizes the EME in the space [4],

$$CCF_x \equiv \frac{E_x^{max}}{\sqrt{P_{input}}} = \frac{8\pi}{\lambda}\sqrt{\frac{5}{\eta_{Rx}}\frac{w_x}{P_{input}}} \quad (9)$$

where w_x is taken as the upper-bound equality in (8). The quantity η_{Rx} is the efficiency of the receive antenna.

Once the cavity calibration factor has been determined for a space, the maximum electric field component amplitude in that space can be predicted to the given confidence level for any input power $P_{input.}$ For source-victim separations greater than a critical distance governed by free-space loss and antenna directivity, the maximum electric field at the victim will be dominated by the diffuse (multipath) field and can be estimated by,

$$E_x^{max} = CCF_x \sqrt{P_{input}} \quad (10)$$

where P_{input} is the total amount of power radiated into the space at the given frequency. (P_{input} is the summation of radiated power from each source in case of multiple emitters.) If the multiple sources are emitting at different frequencies within a given bandwidth, the superimposed maximum field environment can be approximated as the root-sum-square of the maximum fields established at each frequency by the sources. This is a necessary consideration if these multiple frequencies are within the susceptibility bandwidth of the equipment.

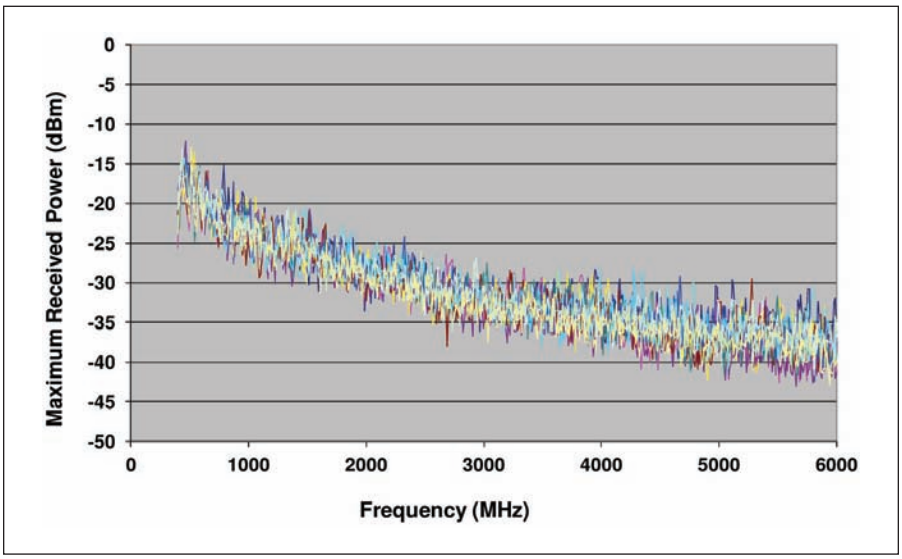


Figure 3: Maximum received power measurements from 12 walk-around trials in high-CCF space in submarine. Input power is 0 dBm.

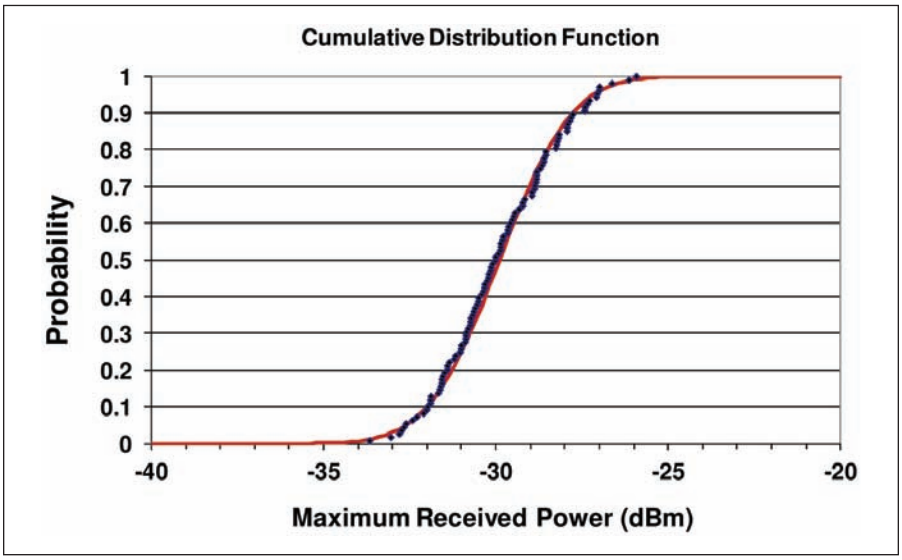


Figure 4: Cumulative distribution function of maximum received power values in high-CCF space in submarine. Input power is 0 dBm at 2.437 GHz.

MEASUREMENTS

The results of random-walk measurements with tracking generator/spectrum analyzer frequency sweeps on Max Hold are provided for two submarine spaces – one with high *CCF*, one with low *CCF*.

The random-walk technique is expected to report maximum values that would be generated from a large number of independent received power measurements obtained as the volume is source stirred and spatially sampled during the walk-arounds. Hence, measured data will demonstrate a "tight" variance in the maximum power distribution. This is confirmed by the very small variations of ±1-2 dB observed in the measured maximum power values in the laboratory setting of the reverberation chamber [6]. In the very complex environment of the submarine below deck, the variation in the collected maximum power data samples is expectedly larger, on the order of ±3-4 dB. This effect is demonstrated in the max-hold traces for the 12 walk-around trials in the submarine.

In addition, the cumulative distribution function in (3), estimated from the 108 maximum power data samples, is also obtained. A visual check on the statistical distribution function fit to the measured maximum received power data is provided. Lastly, the maximum electric field is predicted to a specified confidence level as a function of power emitted into the space. The predicted electromagnetic environment is compared to a maximum level specified for below-deck spaces in MIL-STD-464C [8].

The measured results for the high-*CCF* space are shown in Figures 3-5. The measured max-hold traces for the 12 walk-around trials are shown in Figure 3. The corresponding cumulative distribution function, estimated from 108 maximum power data samples around 2.437 GHz , is shown in Figure 4. The cavity calibration factor $CCF_{0.95}$ = 20.3 V/m/√W. In Figure 5, the maximum electric field environment is predicted at the 95% confidence level as a function of total radiated power (TRP) into the space.

The measured results for the low-*CCF* space are shown in Figures 6-8. The measured max-hold traces for the 12 walk-around trials are shown in Figure 6. The corresponding cumulative distribution function, estimated from 108 maximum power data samples around 2.437 GHz , is shown in Figure 7. The cavity calibration factor $CCF_{0.95}$ = 10.1 V/m/√W. In Figure 8, the maximum electric field environment is predicted at the 95% confidence level as a function of total radiated power (TRP) into the space.

EMI RISK MITIGATION

Wireless communications and sensor networks emit intentional radiated RF energy into the reverberant environment encountered in ship and submarine below-deck spaces. The resultant increase in the ambient electromagnetic environment (EME) has been identified as a cause of electromagnetic interference (EMI) to mission critical electronic

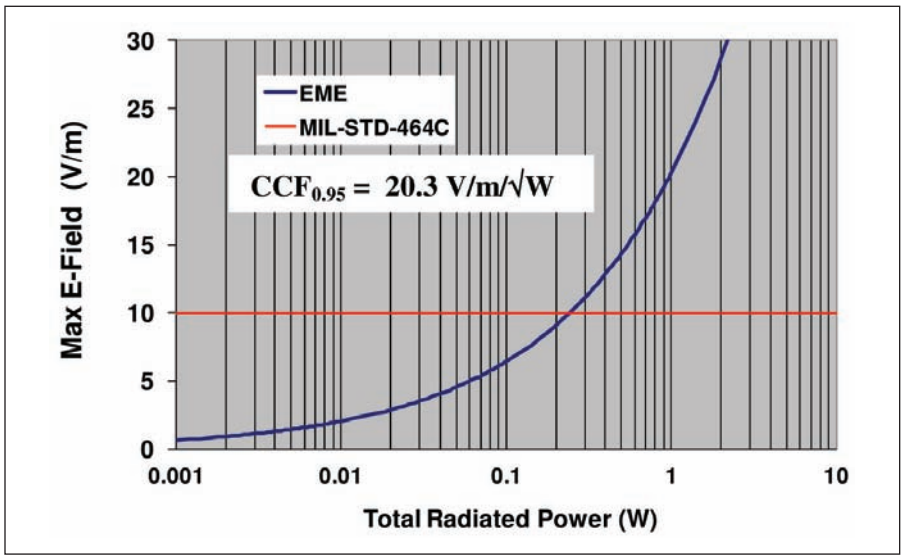


Figure 5: Maximum electric field predicted at 95% confidence level as a function of total radiated power into high-CCF space in submarine at 2.437 GHz.

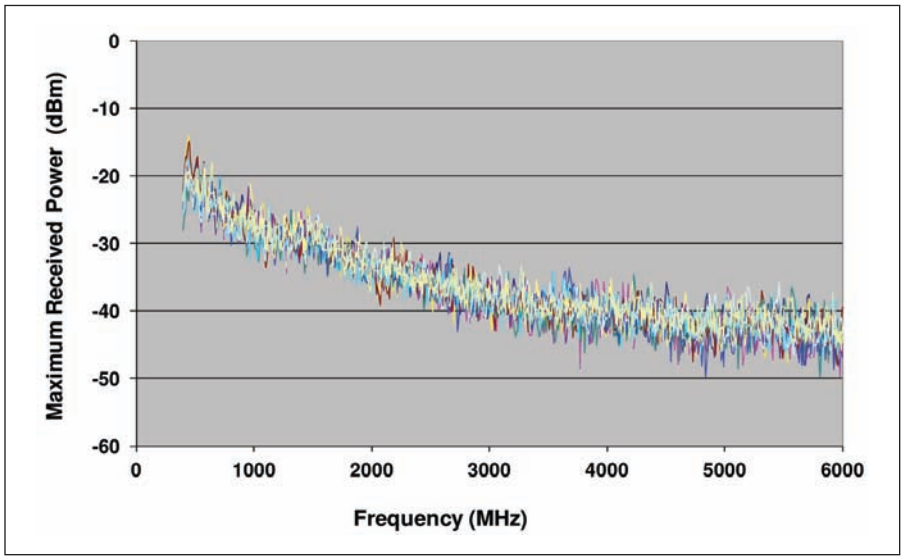


Figure 6: Maximum received power measurements from 12 walk-around trials in low-CCF space in submarine. Input power is 0 dBm.

equipments. Accordingly, interface controls are required to assure total system electromagnetic compatibility. MIL-STD-464C establishes electromagnetic environmental effects (E3) requirements for shipboard internal EME [8]. These EME limits are considerations when deploying wireless systems in below decks spaces.

EMI risk mitigation is based on alignment with a 10-V/m electric field radiated susceptibility requirement, RS103, of MIL-STD-461F [9] and guidance from MIL-STD-464C for ship internal EME. It is strongly recommended that electromagnetic compatibility testing of electronic equipment be conducted using a band-limited white Gaussian noise emission source in a reverberant test environment (a reverberation chamber or the actual/replicated in-situ below-deck space) [10]. Modern spread-spectrum digitally-modulated RF signals possess spectral and temporal properties that can present a more stressful waveform for interfering with electronic components and systems than can waveforms of CW or 50%-duty cycle 1-kHz pulsed signals. The wide power spectral density bandwidth, low temporal coherence time (rapid signal fluctuations), and large amplitude spikes of filtered white Gaussian noise RF emissions serve as upper-bound conditions for digitally modulated wireless RF emissions. Prior compatibility testing has been successful, but is costly and time-consuming, and verifies compatibility at only a single frequency and for a specific communications protocol. The development of a band-limited white Gaussian noise emission source capable of testing a wide swept frequency range, while providing a conservative worst-case test of digital wireless signal spectra and waveforms, enables a cost-effective electromagnetic compatibility test that can be used across all platforms.

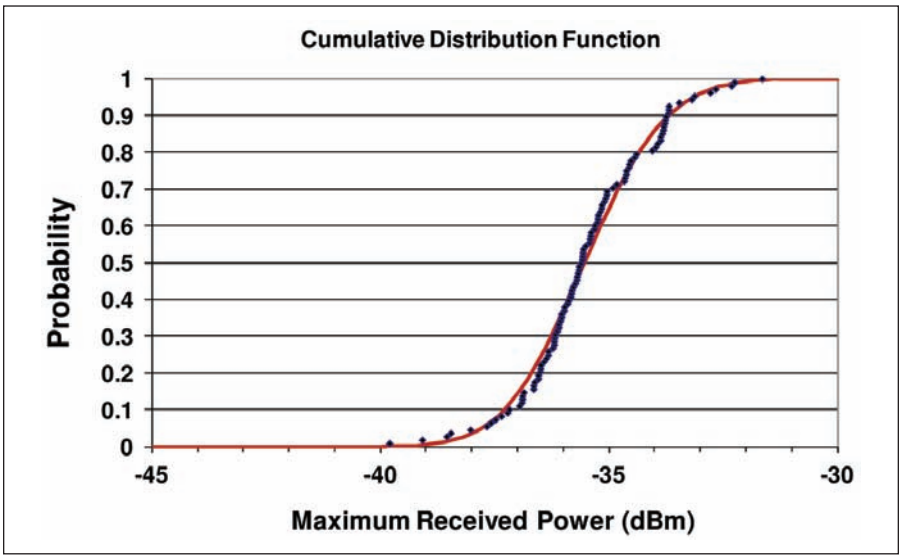


Figure 7: Cumulative distribution function of maximum received power values in low-CCF space in submarine. Input power is 0 dBm at 2.437 GHz.

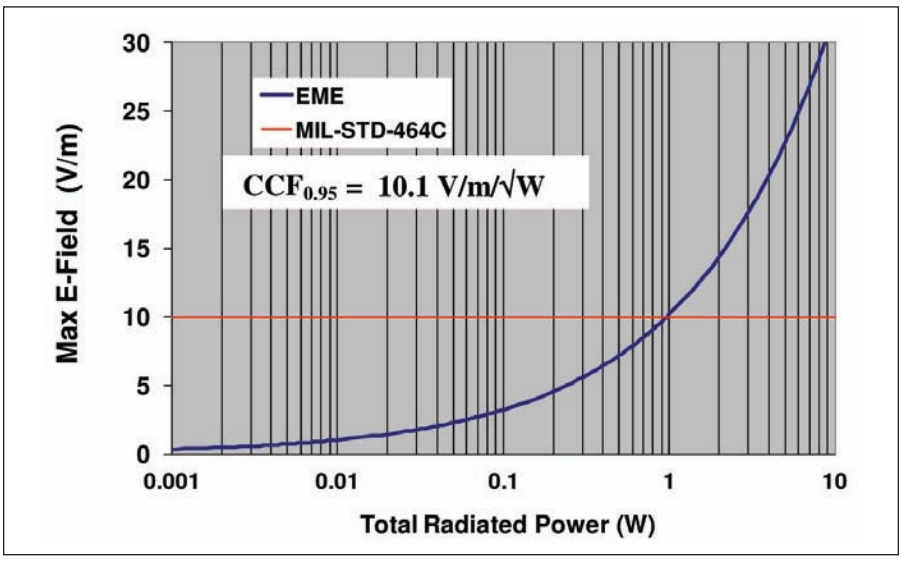


Figure 8: Maximum electric field predicted at 95% confidence level as a function of total radiated power into low-CCF space in submarine at 2.437 GHz.

The total radiated power (TRP) limit of 550 mW for multiple emitters in command and control spaces in surface ships is established in MIL-STD-464C to bound the total aggregate electric field that can build up in a reverberant space. The TRP limit can be applied individually to multiple, widely-separated frequency bands, such as uplink and downlink bands (e.g., 4G-LTE), or different WLAN bands (e.g., ISM, UNII). The maximum radiated power values from all emitters are summed to give the TRP value, giving consideration to available collision avoidance protocols, such as the carrier sense multiple access (CSMA) scheme.

The 550-mW TRP limit in MIL-STD-464C is obtained for a bounding condition $CCF = 13.5$ V/m/√W set from compiled measured data in command and control spaces. In spaces that have been shown by measurement

to have higher or lower reverberant property, i.e., a higher or lower cavity calibration factor (*CCF*), the TRP limit should be set at,

$$TRP(W) < \left[\frac{10\left(\frac{V}{m}\right)}{CCF\left(\frac{\frac{V}{m}}{\sqrt{W}}\right)}\right]^2 \quad (11)$$

In below-deck volumes that are not well-defined confined spaces, a 30-ft. radius sphere centered about each fixed access point can be used to identify individual sub-spaces contained within the larger volume. The TRP limit is applied within each spherical sub-space.

CONCLUSION

The electromagnetic environment created in ship and submarine below-deck spaces by wireless network RF emissions can be predicted from a cavity calibration factor (*CCF*) derived from in-situ maximum received power measurements and statistical complex cavity theory. A random-walk test technique has been developed and applied to measurements conducted in these reverberant spaces. With maximum field strengths predicted to a specified confidence level, it becomes possible to assess the compatibility of the wireless network with mission critical electronic equipments based on the MIL-STD-464C standard. Such assessments rely on knowledge of radiated power characteristics of all emitters and need to be informed by specific wireless network configuration and operating protocols. The use of band-limited white Gaussian noise as a stressful modulation waveform for robust susceptibility testing of electronic equipment and systems is also advocated as an up-front approach to risk mitigation. IN

REFERENCES

1. G.B. Tait, R.E. Richardson, M.B. Slocum, M.O. Hatfield, and M.J. Rodriguez, "Reverberant Microwave Propagation in Coupled Complex Cavities," *IEEE Transactions on Electromagnetic Compatibility*, Vol. 53, No. 1, pp. 229-232, Feb. 2011.

2. G.B. Tait, R.E. Richardson, M.B. Slocum, and M.O. Hatfield, "Time-Dependent Model of RF Energy Propagation in Coupled Reverberant Cavities," *IEEE Transactions on Electromagnetic Compatibility,* Vol. 53, No. 3, pp. 846-849, Aug. 2011.

3. G. Tait, M. Slocum, D. Hilton, C. Dilay, and D. Southworth, "Off-Hull Radio Frequency Emissions from Below-Deck Spaces in Ships," in Proc., 2010 IEEE International Symposium on EMC (Ft. Lauderdale, FL), July 2010, pp. 875-880.

4. IEC 61000-4-21, Electromagnetic Compatibility (EMC) – Part 4-21: Testing and measurements techniques – Reverberation chamber test methods, International Electrotechnical Commission, 2008.

5. D.A. Hill, Electromagnetic Fields in Cavities: Deterministic and Statistical Theories. New York: Wiley-IEEE Press, 2009.

6. G.B. Tait and M.B. Slocum, "Random Walk Technique for Measuring the Electromagnetic Environment in Electrically-Large Reflective Spaces," *IEEE Transactions on Instrumentation and Measurement,* Vol. 60, No. 3, pp. 1003-1009, March 2011.

7. N. Wellander, O. Lunden, and M. Backstrom, "The maximum value distribution in a reverberation chamber," in Proc. IEEE Int. Symp. Electromagnetic Compatibility (Montreal, Canada), Aug. 2001, vol. 2, pp. 751-756.

8. DoD Interface Standard MIL-STD-464C: Electromagnetic Environmental Effects Requirements for Systems, Department of Defense, Dec. 2010.

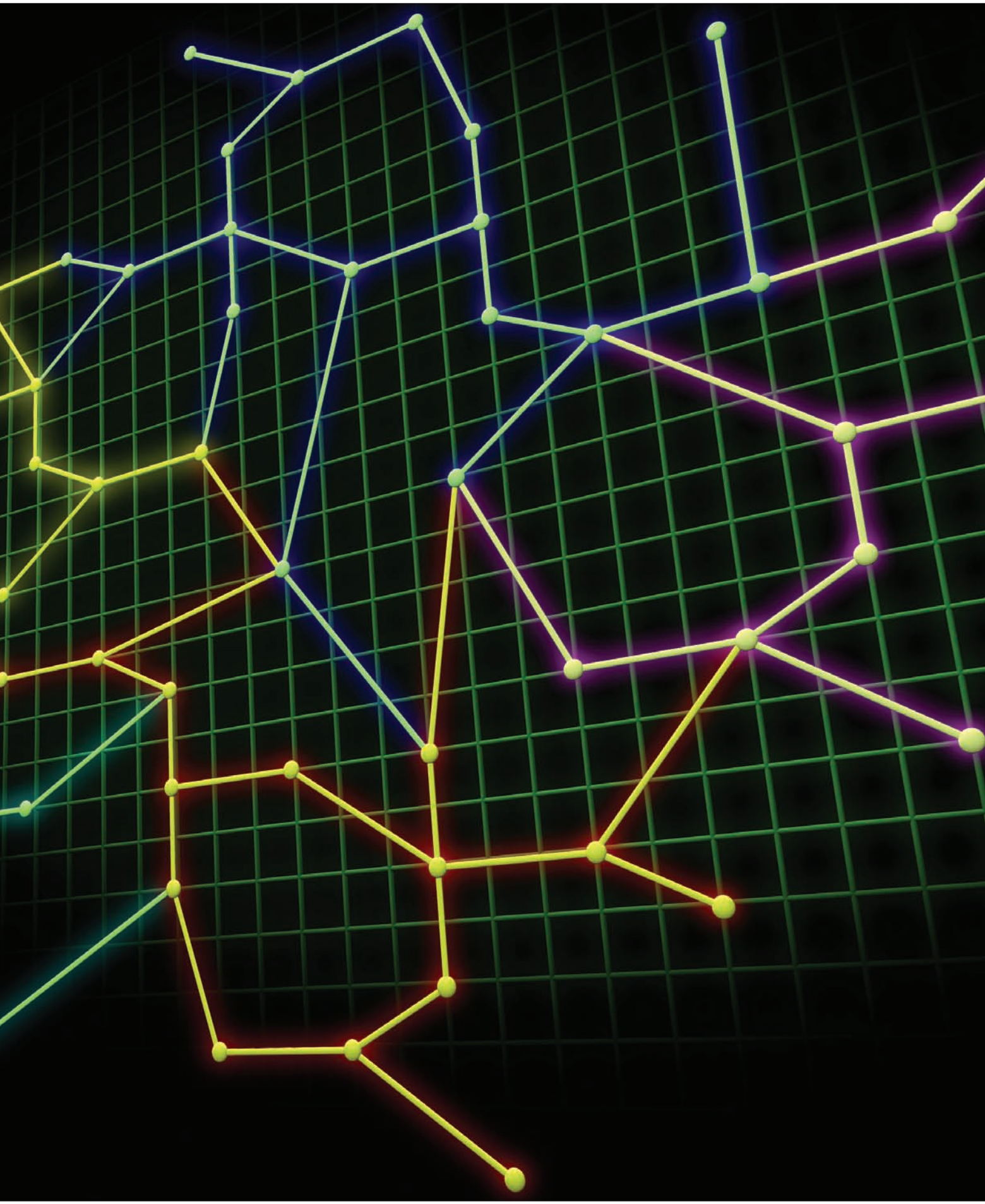
9. DoD Interface Standard MIL-STD-461F: Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, Department of Defense, Dec. 2007.

10. C. Lins-Morstadt, M. Slocum, and G. Tait, "Emission Source for Compatibility Testing of Wireless Networks in the Below-Deck Environment on Ships," in Proc., 2012 IEEE International Symposium on EMC (Pittsburgh, PA), Aug. 2012, pp. 480 – 485.

(the author)

GREGORY TAIT
is currently an electrical engineer with the Electromagnetic and Sensor Systems Department at the Naval Surface Warfare Center Dahlgren Division in Dahlgren, VA. He earned the PhD degree in Electrical Engineering from The Johns Hopkins University. Areas of current interest include stochastic electromagnetics in complex cavities and wireless signal propagation in coupled reflective spaces.

PAUL OPPERMAN
is an electrical engineer with the Submarine Electromagnetic Environmental Effects (E3) Branch at the Naval Undersea Warfare Center in Newport, RI. He holds a Bachelor of Science degree in Electrical Engineering from Boston University. His current efforts include platform level E3 design of submarines, wireless system integration, E3 modeling, and intelligent data processing.



Corona Noise Considerations for Smart Grid Wireless Communication and Control Network Planning

As the wireless receiver sensitivity levels surpass thermal noise levels, reliable operation of smart grid Distributed Generating System (DGS) wireless communication and control devices demands consideration of the power line produced noise spectrum. The power line noise spectrum varies based on voltage and current of transmission lines and load characteristics. The electrical-noise environment is anticipated to be more severe in a DGS than in a Conventional Electrical Power System (CEPS) due to the frequent changes in power distribution routing.

BY DHEENA MOONGILAN

While most measurable noise occurs at frequencies less than 200 MHz, the corona noise spectrum extends up to 2000 MHz. The corona noise spectrum measured near a 26 kV substation was compared with corona generated in the laboratory. Using this data, in-band wireless receiver susceptibility levels for GSM, CDMA and LTE modulation techniques were experimentally evaluated and presented.

INTRODUCTION

Reliable power distribution systems require smarter distribution and control of all accessible quality power generation resources to meet load demands with fewer interruptions. The power distribution system must withstand any loss of a transmission line or a generating station. The voltage, frequency, and steady state and transient stability of power must be within acceptable tolerances. The power distribution system should be safe, secure, low cost, and efficient [1]. An interconnected Distributed Generating System (DGS) with multi-users and multi-generators is inevitable for a smart grid power distribution system. In order to control the components of the DGS, a reliable communication and information exchange system is necessary. The control system should have the ability to monitor and control the generating systems, transmission lines, distribution, distribution substations, and loads connected to the DGS. The control system, sensors, energy meters and communication and information exchange systems should have the ability to operate as intended and should not be susceptible to electrical noise produced either by the DGS or anticipated in the ambient environment. Electrical noise, that exceeds some threshold, will affect timely information flow, decision making processes, and control system function [2].

This article examines the electrical noise spectrum in a typical Conventional Electrical Power System (CEPS) environment. Based on the environmental noise spectrum evaluated, an analysis of the suitability of a reliable and secure wireless communication and control system for DGS operation is presented. Further, an overview of RF noise present in the transmission and distribution system environment is also discussed. Finally, the radiated frequency spectrum is presented for corona noise demonstrating how the corona noise at wireless system in-band frequencies will degrade the receiver sensitivity.

CONVENTIONAL ELECTRICAL POWER SYSTEM (CEPS) AND DISTRIBUTED GENERATING SYSTEM (DGS)

The CEPS architecture resembles an inverted tree in which the generating station is the main trunk, and the branches are transmission lines connected to loads [3]. The power transmission is unidirectional from the generating station to the loads. In contrast, the evolving smart grid DGS transmission architecture resembles a cellular or aero-mobile communication network architecture in which the power flow at any moment could be from any obtainable generating station (local or remote) to any load. Therefore, DGS transmission is characterized by frequent "make" and "break" dynamic architecture as compared to the inherently fixed or static nature of the CEPS architecture. The direction of power flow in DGS transmission lines are constantly changing.

In a DGS, the user and generator interconnected network architecture will be constantly reconfigured depending on power needs and power availability. The computation of anticipated load and available power at any instant must be known. Otherwise, any short circuit condition will lead to a voltage dip and an increase of current (10 to 1000 times) and the clearance of the short circuit condition leads to oscillations. Sudden loss of any generating station results in a drop in voltage while a loss of load results in a rise of voltage on the active part of the network. Any fault clearance typically takes two to three cycles [4], with circuit breakers clearing the fault condition producing corona and arcing for a half to one cycle. The transmission system connects a network of numerous loads and several generating sources. To restore a power system failure, an increment of generating sources must be matched to an increment of loads, then move on to next matching generators and loads. The duration of this matching process may be on the order of several seconds. The electrical noise produced by a DGS is expected to be much more severe than noise produced in CEPS because of frequent power connection and disconnection, controls, and several synchronization processes. Reactive loads in CEPS are typically corrected using centralized compensators. In a DGS, computing and compensating for reactive loads is a major challenge. The excessive reactive power creates over voltage and current conditions on the transmission lines produce corona and sometimes arcing. The transients and steady state noise produced in a power system is electromagnetic in nature and their time, location and severity of occurrence is random. A conceptual simple architecture of a DGS is shown in Figure 1.

ELECTRICAL NOISE IN DGS

The DGS may contain both common mode and differential mode electrical noise. Both noise types conduct and radiate through electrical circuits and associated metallic structures. The common mode noise flow is in the same direction on the live power conductors but flows differentially with respect to the ground conductors. The differential mode noise on any two power conductors is equal in magnitude but the flow is in opposite direction. The power loop area is one of the primary factors that must be considered for deciding the radiated emissions levels. The large loop areas produce the greater radiation. For differential mode noise radiation, the loop area formed between live power conductors must be considered, while, for common mode radiation, the loop area formed between live power conductors and ground conductor must be considered. In un-terminated or open circuited transmission lines, the loop area is formed through the free space similar to a monopole antenna [5]. The electrical noise source could be either from the loads, the DGS, or from natural events (for example, lightning). The noise produced in consumer loads such as electronic and digital devices connected to a DGS are regulated by government agencies (such as FCC, EU and VCCI etc.,) and will not be discussed here. Some electrical noise sources typically found in power system are noted.

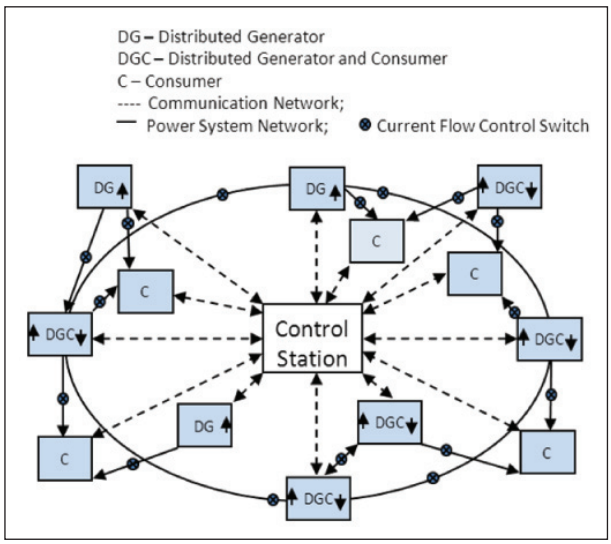


Figure 1: A conceptual architecture of distributed generator system

1. Power sysem that contains non-sinusoidal voltages.
2. Voltage fluctuations, dips and interrupts.
3. Switchgear noise due to circuit opening and closing.
4. Oscillatory transients.
5. Power surges.
6. Power Line Communication (PLC) noise.
7. Ctorona, Gap discharge and arcing.
8. Lightning.

The electrical noise spectrum from Items (1) through (5) above is typically lower than 100 MHz [6]. The PLC produces broad spectrum of noise [7, 8]. The noise spectrum will be based on a single channel data rate and bandwidth of the transmission. The corona, Gap discharge, arcing and lightning noise spectrum extends up to 2 GHz. However, for a typical lightning event, there is significant noise below 200 MHz. Similarly the corona, Gap discharge and arcing events have significant noise below 1000 MHz. The lightning surge frequency spectrum has been studied by several researchers and is indicated in the references [6, 9]. The Gap discharge and arcing frequency spectrum details will not be discussed here. The corona radiates a periodic broadband spectrum for prolonged periods. Therefore, it is one of the interference nuisances to RF devices. The corona radiation effects on the wireless system receiver sensitivity levels are discussed below.

CORONA

Corona is due to accelerated partial ionization, breakdown or discharge of gas molecules or atoms between two conductive surfaces under the influence of high electric fields that could appear as a blue luminous glow with a current typically measured in microamperes [10]. The corona occurs between conductive surfaces where there is a large concentration of charges and at smaller distance from the reference electrode.

At its onset, the corona will be intermittent or pulsating, and if the field is further increased, the corona current reaches a steady state. When the electric field is increased further there will ultimately be a transient or steady state arcing or sparking occurrence with a sudden jump in current.

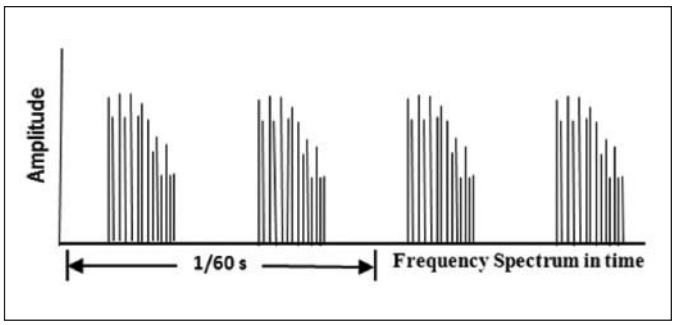


Figure 2: Radiated corona periodic broadband spectral distribution from single phase AC power

The arcing voltage is typically two to six times the corona voltage. The corona does not completely connect the conductive surfaces of electrodes, but arcing bridges the conductive surfaces of electrodes. The corona inception voltage is higher for longer gap distances. But the relationship depends on the dielectric constant, temperature, pressure, and other physical variations between the gap surfaces. The corona is a high impedance phenomena occurring at high voltage and lower current. Not all corona charges from one electrode reach the other. Some portion of charges escapes from the corona and is radiated. Therefore, corona is an interference nuisance to RF devices. The corona radiates a periodic broadband spectrum. A typical corona radiation pattern is shown in Figure 2. As shown in Figure 2, the corona noise period is two times per power cycle.

RADIATED CORONA SPECTRUM MEASUREMENT IN A GHZ TRANSVERSE ELECTROMAGNETIC (GTEM) CELL

Corona frequency spectrum is a well understood subject. The corona itself can directly radiate RF energy without aid of an antenna. The corona frequency spectrum data presented in most publications do not isolate the radiations from the electrical support structure used for corona simulation. The electrical structure could act as an antenna or tuned element and alter the radiation characteristics of the corona stream. The corona streams *direct radiation* is measured and presented in this section in its isolated form.

The radiating frequency spectrum of a corona was investigated in a GTEM cell. The GTEM Cell is a frequency extended variant of the traditional Transverse Electromagnetic (TEM) cell. The GTEM Cell is a large tapered section coaxial stub with air dielectric and a characteristic impedance of 50 _. One end of the stub is a feeding point and the other end is terminated by a combination of non-inductive high power resistors and RF absorbers. When a radiating object is placed between the center plane and outer ground plane, the total radiated power is directly proportional to the power measured at the apex of the GTEM. The radiated power level varies as inverse of distance 'd' between center plane and bottom ground plane. The GTEM supports a frequency spectrum from DC to several GHz. A 25 cm long coaxial cable mounted in the GTEM was used for generating corona. The center conductor at one end of the coaxial cable was looped back closer to the outer metallic shield as shown in Figure 3 (page 40). The approximate diameter of the loop was 2 cm. The gap between the tip of the center

conductor and the metallic shield of the coaxial cable was approximately 2.5 mm. The loop was placed between the GTEM center plane and the bottom ground reference plane, approximately at the center. The diameter of the loop was small enough so that the radiation contribution due to the loop was negligible up to 1 GHz. Several broadband suppression ferrites were added to the coaxial cable to prevent the cable from acting as a monopole antenna. A high voltage single phase AC generator was connected to other end of coaxial cable through the GTEM bottom ground reference plane. For these tests, voltage input applied to the coaxial cable ranged approximately from 2 to 4.5 kV. The stream of produced corona was approximately perpendicular to center plane of GTEM. The loop was rotated in its upright position 360° to provide for highest emission angle. At this angle, the frequency spectrum was measured and plotted for 2.5 mm, 7.5 mm and 10 mm gaps for frequencies between 30 and 1000 MHz. The data plot is presented for 10 mm gap in Graph 1. This setup provides a source of directly radiated corona spectrum that is mostly unaffected by the electrical supporting structures or polluted by the ambient environment. The generated energy spectrum of directly radiated corona is therefore available for use experimentally to compare against other types of interfering signals as applied to real world systems.

RADIATED CORONA SPECTRUM MEASUREMENT FROM 26 KV SUBSTATION

The radiated emission measurements from a local 26 kV/208V sub-station are presented in Graph 2. The measurements were made at an approximate 25 m horizontal distance from the radiating corona transmission conductors connected to string-insulators in the sub-station. The antenna and spectrum analyzers were located at an elevated location relative to the sub-station such that the radiating corona source from the sub-station was in line with the antenna. RF absorbers were placed on the sides and rear of the receive antenna to minimize the ambient noise. An investigative received power level measurement was made for both horizontal and vertical polarization using a broadband bi-log antenna. The received power levels were higher for the vertical polarization of the antenna and are therefore reflected in the plot. To maximize the received signal levels the antenna was moved 1 m distance horizontally and then vertically prior to recording the maximum levels. According to Friis transmission equation [11]

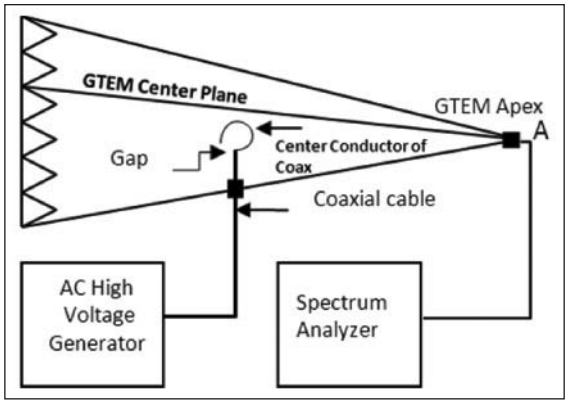


Figure 3: Test setup from measuring corona spectrum in GTEM cell

$$P_r/P_t = (\lambda/4\pi R)^2 G_{or}\, G_{ot} \qquad (1)$$

- P_r is power delivered to any load (Example: 50Ω receiver antenna port)
- P_t is power input to transmit antenna (in this case, it is part of corona stream power that is being radiated)
- G_{ot} is transmit antenna isotropic gain
- G_{or} is measurement antenna (Broadband bi-log) isotropic gain
- λ = free space wavelength of the measured frequency
- R = measurement distance
- $(\lambda/4\pi R)^2$ is free space propagation loss(L) derived in Equation 3

The predicted effective isotropic received power level (P_r/G_{or}) in "dBm" at the measurement distance = (Analyzer reading in dBm – G_{or} in dBi) (P_r/G_{or}) at any linear distance (R) between the radiating source and receive antenna = L (Pt G_{ot}) (2)

Graph 2 shows the measured noise power levels (P_r/G_{or}) in "dBm" for the frequency range from 30 to 1000 MHz. The measurements were made when corona illuminations were observed on certain parts of the conductor. The number of conductors and number of phases involved in corona illumination could not be accurately determined. The Graph indicates that radiation levels extend to 1000 MHz, but the power levels gradually decrease with increasing frequency.

CORONA FIELD LEVEL CALCULATION AT CLOSER DISTANCE

Both Graphs 1 and 2 reveal the existence of a significant amount of radiated power up to 1000 MHz. Graph 2 indicates the measured received power level from the antenna near 1 GHz is -65 dBm at a 25 m distance. If it is assumed that the measuring instrumentation or control wireless transceiver for a DGS must be placed at 1 m distance from the transmission lines on a pole, the expected power level at the receive antenna port at 1 m distance can be calculated using the following Friis free space narrowband propagation path loss (L) equation. (Assuming that the path is clear of terrain or other objects and measurements are made in far-field.)

Free space propagation loss (L) = 20 $\log_{10}$ (Distance in meters) + 20 log10 (Frequency in MHz) – 27.56 dB (3)

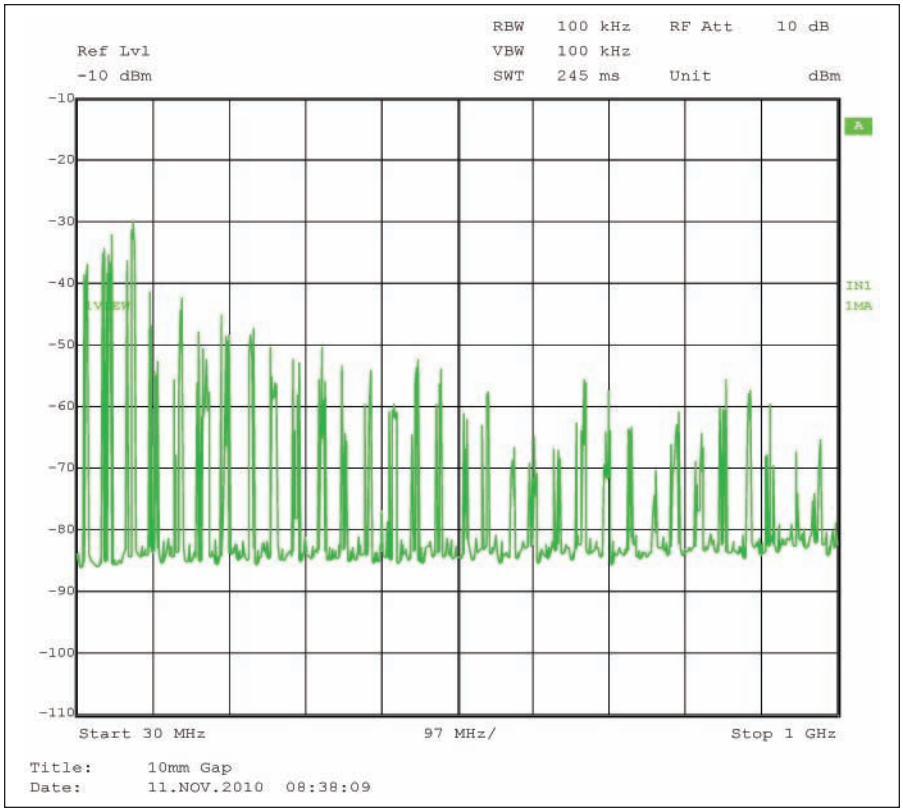
Equation 3 is also successfully applied to broadband short distance propagation loss calculations [12]. The calculated loss (L) at 1000 MHz for 24 m is 60 dB Therefore, the field power at a 1 m distance from the corona producing transmission line is calculated to be -5.0 dBm The effective average field power will be based on the duty cycle of the noise which is the ratio of pulse width and pulse repetition rate.

For pulsed RF, the effective average power is 10 log10 (duty cycle). For 60 Hz power, the pulse repetition rate is 8.3 ms, but the corona noise pulse width for a given spectrum bandwidth is difficult to measure. The corona noise pulse width increases with AC field intensity (kV/cm) between the corona stream conductors. If a 1% duty cycle is assumed, then the effective received average power for the same setup at 1 m distance from the radiating source is -25 dBm.

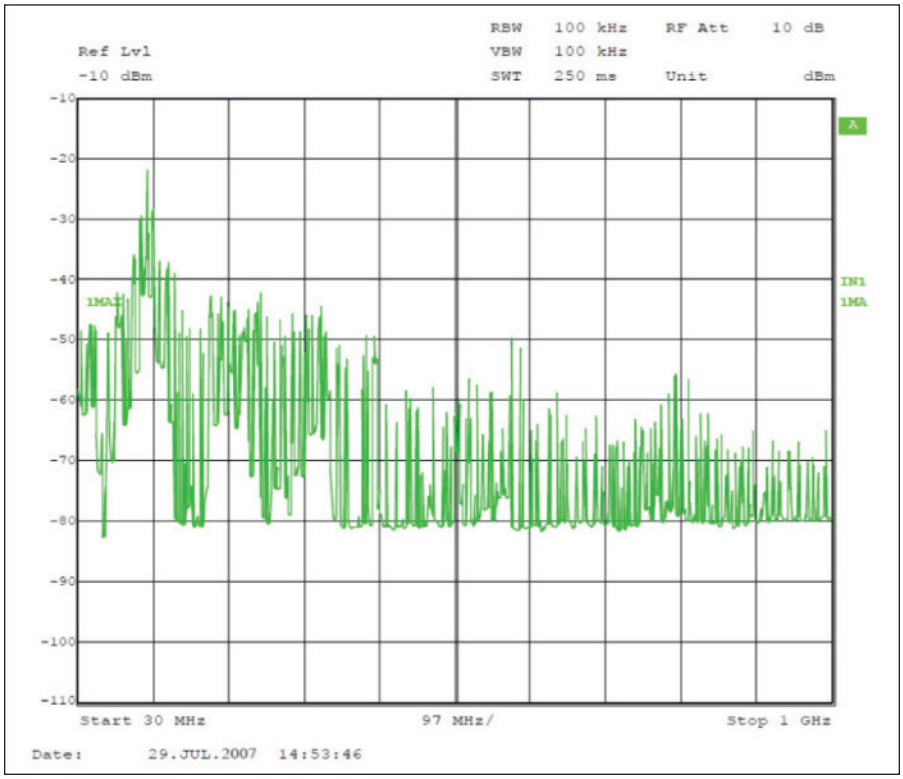
In the absence of interfering noise, the modern wireless receivers using typical antenna are capable of processing signal levels lower than thermal noise levels (-114 dBm/MHz at room temperature). Therefore, the corona noise level is considered very high when compared to the sensitivity of a typical Cellular receiver which is approximately -120 dBm/MHz. This clearly demonstrates that corona radiation must be considered before planning any wireless communication system for controlling the DGS.

WIRELESS COMMUNICATIONS SYSTEM FOR DGS CONTROL FUNCTIONS

In-band noise is the primary concern for any wireless communication system. In-band noise degrades the ability of the communication system to receive low signal levels. There are no dedicated wireless frequency bands available for electrical power system



Graph 1: Radiated frequency spectrum of corona measured from a 10 mm gap



Graph 2: Radiated frequency spectrum of corona measured from a 26kV Substation at 25m distance

controls. Either unlicensed or licensed bands must be used for wireless controls. The corona noise will affect both the unlicensed and licensed bands operating below 1000 MHz.

Although the modern wireless receivers are capable of functioning with the signal levels much lower than the noise levels, the overall signal to noise ratio is still important. For most data systems, after some noise threshold level is reached, the error rate will increase with increasing noise. The comparison of corona (noise) to signal frequency bandwidth and 1% error amplitude is as shown in Figure 4.

Corona Noise and Cellular Base station Receiver Sensitivity

The minimum required signal-to-noise ratio (S/N) of wireless systems must be maintained in order to have a reliable communication link. The presence of increased in-band interference at the antenna receive port requires that the desired signal level must be increased to maintain the S/N ratio. The noise immunity levels are dependent on the wireless devices modulation techniques and receiver bandwidths. The noise immunity levels for the following modulation techniques were investigated using a 1900 MHz GSM Base Station, an 850 MHz CDMA Base Station and a 700 MHz LTE Base Station:

1. GSM (200 kHz)
2. CDMA (1.25 MHz)
3. LTE (5MHz)
4. LTE (10 MHz)

The test setup is shown in Figure 5. The receive port of the base station was tested with a continuous wave (CW), a fixed frequency modulated signal, a random frequency noise level and laboratory generated corona, and the processed demodulated signal was analyzed for data error. Since there are several variations in the operations of diversity ports, they were disengaged during the tests. The modulated signal was fixed at -90 dBm for all tests and no data error was noted at this level. The input noise power level was then increased until a 1% data error was observed.

The following input signals were used as noise:

(a) Continuous Wave (CW) signal

(b) 1 kHz 80% AM signal

(c) Random CW signal to sweep the receive frequency bandwidth at an 8 ms repetition rate. The AC corona noise spectrum repeats at

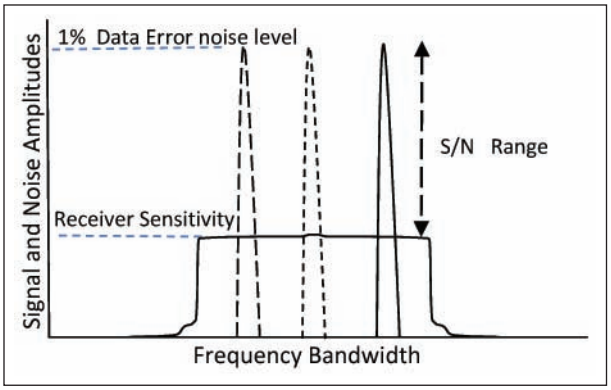


Figure 4: Corona noise level is higher than receiver sensitivity levels

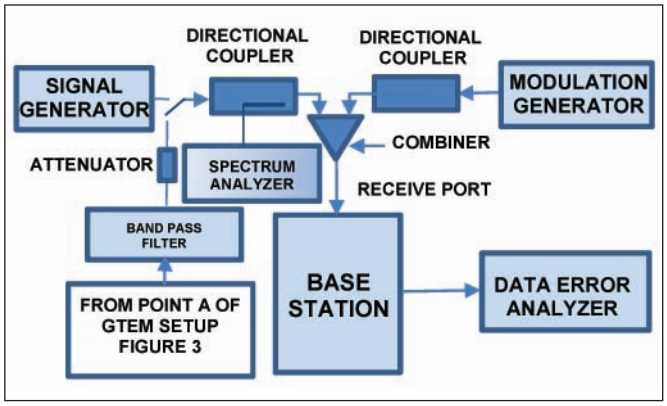


Figure 5: Base station receive port noise immunity test setup

Modulation Technology	Noise Source level above the signal level			
	CW dB	1 kHz 80% AM dB	In-Band random CW at 8 ms repetition rate dB	In-Band corona from GTEM dB
GSM (200 kHz)	10	8	10	**
CDMA (1.25 MHz)	20	18	20	15
LTE (5 MHz) - QPSK	42	42	40	34
LTE (5 MHz) – 64 QAM	37	37	37	32
LTE (10 MHz) – 64 QAM	40	40	40	34

Notes: ** Insufficient corona signal at 1900 MHz **Table 1: Noise level in dB above the signal level for data error reaching approximately 1%**

Table 1: Noise level in dB above the signal level for data error reaching approximately 1%

every half power cycle of power (See Figure 2). For 60 Hz power the half cycle duration is 8.3 ms. Since 8.3 ms repetition rate signal was not available, an 8.0 ms repetition rate signal was used instead.

(d) GTEM generated corona noise at the receiver frequency bandwidth.

The noise signals (a) and (b) were applied at the center frequency of the receive channel. The noise immunity levels for 1% data error for different modulation technologies are shown in Table 1. Noise levels approximately 6 to 10 dB above 1% data error produce a sudden increase in data error (50 to 60% data error) rendering the system useless.

The wireless control stations for DGS will be installed at fixed locations. Therefore, the receiver operating range sensitivity levels can be fixed accounting for the anticipated noise levels and calculated link budget. The corona noise impact levels for a 1% data error are much higher than the signal levels. Therefore, implementation of a noise amplitude limiter circuit can solve the corona noise problems.

CONCLUSIONS

Mapping the land line communication along the power transmission lines for DGS communication and control is one of the major technical and economic challenges. Therefore, wireless should be a more viable alternate. The electrical power noises associated with corona, arcing and lightning will seriously degrade the communication and control frequency band spectrum usage. The immunity test results provided in Table 1 show that wireless system is more susceptible to corona spectrum than the CW or modulated CW signals. The noise levels will be severe, especially during extreme weather conditions when most power outages are likely to occur. This article establishes that Corona has a significant noise frequency spectrum up to 1 GHz. Published works show that extremely high voltage transmission lines produce corona noise up to 2 GHz [13]. For any frequency spectrum use for wireless communication below 2 GHz then special consideration should be provided as follows:

- Plan the link budget so that low sensitivity wireless communication devices may be employed.
- Consider use of broadband wireless communication systems for minimizing interference.
- Modulation techniques using OFDM (such as WiMax and LTE) are more secure and reliable compared to other modulation techniques.

REFERENCES

1. K. Budka et al., "GERI- Bell Labs Smart Grid Research Focus: Economic modeling, Networking, and security and Privacy", 2010 IEEE International Conference on Smart Grid Communication", pp 208-213.
2. IEEE Std 2030, "IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads, 2011, pp 6-13.
3. T.M. Overman, R.W. Sackman, "High Assurance Smart Grid: Smart Grid Control Systems Communications Architecture", 2010 IEEE International Conference on Smart Grid Communication", pp19-24.
4. M.Pavela, P.G.Murthy, "Transient Stability of Power Systems (Theory and practice)" John Wiley & Sons, 1994, pp 4.
5. D. Moongilan, "Radiation characteristics of short unterminated transmission lines", 2009 IEEE International Symposium on Electromagnetic Compatibility, pp 57 – 62.
6. E. N. Skomal, A. A. Smith, Jr., "Measuring the radio frequency environment", Van Nostrand Reinhold Company Inc., 1985 pp 305-311.
7. S. Gali, A. Scaglione, Z. Wang "Power line communication and Smart Grid", 2010 IEEE International Conference on Smart Grid Communication", pp 303-308.
8. M. Tanaka, "High frequency noise power spectrum, impedance and transmission loss of power Line in Japan on intra building power line power line communications", IEEE Transactions on consumer Electronics, Vol. 34, No.2, May 1988 pp 321-326.
9. C. Leteinturier, J. H. Hamelin, A. Eybert-Berard "Submicrosecond characteristics of lightning return-stroke currents.", IEEE transaction on Electromagnetic Compatibility, Vol.33, No.4., November 1991, pp351 - 357.
10. D. Moongilan, "Corona and arcing in power and RF devices" 2009 IEEE Symposium on PSES, pp 1-7
11. C.A. Balanis "Antenna Theory Analysis and Design; 3rd Edition, John Wiley & Sons 2005, pp95
12. H.R. Anderson, "Fixed Broadband Wireless System Design" John Wiley & Sons, 2003, pp 31
13. W.E. Pakala, V.L. Chartier , "Radio noise measurements on overhead power lines from 2.4 to 800 kV," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-90, No.3, May/June 1971, pp. 1155 - 1165.

This article won the Symposium Best Paper Award at the 2012 IEEE International Symposium on Electromagnetic Compatibility in Pittsburg PA.

(the author)

DHEENA MOONGILAN

is a Distinguished Member of Technical Staff at Bell Laboratories of Alcatel-Lucent. He is a Principal EMC design Consultant for Alcatel-Lucent. He has published 20 formal IEEE papers on EMC and holds two US patents. He is a NARTE certified EMC Engineer and Master EMC Design Engineer. He holds a B. E. in electrical engineering and a M. S. E. E. from the College of Engineering at Madras University in Guindy, India, and M. S. E. E. computer engineering from the Illinois Institute of Technology in Chicago.

ESD Standards: An Annual Progress Report

BY THE ESD ASSOCIATION

Industry standards play a major role in providing meaningful metrics and common procedures that allow various manufacturers, customers, and suppliers to communicate from facility to facility around the world. Standards are increasingly important in our global economy.

In manufacturing, uniform quality requirements and testing procedures are necessary to make sure that all involved parties are speaking the same language. In ESD device protection, standard methods have been developed for component ESD stress models to measure a component's sensitivity to electrostatic discharge from various sources. In ESD control programs, standard test methods for product qualification and periodic evaluation of wrist straps, garments, ionizers, worksurfaces, grounding, flooring, shoes, static dissipative planar materials, shielding bags, packaging, electrical soldering/desoldering hand tools, and flooring/footwear systems have been developed to ensure uniformity around the world.

The EOS/ESD Association, Inc. (ESDA) is dedicated to advancing the theory and practice of electrostatic discharge (ESD) protection and avoidance. The ESDA is an American National Standards Institute (ANSI) accredited standards developer. The Association's consensus body is called the Standards Committee (STDCOM) which has responsibility for the overall development of documents. Volunteers from the industry participate in working groups to develop new and to update current ESDA documents.

STDCOM is charged with keeping pace with the industry demands for increased performance. The existing standards, standard test methods, standard practices, and technical reports assist in the design and monitoring of the electrostatic protected area (EPA), and also assist in the stress testing of ESD sensitive electronic components. Many of the existing documents relate to controlling electrostatic charge on personnel and stationary work areas. However, with the ever increasing emphasis on automated handling, the need to evaluate and monitor what is occurring inside of process equipment is growing daily. Since automation has become more dominant, the charged device model (CDM) has become the primary cause of ESD failures and thus the more urgent concern. Together, the human body model (HBM) and charged device model cover the vast majority of ESD events that might occur in a typical factory.

The ESD Association document categories are:

- **Standard (S):** A precise statement of a set of requirements to be satisfied by a material, product, system or process that also specifies the procedures for determining whether each of the requirements is satisfied.
- **Standard Test Method (STM):** A definitive procedure for the identification, measurement and

ESD Association Document Categories

- **Standard (S):** A precise statement of a set of requirements to be satisfied by a material, product, system or process that also specifies the procedures for determining whether each of the requirements is satisfied.
- **Standard Test Method (STM):** A definitive procedure for the identification, measurement and evaluation of one or more qualities, characteristics or properties of a material, product, system or process that yield a reproducible test result.
- **Standard Practice (SP):** A procedure for performing one or more operations or functions that may or may not yield a test result. Note, if a test result is obtained it may not be reproducible.
- **Technical Report (TR):** A collection of technical data or test results published as an informational reference on a specific material, product, system or process.

evaluation of one or more qualities, characteristics or properties of a material, product, system or process that yield a reproducible test result.

- **Standard Practice (SP):** A procedure for performing one or more operations or functions that may or may not yield a test result. Note: if a test result is obtained it may not be reproducible.
- **Technical Report (TR):** A collection of technical data or test results published as an informational reference on a specific material, product, system or process.

The ESDA Technology Roadmap is compiled by industry experts in IC protection design and test to provide a look into future ESD design and manufacturing challenges. The roadmap previously pointed out that numerous mainstream electronic parts and components would reach assembly factories with a lower level of ESD protection than could have been expected just a few years earlier. This prediction has proven to be rather accurate. As with any roadmap, the view of the future is constantly changing and requires updating on the basis of technology trend updates, market forces, supply chain evolution, and field return data. An updated roadmap has been published in March 2013 and industry experts extended the horizon beyond the 2013 predictions. It contains, for the first time, a roadmap for the evolution of ESD stress testing. This includes forward looking views of possible changes in the standard device level tests (HBM and CDM), as well as the expected progress in other important areas, such as transmission line pulsing (TLP), transient latch-up (TLU), cable discharge events (CDE), and charged board events (CBE). A view of work on electrical overstress (EOS) has also been included. EOS is an area that has long been overlooked by the industry, not because it was not important but because it could be a difficult threat to define and mitigate. Recently, a working group has been focusing on this area and will soon be publishing a Technical Report (TR) that helps establish some fundamental definitions and distinctions between various EOS threats. The TR will be followed up with a "best practices" document outlining ways to mitigate EOS threats. Another development has been a request by the aerospace industry for an ESD control document that defines more definitively what ESD controls need to be in place in factories that are in the aerospace industry. This document will be predicated on ANSI/ESD S20.20 but will introduce further limits and controls.

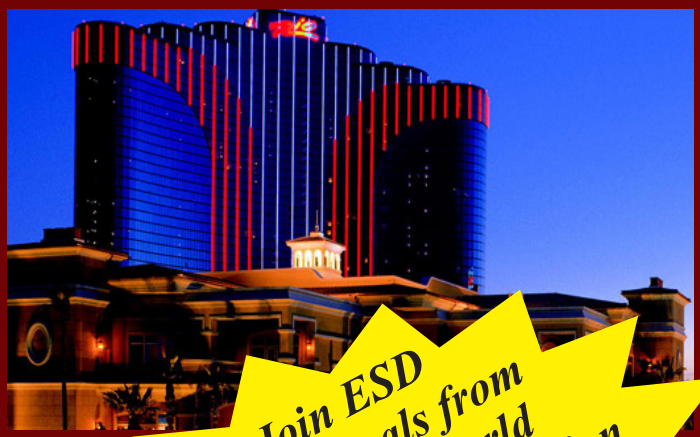
The ESDA Standards Committee is continuing several joint document development activities with the JEDEC Solid State Technology Association. Under the Memorandum of Understanding agreement, the ESDA and JEDEC formed a joint task force for the standardization work in which volunteers from the ESDA and JEDEC member companies can participate. This collaboration between the two organizations has paved the way for the development of harmonized test methods for ESD, which will ultimately reduce uncertainty about test standards among manufacturers and suppliers in the solid state industry. At the time of this publication, ANSI/ESDA/JEDEC JS-001-2012, a third revision of the joint HBM document, has been released for distribution. This document replaces ANSI/ESDA/JEDEC JS-001-2011, the current industry test methods and specifications for human body model device testing. A second joint committee is currently working on a joint charged device model (CDM) document with a goal of publishing in 2014. These efforts will assist manufacturers of devices by providing one test method and specification instead of multiple, almost - but not quite – identical, versions of device testing methods.

The ESDA is also working on a process assessment document. The purpose of this document is to describe a set of methodologies, techniques, and tools that can be used to characterize a process where ESD sensitive items are handled. The goal is to characterize the ability of a process to safely handle ESD sensitive devices that have been characterized by the relevant device testing models. The document will apply to activities that manufacture, process, assemble, install, package, label, service, test, inspect, transport, or otherwise handle electrical or electronic parts, assemblies, and equipment susceptible to damage by electrostatic discharges. At the present time, this document will not apply to electrically-initiated explosive devices, flammable liquids, or powders.

The ESDA standard covering the requirements for creating and

35TH ANNUAL EOS/ESD SYMPOSIUM & EXHIBITS

September 8-13, 2013
Rio All Suites,
Las Vegas, NV



Benchmark your companies operation against the practices of other companies. Solve business challenges in Controlling ESD by Networking with other ESD professionals and industry experts to learn best practices and technology advances for ESD Control

Join ESD professionals from around the world for the latest information on controlling electrostatic discharge!

- *Over 37 Tutorials with New or Revised classes!*
- *Technical Sessions Over 50 Exciting ESD Presentations. Workshops and Exhibits*
- *For stimulating your ESD programs.*
- *Exhibitors "Showcase" ESD technologies with 8 minute presentations during technical sessions.*
- *Two "Year in Review" sessions of factory standards and device standards.*

For more information please visit www.esda.org

Setting the Global Standards for Static Control!

EOS/ESD Association Inc. 7900 Turin Rd Bld 3 • Rome NY 13440
Phone 315-339-6937 • Fax 315-339-6793
info@esda.org • www.esda.org • Join our EOS/ESD Symposium Group on LinkedIn

ESD ASSOCIATION ®

managing an ESD control program is ANSI/ESD S20.20 "ESD Association Standard for the Development of an Electrostatic Discharge Control Program for – Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)". ANSI/ESD S20.20 is a commercial update of and replacement for MIL-STD-1686 and has been adopted by the United States Department of Defense. In addition, the 2007-2008 update of IEC 61340-5-1 edition 1.0 "Electrostatics - Part 5-1: Protection of Electronic Devices from Electrostatic Phenomena General Requirements" is technically equivalent to ANSI/ESD S20.20. A five-year review of ANSI/ESD S20.20 has begun and technical changes are being made to the document based on industry changes and user requests. There are unique constraints with the revision that must be taken into account, including facility certification and continued harmonization with other standards – IEC 61340-5-1 and newly revised JEDEC 625B. A target date of September 2013 has been given for the release of a draft document.

In order to meet the global need in the electronics industry for technically sound ESD Control Programs, the ESDA has established an independent third party certification program. The program is administered by EOS/ESD Association, Inc. through country-accredited ISO9000 certification bodies that have met the requirements of this program. The facility certification program evaluates a facility's ESD program to ensure that the basic requirements from industry standards ANSI/ESD S20.20 or IEC 61340-5-1 are being followed. More than 519 facilities have been certified worldwide since inception of the program. The factory certification bodies report strong interest in certification to ANSI/ESD S20.20, and consultants in this area report that inquiries for assistance remain at a very high level. Individual education also seems of interest once again as 46 professionals have obtained Certified ESD Program Manager status and many more are attempting to qualify as Certified ESD Control Program Managers. A large percentage of the certification program requirements are based on Standards and the other related documents produced by the ESD Association Standards Committee.

CURRENT ESD ASSOCIATION STANDARDS COMMITTEE DOCUMENTS

Charged Device Model (CDM)

ANSI/ESD S5.3.1-2009 Electrostatic Discharge Sensitivity Testing - Charged Device Model (CDM) - Component Level
Establishes the procedure for testing, evaluating, and classifying the ESD sensitivity of components to the defined CDM.

Cleanrooms

ESD TR55.0-01-04 Electrostatic Guidelines and Considerations for Cleanrooms and Clean Manufacturing
Identifies considerations and provides guidelines for the selection and implementation of materials and processes for electrostatic control in cleanroom and clean manufacturing environments. (Formerly TR11-04)

Compliance Verification

ESD TR53-01-06 Compliance Verification of ESD Protective Equipment and Materials
Describes the test methods and instrumentation that can be used to periodically verify the performance of ESD protective equipment and materials.

Electronic Design Automation (EDA)

ESD TR18.0.01-11 – ESD Electronic Design Automation Checks
Provides guidance for both the EDA industry and the ESD design community for establishing a comprehensive ESD electronic design automation (EDA) verification flow satisfying the ESD design challenges of modern ICs.

ESD Control Program

ANSI/ESD S20.20-2007 Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
Provides administrative and technical requirements for establishing, implementing, and maintaining 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.

ESD TR 20.20-2008—ESD Handbook (Companion to ANSI/ESD S20.20)
Produced specifically to support ANSI/ESD S20.20 ESD Control Program standard, this 132-page document is a major rewrite of the previous handbook. It focuses on providing guidance that can be used for developing, implementing, and monitoring an ESD control program in accordance with the S20.20 standard.

Flooring

ANSI/ESD STM7.1-2012 Resistive Characterization of Materials – Floor Materials
Covers measurement of the electrical resistance of various floor materials, such as floor coverings, mats, and floor finishes. It provides test methods for qualifying floor materials before installation or application, and for evaluating and monitoring materials after installation or application.

ESD TR7.0-01-11 Static Protective Floor Materials
This technical report reviews the use of floor materials to dissipate electrostatic charge. It provides an overview on floor coverings, floor finishes, topical antistats, floor mats, paints and coatings. It also covers a variety of other issues related to floor material selection, installation and maintenance.

Flooring and Footwear Systems

ANSI/ESD STM97.1-2006 Floor Materials and Footwear – Resistance Measurement in Combination with a Person
Provides test methods for measuring the electrical system resistance of floor materials in combination with person wearing static control footwear.

ANSI/ESD STM97.2-2006 Floor Materials and Footwear – Voltage Measurement in Combination with a Person
Provides for measuring the electrostatic voltage on a person in combination with floor materials and footwear, as a system.

Footwear

ANSI/ESD STM9.1-2006 Footwear – Resistive Characterization
Defines a test method for measuring the electrical resistance of shoes used for ESD control in the electronics environment (not to include heel straps and toe grounders).

ESD SP9.2-2003 Footwear – Foot Grounders Resistive Characterization
Provides test methods for evaluating foot grounders and foot grounder systems used to electrically bond or ground personnel as part of an ESD Control Program. Static Control Shoes are tested using ANSI/ESD STM9.1.

Garments

ESD DSTM2.1-2013 Garments - Resistive Characterization
Provides test methods for measuring the electrical resistance of garments. It covers procedures for measuring sleeve-to-sleeve resistance and point-to-point resistance.

This is a draft document.

ESD TR2.0-01-00 Consideration for Developing ESD Garment Specifications
Addresses concerns about effective ESD garments by starting with an understanding of electrostatic measurements and how they relate to ESD protection. (Formerly TR05-00)

ESD TR2.0-02-00 Static Electricity Hazards of Triboelectrically Charged Garments
Intended to provide some insight to the electrostatic hazards present when a garment is worn in a flammable or explosive environment. (Formerly TR06-00)

Glossary

ESD ADV1.0-2012 Glossary of Terms
Definitions and explanations of various terms used in Association Standards and documents are covered in this Advisory. It also includes other terms commonly used in the electronics industry.

Gloves and Finger Cots

ANSI/ESD SP15.1-2011 In-Use Resistance Testing of Gloves and Finger Cots
Provides test procedures for measuring the intrinsic electrical resistance of gloves and finger cots.

ESD TR15.0-01-99 ESD Glove and Finger Cots
Reviews the existing known industry test methods for the qualification of ESD protective gloves and finger cots. (Formerly TR03-99)

Grounding

ANSI/ESD S6.1-2009 Grounding
Specifies the parameters, materials, equipment, and test procedures necessary to choose, establish, vary, and maintain an Electrostatic Discharge Control grounding system for use within an ESD Protected Area for protection of ESD susceptible items, and specifies the criteria for establishing ESD Bonding.

Handlers

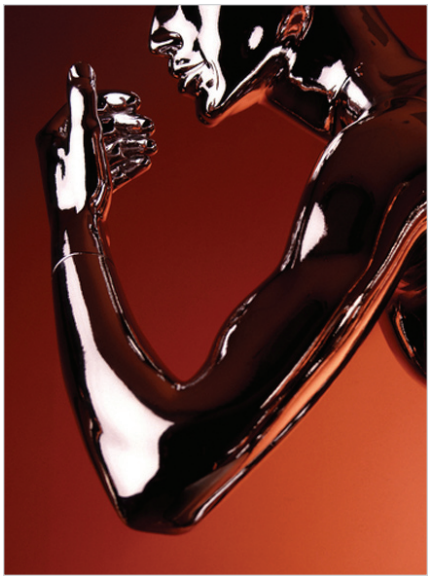
ANSI/ESD SP10.1-2007 Automated Handling Equipment (AHE)
Provides procedures for evaluating the electrostatic environment associated with automated handling equipment.

ESD TR10.0-01-02 Measurement and ESD Control Issues for Automated Equipment Handling of ESD Sensitive Devices below 100 Volts
Provides guidance and considerations that an equipment manufacturer should use when designing automated handling equipment for these low voltage sensitive devices. (Formerly TR14-02)

Hand Tools

ESD STM13.1-2000 Electrical Soldering/ Desoldering Hand Tools
Provides electric soldering/desoldering hand tool test methods for measuring the electrical leakage and tip to ground reference point resistance, and provides parameters for EOS safe soldering operation.

ESD TR13.0-01-99 EOS Safe Soldering Iron Requirements
Discusses soldering iron requirements that must be based on the sensitivity of the most susceptible devices that are to be soldered. (Formerly TR04-99)



Human Body Model (HBM)
ANSI/ESDA/JEDEC JS-001-2012 ESDA/JEDEC Joint Standard for Electrostatic Discharge Sensitivity Testing – Human Body Model (HBM) – Component Level
Establishes the procedure for testing, evaluating, and classifying the electrostatic discharge sensitivity of components to the defined human body model (HBM).

ESD JTR001-01-12, ESD Association Technical Report User Guide of ANSI/ESDA/JEDEC JS-001 Human Body Model Testing of Integrated Circuits
Describes the technical changes made in ANSI/ESDA/JEDEC JS-001-2011 contained in the new 2012 version) and explains how to use those changes to apply HBM (Human Body Model) tests to IC components.

Human Metal Model (HMM)
ANSI/ESD SP5.6-2009 Electrostatic Discharge Sensitivity Testing - Human Metal Model (HMM) - Component Level
Establishes the procedure for testing, evaluating, and classifying the ESD sensitivity of components to the defined HMM.

ESD TR5.6-01-09 Human Metal Model (HMM)
Addresses the need for a standard method of applying the IEC contact discharge waveform to devices and components.

Ionization

ANSI/ESD STM3.1-2006 Ionization
Test methods and procedures for evaluating and selecting air ionization equipment and systems are covered in this standard test method. The document establishes measurement techniques to determine ion balance and charge neutralization time for ionizers.

ANSI/ESD SP3.3-2012 Periodic Verification of Air Ionizers
Provides test methods and procedures for periodic verification of the performance of air ionization equipment and systems (ionizers).

ANSI/ESD SP3.4-2012 Periodic Verification of Air Ionizer Performance Using a Small Test Fixture
Provides a test fixture example and procedures for performance verification of air ionization used in confined spaces where it may not be possible to use the test fixtures defined in ANSI/ESD STM3.1 or ANSI/ESD SP3.3.

ESD TR3.0-01-02 Alternate Techniques for Measuring Ionizer Offset Voltage and Discharge Time
Investigates measurement techniques to determine ion balance and charge neutralization time for ionizers. (Formerly TR13-02)

ESD TR3.0-02-05 Selection and Acceptance of Air Ionizers
Reviews and provides a guideline for creating a performance specification for the four ionizer types contained in ANSI/ESD STM3.1: room (systems), laminar flow hood, worksurface (e.g., blowers), and compressed gas (nozzles & guns). (Formerly ADV3.2-1995)

Machine Model (MM)

ANSI/ESD STM5.2-2012 Electrostatic Discharge Sensitivity Testing - Machine Model (MM) - Component Level
Establishes the procedure for testing, evaluating, and classifying the ESD sensitivity of components to the defined MM.

ANSI/ESD SP5.2.1-2012 Human Body Model (HBM) and Machine Model (MM) Alternative Test Method: Supply Pin Ganging – Component Level
Defines an alternative test method to perform Human Body Model or Machine Model component level ESD tests when the component or device pin count exceeds the number of ESD simulator tester channels. (Formerly ANSI/ESD SP5.1.1-2006)

ANSI/ESD SP5.2.2-2012 Human Body Model (HBM) and Machine Model (MM) Alternative Test Method: Split Signal Pin - Component Level
Defines an alternative test method to perform Human Body Model or Machine Model component level ESD tests when the component or device pin count exceeds the number of ESD simulator tester channels. (Formerly ANSI/ESD SP5.1.2-2006)

ESD TR5.2-01-01 Machine Model (MM) Electrostatic Discharge (ESD) Investigation - Reduction in Pulse Number and Delay Time
Provides the procedures, results, and conclusions of evaluating a proposed change from 3 pulses (present requirement) to 1 pulse while using a delay time of both 1 second (present requirement) and 0.5 second. (Formerly TR10-01)

Ohmmeters

ESD TR50.0-02-99 High Resistance Ohmmeters--Voltage Measurements
Discusses a number of parameters that can cause different readings from high resistance meters when improper instrumentation and techniques are used and the techniques and precautions to be used in order to ensure the measurement will be as accurate and repeatable as possible for high resistance measurement of materials. (Formerly TR02-99)

Packaging

ANSI/ESD STM11.11-2006 Surface Resistance Measurement of Static Dissipative Planar Materials
Defines a direct current test method for measuring electrical resistance, replacing ASTM D257-78. This test method is designed specifically for static dissipative planar materials used in packaging of ESD sensitive devices and components.

ANSI/ESD STM11.12-2007 Volume Resistance Measurement of Static Dissipative Planar Materials
Provides test methods for measuring the volume resistance of static dissipative planar materials used in the packaging of ESD sensitive devices and components.

ANSI/ESD STM11.13-2004 Two-Point Resistance Measurement
Measures the resistance between two points on a material's surface without consideration of the material's means of achieving conductivity. This test method was established for measuring resistance where the concentric ring electrodes of ANSI/ESD STM11.11 cannot be used.

ANSI/ESD STM11.31-2012 Bags
Provides a method for testing and determining the shielding capabilities of electrostatic shielding bags.

ANSI/ESD S11.4-2012 Performance Limits for Bags
Establishes performance limits for bags that are intended to protect electronic parts and products from damage due to static electricity and moisture during common electronic manufacturing industry transport and storage applications.

This is a draft document.

ANSI/ESD S541-2008 Packaging Materials for ESD Sensitive Items
Describes the packaging material properties needed to protect electrostatic discharge (ESD) sensitive electronic items, and references the testing methods for evaluating packaging and packaging materials for those properties. Where possible, performance limits are provided. Guidance for selecting the types of packaging with protective properties appropriate for specific applications is provided. Other considerations for protective packaging are also provided.

ESD ADV11.2-1995 Triboelectric Charge Accumulation Testing
Provides guidance in understanding the triboelectric phenomenon and relates current information and experience regarding tribocharge testing as used in static control for electronics.

Seating

ESD DSTM12.1-2013 Seating – Resistive Measurement
Provides test methods for measuring the electrical resistance of seating used for the control of electrostatic charge or discharge. It contains test methods for the qualification of seating prior to installation or application, as well as test methods for evaluating and monitoring seating after installation or application.

This is a draft document.

Socketed Device Model (SDM)

ANSI/ESD SP5.3.2-2008 Electrostatic Discharge Sensitivity Testing – Socketed Device (SDM) – Component Level
Provides a test method for generating a Socketed Device Model (SDM) test on a component integrated circuit (IC) device.

ESD TR5.3.2-01-00 Socket Device Model (SDM) Tester
Helps the user understand how existing SDM testers function, offers help with the interpretation of ESD data generated by SDM test systems, and defines the important properties of an "ideal" socketed-CDM test system. (Formerly TR08-00)

Static Electricity

ESD TR50.0-01-99 Can Static Electricity Be Measured?
Gives an overview of fundamental electrostatic concepts, electrostatic effects, and most importantly of electrostatic metrology, especially what can and what cannot be measured. (Formerly TR01-99)

Susceptible Device Concepts

ESD TR50.0-03-03 Voltage and Energy Susceptible Device Concepts, Including Latency Considerations
Contains information to promote an understanding of the differences between energy and voltage susceptible types of devices and their sensitivity levels. (Formerly TR16-03)

Symbols

ANSI/ESD S8.1-2012 Symbols – ESD Awareness
Three types of ESD awareness symbols are established by this document. The first one is to be used on a device or assembly to indicate that it is susceptible to electrostatic charge. The second is to be used on items and materials intended to provide electrostatic protection. The third symbol indicates the common point ground.

System Level ESD

ESD TR14.0-01-00 Calculation of Uncertainty Associated with Measurement of Electrostatic Discharge (ESD) Current
Provides guidance on measuring uncertainty based on an uncertainty budget. (Formerly TR07-00)

ESD TR14.0-02-13 System Level Electrostatic Discharge (ESD) Simulator Verification
Developed to provide guidance to designers, manufacturers, and calibration facilities for verification and specification of the systems and fixtures used to measure simulator discharge currents. (Formerly ANSI/ESD SP14.1)

Transient Latch-up

ESD TR5.4-01-00 Transient Induced Latch-Up (TLU)
Provides a brief background on early latch-up work, reviews the issues surrounding the power supply response requirements, and discusses the efforts on RLC TLU testing, transmission line pulse (TLP) stressing, and the new bi-polar stress TLU methodology. (Formerly TR09-00)

ESD TR5.4-02-08 Determination of CMOS Latch-up Susceptibility - Transient Latch-up - Technical Report No. 2
Intended to provide background information pertaining to the development of the transient latch-up standard practice originally published in 2004 and additional data presented to the group since publication.

ESD TR5.4-03-11 Latch-up Sensitivity Testing of CMOS/Bi CMOS Integrated Circuits – Transient Latch-up Testing – Component Level Supply Transient Stimulation
Developed to instruct the reader on the methods and materials needed to perform Transient Latch-Up Testing.

Transmission Line Pulse

ANSI/ESD STM5.5.1-2008 Electrostatic Discharge Sensitivity Testing – Transmission Line Pulse (TLP) – Component Level
Pertains to Transmission Line Pulse (TLP) testing techniques of semiconductor components. The purpose of this document is to establish a methodology for both testing and reporting information associated with TLP testing.

ANSI/ESD SP5.5.2-2007, Electrostatic Discharge Sensitivity Testing - Very Fast Transmission Line Pulse (VF-TLP) - Component Level
Pertains to Very Fast Transmission Line Pulse (VF-TLP) testing techniques of semiconductor components. It establishes guidelines and standard practices presently used by development, research, and reliability engineers in both universities and industry for VF-TLP testing. This document explains a methodology for both testing and reporting information associated with VF-TLP testing.

ESD TR5.5-01-08 Transmission Line Pulse (TLP)
A compilation of the information gathered during the writing of ANSI/ESD SP5.5.1 and the information gathered in support of moving the standard practice toward re-designation as a standard test method.

ESD TR5.5-02-08 Transmission Line Pulse Round Robin
Intended to provide data on the repeatability and reproducibility limits of the methods of ANSI/ESD STM5.5.1.

Workstations

ESD ADV53.1-1995 ESD Protective Workstations
Defines the minimum requirements for a basic ESD protective workstation used in ESD sensitive areas. It provides a test method for evaluating and monitoring workstations. It defines workstations as having the following components: support structure, static dissipative worksurface, a means of grounding personnel, and any attached shelving or drawers.

Worksurfaces

ANSI/ESD S4.1-2006 Worksurface - Resistance Measurements
Provides test methods for evaluating and selecting worksurface materials, testing of new worksurface installations, and the testing of previously installed worksurfaces.

ANSI/ESD STM4.2-2012 ESD Protective Worksurfaces - Charge Dissipation Characteristics
Aids in determining the ability of ESD protective worksurfaces to dissipate charge from a conductive test object placed on them.

ESD TR4.0-01-02 Survey of Worksurfaces and Grounding Mechanisms
Provides guidance for understanding the attributes of worksurface materials and their grounding mechanisms. (Formerly TR15-02)

Wrist Straps

ESD DS1.1-2013 Wrist Straps
A successor to EOS/ESD S1.0, this document establishes test methods for evaluating the electrical and mechanical characteristics of wrist straps. It includes improved test methods and performance limits for evaluation, acceptance, and functional testing of wrist straps.

This is a draft document.

ESD TR1.0-01-01 Survey of Constant (Continuous) Monitors for Wrist Straps
Provides guidance to ensure that wrist straps are functional and are connected to people and ground. (Formerly TR12-01)

ABOUT THE EOS/ESD ASSOCIATION, INC.

Founded in 1982, the EOS/ESD Association, Inc. 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 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.

Dedicated to Delivering

News, Articles, and Ideas on EMC, Product Safety, Designing for Compliance and Regulatory Updates.

Print editions
every month!

Digital editions
monthly and archives online!

InCompliancemag.com
for compliance information 24/7!

The World In Compliance and
e-Product Showcase e-Newsletters!

We help you stay informed.

Sign up for free subscriptions at **www.incompliancemag.com.**

BUSINESS News

Acopian's Newest Online Custom Power Supply System Builder Speeds Time to Market

Acopian has announced the launch of its newly expanded Online Custom Power Supply System Builder. The Online Custom Power Supply System Builder is developed to assist design engineers meet the market's demand for fast delivery of customized multiple output power systems at off-the-shelf prices. Through a series of intuitive steps, engineers are able to custom design DC-DC and AC-DC power supplies, high-voltage DC-DC and AC-DC power supplies, redundant systems and unregulated power supplies. The custom-designed units are notably available in voltages ranging from 0V-30kV, with 1 to 30 outputs, and with 0.025W to 2400W of output power.

To view Acopian's newest Online Custom Power Supply System Builder, visit http://www.acopian.com/powersys.aspx.

TESEQ and IFI Co-Honored as Advanced Test Equipment Rentals' Vendors of the Year

Advanced Test Equipment Rentals (ATEC) co-honored TESEQ and IFI (now a TESEQ company) with the Vendor of the Year Award in San Diego, California earlier this month. Following the ISO 9001 review, an annual assessment of quality standards, it was determined that TESEQ/IFI ranked the highest in all areas of service including timeliness, product quality and customer service.

For information on ATEC's services, visit www.atecorp.com.

Agilent Technologies Offers New Designing and Verifying Multi-Standard Radios Application Note

Agilent Technologies has released a new application note "Solutions for Designing and Verifying Multi-Standard Radios" (5991-2133EN) that offers insight into achieving fast, accurate and efficient testing of MSR base-station transmitter and receiver devices. The free application note is available at www.agilent.com/find/powerofx.

ANSYS Appoints Walid Abu-Hadba as Chief Product Officer

ANSYS, Inc. has announced that 20-year Microsoft veteran Walid Abu-Hadba has joined the Company as chief product officer (CPO), effective immediately, reporting directly to Jim Cashman, president and CEO. Abu-Hadba will be responsible for providing leadership for the overall strategy and management of the activities within our technical business units, including integration, development, research and patents. Visit www.ansys.com for more information.

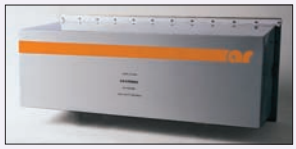
API Technologies Expands High Performance Power Amplifier Line

API Technologies Corp. has announced the expansion of their Power Amplifier line of products to include the latest in GaN technology driven designs. This expanded line is specially intended for use in electronic warfare, RCIED countermeasures, and national security jammer applications where the use of rugged and highly reliable power amplifier designs is mission critical.

For more information about API Technologies' RF/Microwave & Microelectronics product line, including high performance power amplifier solutions, please call 888- 553-7531 or email microwavesales@apitech.com.

AR's "Cavitenna" RF Antenna Uses Shielded Room as a Reverberating Antenna

AR has announced their top-loaded monopole, the Cavitenna, model ATC25M1G, uses a shielded room as a reverberating antenna, and the wall as the antenna's ground plane. As a result, it accommodates extremely high power and corresponding field intensities, comparable to those of log-periodic antennas four times the size of the Cavitenna. For detailed specifications on the Cavitenna, visit www.arworld.us.



Averna Announces DOCSIS Design-Validation Partnership with Pace for SCTE-40 Certification

Averna has announced a successful design-validation partnership with Pace, a leading global developer of advanced technologies for service providers, to help gain SCTE-40 certification on various customer-premise equipment (CPE) for the cable and broadband industry. Pace selected Averna's DOCSIS Channel Emulator (DCE) to test 8-bonded downstream channels simultaneously, with all necessary impairments to complete performance and resilience tests required by multi-system operators (MSOs). For more information, visit www.averna.com.

New Open-Ended Card Edge Connectors from AVX Provide a Miniature, Cost-Effective and High Density Pin-Count Solution for Linear LED Strip Lighting

AVX Corporation has introduced a unique new open-ended card edge connector specifically designed to provide lighting engineers with a miniature, cost-effective, and high density pin-count solution for use in linear LED strip lighting. Designed without plastic end-walls to minimize length, AVX's new 00-9159 Series connectors feature a double-sided configuration for increased pin-count density, a central keying rib for strength and alignment, and a tin-to-tin contact interface for financial economy.

For more information, please visit www.avx.com or call 864-967-2150.

Black & Veatch Achieves Top Ranking in Telecom

Black & Veatch is once again the top U.S. engineering and design company for telecommunications, according to a just-released study by Engineering News-Record (ENR). This is the fourth consecutive year that Black & Veatch has achieved the number one ranking in telecommunications. In ENR's Top 500 Design Firms list, Black & Veatch is also ranked 3rd in Power, 3rd in Sewer/Wastewater and 7th in Water. The company is ranked 14th overall on the Top 500 list.

For more information on Black & Veatch, visit www.bv.com.

Chroma's New 3 and 4 Channel Power Meters - High Speed, High Accuracy and Low Cost

Chroma has introduced 66203/66204 Power Meters that are designed for multiple phase power measurement applications. The wiring mode function allows the user to take accurate power measurements for various wiring modes as well as providing accurate standard power measurements common for most electrical devices. For detailed specifications, visit www.chromausa.com.

Cree SiC MOSFET's Enable Next-Generation Solar Inverters From Delta Energy Systems

Cree, Inc. and Delta Energy Systems announced a breakthrough in the photovoltaic (PV) inverter industry with the release of Delta's new generation of solar inverters, which utilize SiC power MOSFETs from Cree. The use of SiC MOSFETs in the next-generation PV inverters can enable significant new milestones in power density, efficiency and weight.

For more information, please visit www.cree.com/power or contact a local Cree sales person or distributor.

New 6000 MHz Voltage Controlled Oscillator from Crystek

Crystek has introduced the CVCO33BE-6000-6000 VCO (Voltage Controlled Oscillator) that operates at 6000 MHz with a control voltage range of 0.5V~4.5 V. This VCO features a typical phase noise of -85 dBc/Hz @ 10KHz offset and has excellent linearity. Output power is typically +5 dBm.

For additional information, email sales@crystek.com or visit www.crystek.com

East West Manufacturing Adds Medical and Electronic Divisions to Vietnam Operations

East West Manufacturing has announced the addition of two divisions that will expand its Vietnam operations. East West's Vietnam facility's ISO 9001:2008 and ISO13485:2003 certifications support the new Medical Device Contract Manufacturing and Electronic Manufacturing Services (EMS) divisions. The divisions will be housed in the company's wholly-owned, three-building complex located in the Binh Duong province of Vietnam.

For more information about EW's Domestic Offshore Manufacturing® model, visit www.ewmfg.com.

Elite Announces Appointment as a Jaguar Land Rover Recognized EMC Laboratory

Elite has announced that they have recently become a Jaguar Land Rover Recognized EMC Laboratory. With only two other JLR recognized labs in the United States, they are now part of a select group of testing facilities that offer data approval for Jaguar Land Rover component and subsystem testing. Elite had to meet a list of criteria to achieve this recognition.

For more information on Jaguar Land Rover testing and certification at Elite, contact EMC Lab Manager, Craig Fanning at 800-354-8311 x160.

Fil-Coil to Manufacture and Install an Electromagnetic Pulse in South Korea

Fil-Coil Inc. has announced and concluded a Joint Venture (J.V.) agreement with an entity in the Republic of Korea (R.O.K.),

BUSINESS News

to manufacture and install Electromagnetic Pulse (EMP) in a major secured military facility in South Korea. For additional information, visit www.custompowersystems.com.

New Giga-tronics ASCOR Switching Catalog and Selection Guide Now Available

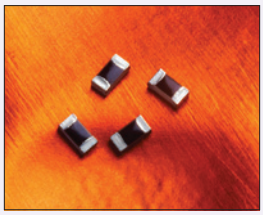
Giga-tronics has released a new catalog highlighting their ASCOR switching products and a selection guide. The catalog also describes RF/microwave switching chassis solutions, datasheets and much more. To view an electronic version of the catalog, visit www.gigatronics.com.

IQD launch ±0.05ppb Rubidium Oscillator

IQD's has introduced their latest high performance oscillator, the IQRB-1. It offers a stability around a 1,000 times more accurate than a typical Oven Controlled Crystal Oscillator (OCXO). This means it can be used as a free run frequency source in applications such as LTE (Long Term Evolution) systems that require exceptional timing accuracy and can also be used for UTMS as well as extended holdover for CDMA and WiMax. For more information, visit www.iqdfrequencyproducts.com.

KOA Speer Introduces 0402-Size RN73H1E Ultra Precision Chip Resistors

KOA Speer Electronics has introduced the 0402 (1E) size of their RN73H line of ultra precision chip resistors. These thin film (metal) chip resistors feature high heat resistance (up to +155°C) and ultra high precision (±0.1%) tolerance. Used primarily as reliable precision resistors that are robust to humidity and high temperature (+155°C), RN73H1E chip resistors are ideal for applications within the transportation, avionics and medical markets, specifically any applications where high temperature/high humidity are design considerations. For additional information, visit www.koaspeer.com.



Laird Technologies Launches Low Energy Bluetooth Smart™ Modules for Medical and Other Devices

Medical devices that send small amounts of data wirelessly will be able to run for months or even years on a coin cell battery when they use new Bluetooth Smart™ modules announced by global technology leader Laird Technologies. What makes the BL600 modules unique is Laird's smartBASIC, an event-driven programming language that simplifies BLE module integration. Even those with little software or Bluetooth expertise can develop fully functional applications in just days. Each BL600 module version – with an integrated antenna, an IPEX MHF4 antenna connector, or trade pads for an external antenna – has a compact footprint of 19 mm x 12.5 mm, making it suitable for even the smallest portable devices. A BL600 module can connect to a wide array of external sensors via its I2C, SPI, UART, ADC, and GPIO interfaces.

Additional details can be found at www.lairdtech.com/bluetooth.

High Density DC-DC Converter Modules from PowerStax

Powerstax has introduced a new series of DC-DC converter power modules specifically aimed at fuel cell power generation. The modules in the FC series accept 50V to 120V input direct from many popular fuel cells and deliver a stabilised output of up to 500W. Power efficiency levels are up to 91%. They are offered in an industry standard full brick (11.68cm x 6.10cm x 1.27cm) format, with power densities of up to 5.53W/cm^3. For more information, visit www.powerstaxplc.com.

RBD Instruments Improves Low DC Current Measurements with Actuel USB Picoammeter Sync Feature

RBD Instruments Inc. introduced a new feature to its Actuel data logging software that enables multiple 9103 USB picoammeters to be synced. This added feature opens up new applications for low DC current measurement. The 9103 USB picoammeter is designed to provide reliable and accurate bipolar DC current measurements in the range of picoamps to milliamps. For more information, visit www.rbdinstruments.com.

Flexible Rohde & Schwarz High-End Vector Signal Generator Creates Complex Multichannel Scenarios for Highest Demands

The new R&S SMW200A high-end vector signal generator from Rohde & Schwarz combines maximum flexibility, outstanding performance and intuitive operation to outperform all comparable solutions available on the market. It is the perfect tool for generating complex, digitally modulated signals of high quality. Thanks to versatile configuration options, its range of applications extends from single-path vector signal generator to multi-channel MIMO receiver tester. Watch the video for further information: http://www.rohde-schwarz.com/campaigns/en/smw/video.html.

Saelig Introduces Economical 0.65-20 GHz Fast-Switching Synthesizer

Saelig Company, Inc. has introduced the APSYN420B - an economical, wideband, fast-switching, low phase-noise 0.65GHz to 20 GHz frequency synthesizer with a remarkable resolution of 0.001Hz and phase resolution of 0.1deg, providing a nominal output power of +13 dBm into 50 ohms. The module features a high-stability internal reference which can be phase-locked to a user-configurable external reference or used in a master-slave configuration for highest phase coherence. For detailed specifications, visit www.saelig.com.

New Sorensen SG 1000V DC Power Supply Extends Capabilities to High-Voltage Applications

AMETEK Programmable Power has announced the extension of its Sorensen SG Series high-power DC power supply line with the introduction of the new SG 1000V, which can supply up to 1,000V DC for applications such as testing photovoltaic (PV) inverters and electric vehicles. The new 1000V DC model of SG Series power supplies can provide up to 15 kW in a 3U package. The SG 1000V, for example, can supply up to 15 A in the standard 3U package. Users also can select from 5 kW and 10 kW models. For users who need more output power, up to five 15 kW units can be connected in parallel to supply up to 75 kW. In addition, the Sorensen SG Series offers fast voltage and current slew rates, exceptional load transient response, low noise, and built-in power factor correction.

For more information on the SG series of power supplies, visit www.programmablepower.com.

TDK Announces New EPCOS PFC Controllers With Expanded Functionality

TDK Corporation announced the introduction of two new types of the BR7000 series of EPCOS power factor controllers. The BR7000-T power factor controller offers 15 transistor outputs instead of 15 relay outputs. It is designed for applications that require fast switching operations and enables delay-free switching of thyristor modules, such as the EPCOS TSM series. The second innovation is the EPCOS BR7000-I with an RS485 interface, which can be used for embedding into networks, for controller coupling and for visualization via PC.

Further information on the products can be found at www.epcos.com/pfc_controllers.

TÜV Rheinland Launches New HazLoc/Functional Safety Business Line

TÜV Rheinland of North America has announced a new business line offering premium certification cervices in Functional Safety (FS) and hazardous locations (HazLoc). The business line will address the growing need for the services in the region and allow the company to offer enhanced, highly personalized customer service to clients. Specifically, TÜV Rheinland HazLoc/Functional Safety team provides a full range of global certification options per IEC/EN/UL/ANSI/ISA 60079 series of standards, IEC 61508, IEC 61511 as well as industry specific standards (ISO 26262, ISO 13849, EN/IEC 62061, EN 50271, etc.), allowing clients to show compliance to the market entry requirements and get their products to market quickly.

To learn more about the TÜV Rheinland HazLoc/Functional Safety, email fs@us.tuv.com with questions about FS, Hazloc@us.tuv.com with questions about HazLoc, or call 978- 266-9500.

Gore® Automotive Vents Protect Powertrain Components from Harsh Environments

W. L. Gore & Associates has expanded its line of GORE® Automotive Vents to include the new Series: AVS 41 (P/N VE2048) venting solution, which is engineered specifically for powertrain components. This new vent improves component reliability by equalizing pressure, preventing contamination from water, dust, dirt and other automotive fluids and simplifying design challenges, ultimately resulting in lower overall costs. For more information about the Series: AVS 41 (P/N VE2048), visit www.gore.com/autovents.

SMD EMI Contact Fingers Eliminate EMI

Wurth Electronics has announced the expansion of its shielding materials with EMI contact fingers. Fifteen different versions are currently available ranging from heights of 1.5 mm to 13.0 mm. The contact spring material from the WE-SECF series is made of copper-beryllium and, in contrast to competitor products, gold-plated. Due to the construction, the contact spring materials cannot corrode and are also very low resistance. For free samples, visit www.we-online.com.

(Authors)

We wish to thank our community of knowledgeable authors, indeed, experts in their field - who come together to bring you each issue of *In Compliance*. Their contributions of informative articles continue to move technology forward.

GARY FENICAL
Senior EMC Engineer and NARTE Certified EMC Engineer, Gary has been with Laird Technologies for 30 years. He is a specialist in RF shielded enclosures and has been responsible for the design and/or measurement and quality control of hundreds of large-scale shielded enclosures, as well as a number of shielded equipment cabinets and housings. For Gary's full bio, please vistit page 26.

NIELS JONASSEN, MSC, DSC,
worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate.
Mr. Jonassen passed away in 2006.
For Mr. Jonassen's full bio, please see page 17.

DHEENA MOONGILAN
is a Distinguished Member of Technical Staff at Bell Laboratories of Alcatel-Lucent. He is a Principal EMC design Consultant for Alcatel-Lucent. He has published 20 formal IEEE papers on EMC and holds two US patents. For Mr. Moongilan's full bio, please visit page 43.

PAUL OPPERMAN
is an electrical engineer with the Submarine Electromagnetic Environmental Effects (E3) Branch at the Naval Undersea Warfare Center in Newport, RI. He holds a Bachelor of Science degree in Electrical Engineering from Boston University. For Paul's full bio, please visit page 35.

GREGORY TAIT
is currently an electrical engineer with the Electromagnetic and Sensor Systems Department at the Naval Surface Warfare Center Dahlgren Division in Dahlgren, VA. He earned the PhD degree in Electrical Engineering from The Johns Hopkins University. For his full bio, please visit page 35.

MIKE VIOLETTE
is President of Washington Labs and Director of American Certification Body (mikev@wll.com).

(Advertisers)

Advertiser Name	Page	Advertiser Name	Page
A.H. Systems	C2	The MuShield Company	9
AR	11	Panashield Inc.	25
E. D. & D., Inc.	15	Rigol Technologies	23
EOS/ESD Association Inc.	47	Spira Manufacturing Corporation	3
ETS-Lindgren	C3	Swift Textile Metalizing LLC	19
Fotofab	31	Teseq	C4
IEEE EMC 2013 Symposium	27	Timco Engineering, Inc.	16
Leader Tech Inc.	7	Washington Laboratories Academy	17
Monroe Electronics	10		

When Our Experience Goes in… EMI/RFI Noise Stays Out.

For reliable EMI/RFI shielding performance, turn to the most experienced manufacturer in the shielding industry: ETS-Lindgren. No other shielding company provides the product development, design/consultation, engineering expertise, and quality testing that result in the industry's most effective EMI/RFI protection from interference.

The ETS-Lindgren group of companies provides the industry's widest range of shielding systems and solutions, an unmatched understanding of proven shielding principles and techniques, and full service capabilities from design through certification.

For application assistance or to request our literature, visit our website at ets-lindgren.com.

We offer:

- Double Electrically Isolated (DEI) High-performance Screen or Solid Enclosures
- Cell Type Series 81/71 Shielded Rooms
- High-performance Welded Enclosures
- Series 101 Pan Shielding
- Highly-reliable Portable and Automated Test Boxes
- Automated and Manual RF Shielded Doors
- EMI/RFI Power/Signal Line Facility Filters

Enabling Your Success™

ETS•LINDGREN™

An **ESCO Technologies** Company

www.ets-lindgren.com

Phone +1.512.531.6400 • info@ets-lindgren.com

Offices in the US, Brazil, Germany, Finland, UK, France, India, Japan, Singapore, China, Taiwan

NSG 437 ESD SIMULATOR – COST-EFFECTIVE 30 KV TESTING

The NSG 437 was designed to deliver 30 kV ESD simulation on any budget. It has all the performance and reliability of Teseq's proven NSG 438 ESD simulator in an economical package. The keyword here is convenience. The NSG 437's ergonomic handheld pistol-grip design that features a large touch screen display with a virtual keypad makes the NSG 437 easy to operate. A wide range of easily interchangeable R/C networks enables testing to all international and automotive standards. Networks can be pushed into place in seconds to simplify test procedures. Teseq offers accredited calibration services through our global network of customer service centers.

NSG 437 Highlights:

- **Air- and contact-discharge up to 30 kV**
- **Convenient touch screen display**
- **Easily interchangeable network modules**
- **Custom R/C networks from 0 Ohms and up to 2 nF**
- **Automatic polarity reversal**
- **Exceeds 5 second voltage hold time requirement**
- **Compliant with IEC, ANSI, SAE, ISO standards**

Teseq Inc. Edison, NJ USA
T + 1 732 417 0501 F + 1 732 417 0511
usasales@teseq.com www.tesequsa.com

a TESEQ Company

MILMEGA
a TESEQ Company

TESEQ
Advanced Test Solutions for EMC