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PLUS

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Site Attenuation Measurements
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A Primer

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Part 1

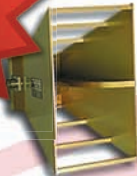
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IN COMPLIANCE

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

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subscriptions

In Compliance Magazine subscriptions
are free to qualified subscribers
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Subscriptions outside North America
are \$129 for 12 issues.
The digital edition is free.

Please contact our circulation department
at circulation@incompliancemag.com

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For information about advertising contact:
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60 The Evolution of EMC Testing for Electrified Powertrains in Automotive Vehicles

A brief history of automotive EMC testing and standards development

Rob Kado, Jim Muccioli, Dale Sanders and Terry North

SPECIAL FEATURE:

34 2012 IEEE International Symposium on EMC A Sneak Preview of EMC's Largest Annual Event *Pittsburgh, PA*

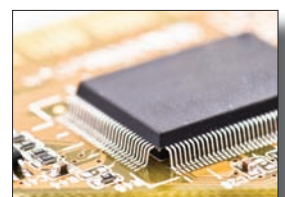
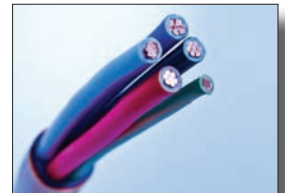


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Michael G. Khazhinsky



Letter from the editor

Dear Reader,

It is with great pleasure that we announce the formation of our inaugural Editorial Advisory Board.

Here members of our newly formed board briefly describe their backgrounds and their current work in the field of compliance engineering.

MR. HOMI AHMADI

Extron Electronics
Anaheim, CA

Experience:

Mr. Ahmadi joins the In Compliance Editorial Advisory Board with over 25 years of experience in various engineering capacities but with focus in compliance engineering. Mr Ahmadi has worked with regulatory agencies both domestically as well as internationally and is an IEEE Senior Member and an iNARTE product safety engineer.



Education:

BS in Engineering, University of Mid-Glamorgan, Wales-UK

Areas of Expertise:

Mr. Ahmadi will be advising us in all areas of compliance engineering, with a primary focus on product safety, international certification and environmental issues such as RoHS, REACH, Energy Star.

DR. BRUCE ARCHAMBEAULT

Four Oaks, NC

Experience:

Dr. Archambeault joins our board with more than 30 years in commercial and TEMPEST EMC and more than 20 years in simulation and modeling EM.



Education:

PhD EE (computational electromagnetics speciality)

Areas of Expertise:

Dr. Archambeault will be advising us in the areas of EMC design, PCB design, EMC tools, simulation/modeling.

MR. GLEN DASH

Woodstock, CT

Experience:

Mr. Dash is the founder of Dash, Straus and Goodhue, Compliance Design, and Compliance Engineering.

Education:

BSEE, Massachusetts Institute of Technology, 1975
MBS, Massachusetts Institute of Technology, 1981
JD, Harvard Law School, 1981

Areas of Expertise:

Mr. Dash will be advising us in the areas of regulatory law, EMC design, electromagnetic field theory.

MR. DARYL GERKE, PE

Kimmel Gerke Associates, Ltd.
Mesa, AZ

Experience:

Daryl Gerke has over 40 years experience with EMI/EMC in a wide range of industries: computers, military, industrial controls, vehicular electronics, medical, facilities, and more. Almost 25 years as a full time EMC consulting engineer, plus over 25 years of EMI/EMC training experience.



Daryl is a co-founder of Kimmel Gerke Associates, Ltd., an electrical engineering consulting firm specializing in EMI/EMC issues. Daryl and his business partner, Bill Kimmel, have solved hundreds of EMI/EMC problems across the electronics industry. They also have trained over 10,000 engineers about EMI/EMC through their public and in-house training seminars.

Education:

BSEE, University of Nebraska, 1968

Areas of Expertise:

Mr. Gerke will be advising us in the areas of: EMC design issues – circuit boards to systems to facilities, EMC training issues, power quality, ESD as an EMI issue, and EMC troubleshooting

MR. DANIEL HOOLIHAN

Hoolihan EMC
Consulting
Lindstrom, MN

**Experience:**

2000-Present –
Hoolihan EMC
Consulting, Principal
1994-1999 –
TUV SUD America, Vice-President,
Minnesota Operations
1984-1993 – AMADOR Corporation,
Chief Operating Officer
1969-1984 – Control Data Corporation,
Manager, EMC Lab

Additionally, Mr. Hoolihan presently serves and has served the EMC Community as: Chair of the ANSI-ASC C63R Committee (2012 – 2014), Senior Member of the IEEE, Long-time Member of the IEEE EMC Society including Past-President (1998-1999).

Education:

MBA, University of Minnesota, 1975
Masters in Physics, Louisiana State University, 1969
Bachelors in Physics, St. John's University (MN), 1966

Areas of Expertise:

Mr. Hoolihan will be advising us in the areas of laboratory accreditation – EMC and telecom, EMC standards, EMC testing – emission and immunity, EMC and medical devices, and EMC measurement uncertainty.

MR. KEN JAVOR

EMC Compliance
Huntsville, AL

Experience:

30 years EMC, industry representative to MIL-STD-464 and MIL-STD-461 DoD Tri-Service Working Groups, over twenty published papers, handbook on EMI control and test methods

Education:

BS Physics

Areas of Expertise:

Mr. Javor will be advising us in the areas of EMI/EMC standards, test methods, instrumentation, electromagnetism

MR. WILLIAM KIMMEL

Kimmel Gerke Associates, Ltd.
South St. Paul, MN

**Experience:**

Mr. Kimmel is a partner with Kimmel Gerke Associates, Ltd, an engineering consulting firm specializing in Electromagnetic Interference/ Electromagnetic Compatibility (EMI/EMC) focusing on issues of EMC design, troubleshooting and training in a range of disciplines, including military, avionics, aerospace, vehicular, industrial and medical equipment.

Previous assignments were with Sperry Defense Systems (now part of Lockheed Martin) and Control Data Corporation. Assignments included signal integrity design of high speed electronics, R&D on nuclear radiation effects, EMC systems design on military avionics and naval equipment.

Education:

BS (Electrical Engineering) with Distinction, University of Minnesota Institute of Technology, 1962

Areas of Expertise:

Mr. Kimmel will be advising us in the areas of EMC design of electronic equipment for regulatory or contractual requirements for electromagnetic emissions and immunity, for commercial, industrial, military, avionics, aerospace, vehicular, and medical devices.

W. MICHAEL KING, PH.D.

Costa Mesa, CA

**Experience:**

Dr. King joins our editorial advisory board with a background in systems EMC design with a career spanning over five decades: engaged in the definition, design, evaluation, implementation, management and execution of well over one thousand projects and systems. Positions held across the range from Systems Engineer to Director of Systems Engineering, and Chief Electronics Engineer. Dr. King has served as an advisor to executive management (government agencies and commercial corporations). His initial period in engineering was in programs allocated broadly to approximately 400 government communications, surveillance, counter-ops (ELINT), and military projects (AD and Deployment phases). Projects spanned include "sensitive" technologies across the frequency range from sub-hertz to tens of gigahertz with system amplitudes ranging from minus 140 dbm to energy in megajoules. He devised many terms used for PC board layout, such as the "3-W Rule", the "V-plane Undercut Rule", and "ground stitching nulls". He is generally recognized for his work in systems integration, EMC emission and susceptibility control for all forms of systems, and occasionally serves as a manager or systems integrator. He has collaborated on the formations of many networks and standard practices, including the study group for 10/100BASEt.

Education:

BS/MSEE, Capitol Radio Engineering Institute & Capitol Institute of Technology, 1959-1966.
Ph.D. Psychology; Altadena Guidance Institute, 1982
Ph.D. Psychology; Pass Christian University, 2010

Areas of Expertise:

Dr. King will be advising us in the areas of systems integration, EMC emission and susceptibility control for all forms of systems.

Letter from the editor

MR. BRIAN LAWRENCE

iNARTE
New Bern, NC



Experience:

45 years designing and marketing stealth materials, RF absorbers, EMC and antenna test facilities. Almost 6 years as executive director for a credentialing agency serving telecommunications, EMC, ESD and product safety engineers

Education:

B Sc General Sciences, (Math, Physics and Chemistry)

Areas of Expertise:

Mr. Lawrence will be advising us in most areas of EMC, test and measurement, global markets (particularly Asia), and a multitude of diverse electromagnetic disciplines.

MR. HENRY OTT

Henry Ott Consultants
Livingston, NJ



Experience:

1st Lieutenant, USAF, Air Research & Development Command, 1957-1960
Distinguished Member of the Technical Staff, Bell Laboratories, 1960-1987, President/Principal Consultant, Henry Ott Consultants, 1988-present
Life-Fellow of the IEEE

Author of:

"Electromagnetic Compatibility Engineering," Wiley, 2009
"Noise Reduction Techniques in Electronic Systems," 2nd Edition, Wiley, 1988
"Noise Reduction Techniques in Electronic Systems," 1st Edition, Wiley, 1976

Education:

BSEE, New Jersey Institute of Technology, 1957
MSEE, New York University, 1963

Areas of Expertise:

Mr. Ott will be advising us in the areas of electromagnetic compatibility engineering, regulatory compliance, PCB layout and stackup for EMC, ESD, EMC education and training, and precompliance EMC diagnostics and testing.

MR. DOUG SMITH

D.C. Smith Consultants
Boulder City, NV



Experience:

Mr. Smith held an FCC First Class Radiotelephone license by age 16 and a General Class amateur radio license at age 12. Mr. Smith joined AT&T Bell Laboratories as a Member of Technical Staff. He retired in 1996 as a Distinguished Member of Technical Staff. From February 1996 to April 2000 he was Manager of EMC Development and Test at Auspex Systems in Santa Clara, CA. Mr. Smith currently is an independent consultant specializing in high frequency measurements, circuit/system design and verification, switching power supply noise and specifications, EMC, and immunity to transient noise. He is a Senior Member of the IEEE and a former member of the IEEE EMC Society Board of Directors.

Mr. Smith has lectured at Oxford University, The University of California Santa Barbara, The University of California Berkeley, Vanderbilt University, AT&T Bell Labs, and internationally at many public and private seminars on high frequency measurements, circuit design, ESD, and EMC. He is author of the book *High Frequency Measurements and Noise in Electronic Circuits*.

Education:

BEEE, Vanderbilt University, 1969
MSEE, California Institute of Technology, 1970

Areas of Expertise:

Mr. Smith will be advising us in the areas of high frequency measurements, design troubleshooting, ESD design and troubleshooting, and EMC design and troubleshooting

MR. JEFFREY VIEL

NTS
Boxborough, MA




Experience:

20 years experience in EMI/EMC test engineering, and EMI design consultant.
14 years working with NTS Technical Systems, 8 years as the EMI Test Laboratory Manager, and Engineering Services Manager.

Education:

BSEE, North Eastern University

Areas of Expertise:

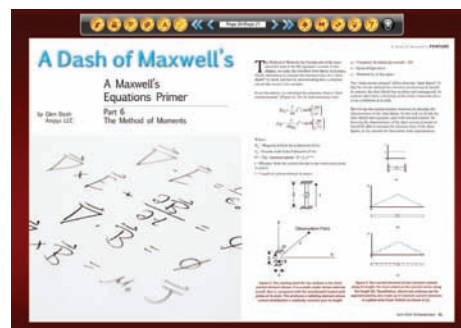
Mr. Viel will be advising us in the areas of Defense EMI, E³ and power quality certification requirements (MIL-STD-461A-F, MIL-STD-464 A-C, MIL-STD-1399 section 300A, MIL-STD-704 A-F, MIL-STD-1275), Aerospace EMI and power quality certification requirements (RTCA DO160 C-F, ABD0100.1.2 - 1.9), Nuclear EMI certification requirements (EPRI 102323, Nuclear Regulatory Guide 1.180), telecommunication EMI and power variation certification requirements (GR1089 I5 & I6, ATT76200, ETSI 3003-86, ETSI 300-132-2 &3) 



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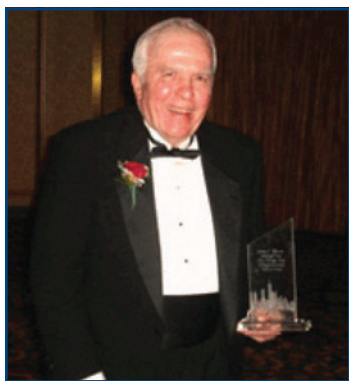
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Remembering James C. Klouda

Passing of James C. Klouda, CEO and Founder of Elite Electronic Engineering, Inc.



James C. Klouda (1928 - 2012)

a life-long entrepreneur, but most of all he loved people. He was a great man who always found the good in family, friends, employees, and professional associates around him," said Raymond Klouda, Jim's son and current President of Elite.

Jim, it will be recalled, recognized at a very early stage the need for testing electronics and receivers for radio frequency interference. With the support of his wife Marilyn, he founded Elite Electronic Engineering in 1954. Working in a copper-lined shielded enclosure that he and his father built, Jim used a Stoddard RF analyzer to begin making radio frequency measurements. He designed filters and other treatments

It is with great sadness that we share the news of the death of **Mr. James Calvin Klouda**, CEO and founder of Elite Electronic Engineering, Inc. Jim, aged 84 years, passed peacefully July 10th, 2012 with his family at his side.

"Jim Klouda was an EMC testing pioneer, a brilliant engineer, a visionary, and

that would help manufacturers develop products that were compatible with their electromagnetic environment. From one of the first independent electromagnetic compatibility testing laboratories in the world, Jim grew the company to become a world-recognized leader in the electronics testing industry.

Jim Klouda was a charitable man who will be known for his generosity to his alma mater the Illinois Institute of Technology in Chicago, where a science laboratory bears his name. Jim's philanthropy also extended to his church and many other causes close to him and his family.

Jim was a life member of the IEEE EMC Society, and active throughout his career with the Society of Automotive Engineers (SAE), and Institute of Environmental Science and Technology (IEST). In 2007 Jim Klouda was inducted into the Chicago Area Entrepreneurship Hall of Fame.

Through his children, grandchildren and his company, Elite Electronic Engineering, we are reassured that he has left behind an enduring legacy. The EMC and environmental stress testing services sector will miss him dearly.

Jim Klouda is survived by his wife of 60 years, Marilyn, daughter Janet (Gerry), and sons James (Julianne), Raymond, Joseph, and Thomas (Margaret), along with nine grandchildren.

In many ways, Elite Electronic Engineering began aboard a United States Air Force bomber. Flying out of Wright Patterson Air Force Base in Dayton, Ohio, the bomber was equipped for the first time with a new, aerial camera. That camera could produce consistent photographic intelligence by adjusting automatically to the plane's altitude and speed.

That first flight took place in the 1950s—and it didn't go well. As soon as the camera was turned on and began to function, its electronics began to interfere with the bomber's autopilot programming. The plane would gain altitude, then readjust to its original setting, and then gain altitude again. In no time, the camera was turned off and the bomber was back on the ground. An urgent call was placed to the manufacturer's engineer in Chicago, James C. Klouda—Elite's founder.

With a little sleuthing—and a little shielding—Klouda made the necessary adjustments to the firm's prototype model and air-shipped it to the Air Force base for testing the next day. There was no interference the next day and the in-flight test went off without a hitch.

Elite's founder went to work expanding his knowledge—and understanding the application—of EMC testing technology. About five years later, James Klouda

approached the military about creating an engineering firm with a testing focus on EMC. He was encouraged to do so.

While the company has grown exponentially in both customers served and services offered, the original values that Elite was founded on still hold true today. They include:

- Constant investment in new technology
- Cost-efficient and time-efficient testing
- Comprehensive dedication to the customer

Those principles have helped Elite become a leader in the industry—and have helped the company grow consistently during the past half century. In 1954, Elite had two employees and operated out of a 2,500 square foot storefront in south Chicago. By 1973, the company had 20 employees and occupied 22,000 square feet. Today, with 60 employees, and more than 45,000 square feet, Elite can offer unmatched expertise and equipment.

The company is substantially larger, the technology is significantly more advanced and the customer base is greatly diversified, but one thing hasn't changed in 58 years: James Klouda's vision and values are reflected every day in the way Elite conducts its business—and treats its customers.

Remembering Clayton R. Paul

A memoriam composed by Clayton Paul prior to his passing.



Dr. Clayton R. Paul (1942-2012)

Clayton R. Paul passed away on June 27, 2012. He was 70 years of age and was born and raised in Macon, GA. He graduated from Alexander III Grammar School and Lanier High School, class of 1959. He received the Bachelor of Science degree from The Citadel in 1963, the Master of Science degree from Georgia Institute of Technology in 1964, and the PhD degree from Purdue University

in 1970, all in Electrical Engineering. He began his career as a Professor of Electrical Engineering at the University of Kentucky in 1971 after serving on a Post Doctoral Fellowship with the Rome Air Development Center from 1970-1971. He retired from the University of Kentucky in 1998 and joined the School of Engineering at Mercer University in 1998 as the Sam Nunn Eminent Professor of Aerospace Engineering and Professor of Electrical and Computer Engineering retiring in 2012.

Through his over 49 year career as a teacher of Electrical Engineering he has published 19 textbooks on electrical engineering and interference in electronic systems and has published over 200 technical papers, symposia papers, and technical reports and given numerous presentations. He is a Life Fellow of the Institute of Electrical and Electronics

Engineers (IEEE) and Honorary Life Member of the IEEE EMC (Electromagnetic Compatibility) Society. He was awarded the prestigious 2005 IEEE Electromagnetics Award and the 2007 IEEE Undergraduate Teaching Award. He was awarded the IEEE EMC Society's prestigious Hall of Fame Award in 2011. His resume can be seen at http://faculty.mercer.edu/paul_cr. He was an FAA Certified Flight Instructor-Airplanes and Instruments (CFII) and an FAA Advanced Ground and Instrument Instructor since 1970.

He was also an accomplished Bluegrass musician for 45 years. While at Purdue University he played with the Chestnut Hill Boys Bluegrass Music Band, and recorded with Bob Anderson and the Country Ramblers old time string band. He has played with Cedar Hill, The Oconee River Boys and various other Bluegrass Music Bands.

He is survived by his beloved wife Carol and their companion animals. Anyone who is interested in the humane and compassionate treatment of animals is encouraged to donate to The Clayton and Carol Paul Fund for Animal Welfare c/o the Community Foundation of Central Georgia, 277 MLK, Jr. Blvd, Suite 303, Macon, GA 31202. The purpose of this fund is to make monetary grants to (1) animal humane societies, (2) animal shelters, (3) animal adoption agencies, (4) low-cost spay-neuter clinics (5) individual wildlife rehabilitators and (6) other deserving animal care organizations in order to allow these volunteer organizations to use their enormous enthusiasm, drive and willingness to reduce animal suffering and homelessness through the monetary maintenance of their organizations where little or no monetary funds existed previously.

EMC Community Loses an Icon

Clayton Paul passed away on June 27, 2012 at the age of 70. He was a great mentor for many of those in our industry, and will be sorely missed. His passion was to educate young electrical engineers, and he was always willing to take the time to explain and discuss a technical subject with those new to the industry.

Clayton was not only an educator but also a prolific writer, having written 19 textbooks, and published over 200 technical papers. I was honored to have been able to co-author, with Clayton and Bob German, the award winning* paper "Effect of an Image Plane on Printed Circuit Board Radiation."

I just finished reviewing his latest book, "Transmission Lines in Digital Systems for EMC Practitioners" (Wiley, 2012) for the IEEE EMC Society Magazine. The review will be published in the upcoming spring issue. I believe that this book, his last, is one of his best.

* The 1990 IEEE International Symposium on EMC best paper award winner.

Clayton was both a very dear personal friend and colleague of mine for over 30 years. I fondly remember our many technical discussions and debates, especially those on the subject of partial inductance. I know that I am a better person for having known him.



The true measure of a man's life is not the material things that he acquires, but rather the legacy that he leaves. By this criterion, Clayton was a giant among men.

His big smile and cheery attitude will be missed from future EMC Symposia, but the legacy that he leaves will always be with us.

God bless you Clayton, we will all miss you dearly.

Henry W. Ott
Henry Ott Consultants

Join us for this 3-Day Intensive Course

presented by renowned
EMC expert Henry Ott

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a course in noise and interference control in electronic systems

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In this 3-day intensive course we'll cover practical aspects of noise and interference control in electronic systems and provide a working knowledge of EMC principles. Ideas are illustrated with examples of actual case histories and mathematic complexity is kept to a minimum. Participants will gain knowledge needed to design electronic equipment compatible with the electromagnetic environment and in compliance with national and international EMC regulations.

COURSE CONTENT

CABLING

Electric and magnetic field coupling, crosstalk. Cable types: coax, twisted pair and ribbon cables. Cable shielding and terminations.

GROUNDING PRINCIPLES

Why do we ground? Ground systems: single point, multipoint, hybrid. Ground loops. Return current paths, split reference planes. EMC grounding philosophy. AC power grounds.

DIGITAL LAYOUT & GROUNDING

Noise sources, PCB layout, power distribution, ground grids, characteristics of ground planes. Decoupling capacitors: value, placement, resonance and limitations.

HIGH SPEED DIGITAL DECOUPLING

Alternative decoupling methods, use of distributed decoupling capacitance, power supply isolation, effect of paralleling capacitors. Embedded PCB capacitance.

DIFFERENTIAL-MODE EMISSION

Radiated emission mechanisms. Fourier spectrum. Methods of controlling differential-mode emission. Clock dithering. Cancellation techniques.

COMMON-MODE FILTERING

Basic C-M filter theory. Filter source and load impedances. Single and multi-stage filters. Ferrite chokes versus shunt capacitors. Effectiveness of various filter configurations. Filter mounting and layout.

TRANSMISSION LINES

What is a transmission line? Transmission-line effects, transmission-line radiation, and matching. How currents flow on transmission lines. Series, shunt and AC terminations. Simulation.

MIXED SIGNAL PCBs

Defining the problem, A/D converter requirements, return current paths, split ground planes, PCB partitioning, bridges & moats, routing discipline.

RF & TRANSIENT IMMUNITY

RF immunity: circuits affected, PCB layout, audio rectification, RFI filters. Transient immunity: circuits affected, the three-prong approach, keeping transient energy out, protecting the sensitive devices, designing software/firmware for transient immunity.

CONDUCTED EMISSION

AC power line conducted emission models, switching power supplies, parasitic capacitance, layout. Common-mode and differential-mode conducted emission, common-mode chokes, saturation. Power line filters.

SHIELDING

Absorption and reflection loss. Seams, joints, gaskets, slot antennas, and multiple apertures. Waveguides below cutoff, conductive coatings. Cabinet and enclosure design.

EMC EXHIBITS AND EVENING RECEPTION: WEDNESDAY, SEPTEMBER 26, 2012

Exhibitors: for information contact Sharon Smith - e-mail: sharon.smith@incompliancemag.com or call (978) 873-7722

REGISTRATION

COURSE DATES/TIME:

September 25-27, 2012
Tuesday and Thursday 8:30 a.m. to 4:30 p.m.
Wednesday 8:30 a.m. to 5:00 p.m.

COURSE LOCATION: Millennium Harvest House Boulder,
1345 28th Street, Boulder, CO 80302

COURSE FEE: \$1,495 (\$1,295 until 8/17/2012). Fee includes notes, textbook*, breakfast, luncheon and beverage breaks. Payment required prior to course. Hotel accommodations are NOT included.

CANCELLATION POLICY: You may cancel your registration up to two weeks prior to the course and receive a full refund. For cancellations received after this time there will be a \$100 cancellation fee, or you can send a substitute, or use the registration for a future

course. No-shows will not receive a refund; however the seminar fee may be applied to a future course.

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HOTEL RESERVATIONS: Call the Millennium Harvest House Boulder at 303-443-3850. Room rates start at \$126 per night (tax not included). Book by September 8 to receive this rate. Rate is based on availability. You must mention In Compliance Magazine when making reservations to get this special rate. The hotel is holding a limited block of rooms.

***Electromagnetic Compatibility Engineering**, by Henry W. Ott

Who Should Attend

This course is directed toward electrical engineers. However, mechanical engineers, reliability and standards engineers, technical managers, systems engineers, regulatory compliance engineers, technicians and others who need a working knowledge of electromagnetic compatibility engineering principles will also benefit from the course.

Feedback from recent participants

"This is really a fantastic course. Everything is very practical, and I have a much more intuitive feel for what is important in EMC and why."

"Very enjoyable presentation; passionate about subject, used good practical examples."

"Henry is the best in EMC."

"Probably the most useful technical seminar I have ever attended. Should have learned this 20 years ago."

"Thank You. Your work is very valuable and your presentation style is refreshing!"

"Really happy I flew all the way here."

"Excellent course! Presented in a very understandable way, even for a mechanical engineer."

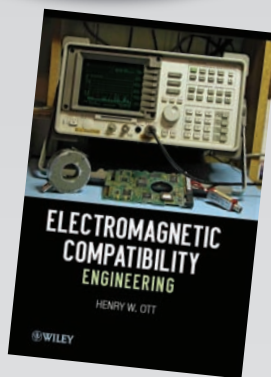
"Should be required training for all engineers."

"This is the best practical course available."

"An excellent seminar presented by a pragmatic, knowledgeable and entertaining teacher."

"This seminar exceeded by far my expectations, and my expectations were high already."

Includes Henry Ott's latest book!



HENRY OTT



Henry W. Ott is President and Principal Consultant of Henry Ott Consultants (www.hottconsultants.com), an EMC training and consulting organization. He has literally "written the book" on the subject of EMC and is considered by many to be the nation's leading EMC educator. He is the author of the popular EMC book Noise Reduction Techniques in Electronic Systems (1976, 1988). The book has sold over 65,000 copies and has been translated into six other languages. In addition to knowing his subject, Mr. Ott has the rare ability to communicate that knowledge to others.

Mr. Ott's newly published (Aug. 2009) 872-page book, Electromagnetic Compatibility Engineering, is the most comprehensive book available on EMC. While still retaining the core information that made Noise Reduction Techniques an international success, this new book contains over 600 pages of new and revised material.

Prior to starting his own consulting company, Mr. Ott was with AT&T Bell Laboratories, Whippany, NJ for 30 years, where he was a Distinguished Member of the Technical Staff and a consultant on EMC.

Mr. Ott is a Life Fellow of the IEEE and has served the EMC Society in various capacities including: membership on the Board of Directors, Education Committee Chairman, Symposium Committee Chairman and Vice President of Conferences. He is also a member of the ESD Association and a NARTE certified ESD engineer. He is a past Distinguished Lecturer of the EMC Society, and lectures extensively on the subject of EMC.

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Make checks payable to Henry Ott Consultants.

FCC News

FCC Adjusts New Equipment Authorization Program, Contemplates Further Changes

The Federal Communications Commission (FCC) has made a small but significant change to its equipment authorization program to support the increased demand for FCC identification codes.

By an Order issued in June 2012, the Commission has modified its rules to lift the restriction limiting grantee codes to not more than three characters. The Commission says that this action will greatly increase the supply of available codes in support of requests to certify new equipment.

The Commission notes that it issued 1275 new ID codes in 2011, making the rule change essential.

Perhaps most important, the Commission also says that it is also exploring ways to improve the current equipment authorization program, "including clarifying or modifying the administrative requirements and responsibilities of the Telecommunications Certification Bodies that perform equipment certification."

The complete text of the Commission's Order on FCC IDs is available at incompliancemag.com/news/1208_01.

FCC Allocates Spectrum for Medical Body Area Networks

The Federal Communications Commission (FCC) has adopted rules to support the deployment of new wireless medical technology that promises to provide hospitalized patients with better healthcare and greater freedom.

In a Report and Order issued in May 2012, the Commission has authorized the use of so-called medical body area networks (MBANs). MBANs are low-powered networks that transmit a range of patient data from multiple body-worn sensors to a control device. MBANs can be used to monitor patient vital health signs in real time, thereby providing advanced notice of potential problems. And, because they are wireless, MBANs make it easier to move patients to different areas of a healthcare facility for specialized treatment.

The Commission has allocated 40 MHz of spectrum in the 2360-2400 MHz band for MBAN use on a secondary basis. To facilitate the rapid development of new MBAN devices and applications, the Commission has also modified the provisions of its rules governing medical device radio communications so that users will not have to apply for individual operating licenses.

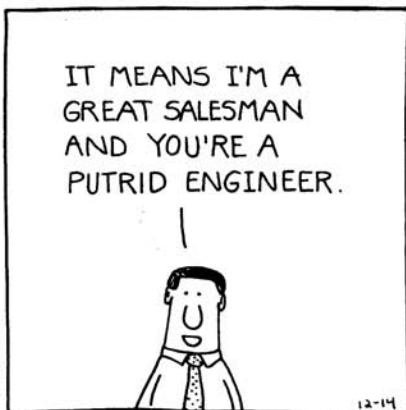
The complete text of the Commission's First Report and Order on spectrum for medical body networks is available at incompliancemag.com/news/1208_02.

FCC Eases SMR Restrictions in 800 MHz Band

Taking additional steps to reduce barriers to the further deployment of wireless broadband Internet services, the Federal Communications Commission (FCC) has modified its rules to ease constraints on 800 MHz Specialized Mobile Radio (SMR) licensees.

Under a Report and Order issued in May 2012, the Commission has amended its rules to allow geographically-based SMR licensees to operate across contiguous channels without a rigid channel spacing requirement or bandwidth limitation. The Commission says that these changes will allow SMR licensees to more efficiently use their licensed spectrum and speed their transition from legacy communications systems to 3G and other advanced technologies that can operate on either contiguous or non-contiguous spectrum.

At the same time, the Commission affirmed that the changes will not jeopardize public safety communications operating in the 800 MHz band or create undue interference.



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FCC News

The complete text of the Commission's Report and Order on Mobile Radio Licenses is available at incompliancemag.com/news/1208_03.

FCC Seeks Comment on Emergency Aerial Communications

The Federal Communications Commission (FCC) is actively exploring the potential use of aerial communications technologies to provide emergency communications during or immediately after a major disaster in which land-based communications systems have been damaged or destroyed.

comment on how best to coordinate and manage the use of DACA technologies, and what steps should be taken to provide spectrum to support their operation.

The Commission's Notice of Inquiry on DACA technologies follows the publication of an FCC white paper earlier this year entitled "The Role of Deployable Aerial Communications Architecture in Emergency Communications and Recommended Next Steps", which offers an in-depth analysis of DACA technologies and their potential benefits in providing emergency communications.

The complete text of the Commission's Notice of Inquiry on the use of DACA technologies is available at

operation on these segments within 110 kilometers of the common border. In addition, a bi-national task force will be created to aid in the efficient transition to the new plan by incumbent spectrum holders operating along the border.

A separate protocol for the 1.9 GHz band will allow Sprint Nextel Corporation to deploy CDMA cellular service along the Mexican border. Sprint acquired access to the 1.9 GHz spectrum several years ago as compensation for agreeing to vacate its spectrum holding in the 800 MHz band.

The rebanding of spectrum was deemed necessary to alleviate interference to public safety licensees due to commercial cellular operations.

The FCC is actively exploring the potential use of aerial communications technologies to provide emergency communications during or immediately after a major disaster in which land-based communications systems have been damaged or destroyed.

Technology based on deployable aerial communications architecture (DACA) would rely on state-of-the-art communications systems positioned on aerial platforms, such as manned aircraft, unmanned aerial vehicles and balloons, capabilities that are already available for military operations. The Commission believes that a DACA-based backup plan could play a vital link in restoring critical communications in the first 72 hours following a natural or man-made disaster.

In a Notice of Inquiry issued in May 2012, the Commission solicited public comments on issues related to the deployment and operation of DACA technologies, and the associated cost and benefits. The Commission also sought

incompliancemag.com/news/1208_04. The Commission's DACA white paper is available at incompliancemag.com/news/1208_05.

U.S./Mexico Reach Spectrum Sharing Agreement

The U.S. and Mexico have signed agreements that will enable the cooperative sharing of the 800 MHz and 1.9 GHz band spectrum in areas along the U.S.-Mexican border.

According to a press release issued by the Federal Communications Commission (FCC), a new 800 MHz protocol will allot band segments between the U.S. and Mexico and specifies the technical parameters for

"These agreements...will unleash investment and benefit consumers near the border by enabling the rollout of advanced wireless broadband service and advanced systems for critical public safety and emergency response communications," noted FCC Chairman Julius Genachowski.

FCC Releases First Quarter 2012 Consumer Complaints

The U.S. Federal Communications Commission (FCC) has released its report on inquiries and complaints made by consumers to the agency's Consumer & Government Affairs Bureau during the first quarter of 2012.

FCC News

The Bureau regularly tracks inquiries and complaints from consumers on matters within the scope of the Commission's jurisdiction. In the area of wireline telecommunications matters, the Bureau is particularly interested in instances of "cramming" (the placing of unauthorized, misleading or deceptive charges on a telephone bill) and "slamming" (the practice of changing a subscriber's telecommunications service provider or calling plan without the subscriber's permission). The Commission also tracks violations of the Federal Telephone Consumer Protection Act (TCPA), which includes

regulations covering both the National Do Not Call Registry and unsolicited fax advertisements.

During the period from January through March 2012, the Bureau received a total of 36,032 complaints regarding wireline telecommunication services, with 33,132 complaints (91.9% of the total) in the area of TCPA issues alone, and more than 3,038 complaints in connection with unsolicited fax advertisements. This compares with 29,480 total complaints during the January-March 2011 period, when 26,020 (88.3% of the total) involving TCPA issues.

In the area of inquiries, the Bureau also received 7,551 inquiries in connection with wireline telecommunications, including 4,893 inquiries dealing with TCPA issues, during the period from January through March 2012. This compares with 8,536 total inquiries during the first quarter of calendar year 2011, of which 5,445 were related to TCPA issues.

The complete text of the Commission's most recent quarterly report is available at incompliancemag.com/news/1208_06.

News is continued on page 114



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Introductions

BY BRIAN LAWRENCE

It is now time to introduce the officers and staff of RABQSA International who will be responsible for the running and development of the iNARTE Brand in the future.

My wife, Kathy, and I, who have had this responsibility for the last 6 years, will be serving in a training and advisory role during the management transition period. It has been a great pleasure to have been of service to the engineers and technicians who practice in the different iNARTE disciplines, and particularly rewarding when we hear how iNARTE certification has helped secure employment or career advancement for someone.

Your new management team will be:

Peter Holtmann, President and CEO,
pholtmann@rabqsa.com

Adam Maxwell, Director of Global Operations, amaxwell@rabqsa.com

Frank Phillips, Manager of Business Development, fphillips@rabqsa.com

Monique Inman, Manager of Operations USA, minman@rabqsa.com

Technology transfer and moving of hardware from our New Bern, NC office to the RABQSA Milwaukee office has begun. This process will take place gradually over the next two months in order that it is not too disruptive to our operations. Nevertheless, we expect that some longer than normal times will be needed in processing certification requests and marking of examination results during this period. By the end of August all systems should be operating smoothly in the new RABQSA offices.

INARTE EMC DESIGN ENGINEER CERTIFICATION

As reported last month, iNARTE attended the High-speed digital engineering and EMC series of courses at the University of Oxford. Although the university and course presenters showed great enthusiasm for our involvement, we were unable to attract any of the attendees to participate in the examination phase. Talking to some attendees, we found that many of them were most interested in the

digital design engineering courses but did not fully understand how this work would need to be integrated with EMC disciplines. It seems that so many companies keep these two departments separated, which often results in designs evolving to an advanced stage before an EMC survey or simulation effort takes place. The design course attendees understood this problem, but attendance fees were being paid by their employers and funds for non essential workshop or tutorial programs were nonexistent this year.

Oxford University wants to continue to keep EMC as part of this annual digital design course and expects that the value of this connection and the added value of a credential for EMC Design in digital engineering will become apparent over the next year or two.

We did get one applicant for certification but he did not realize that EMC had nothing to do with Extra Marital Curricula, or Excommunication from Mother Church, so unfortunately as impressive as his credentials seemed to be, we were not able to assist him.



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Part 1 EMC FUNDAMENTALS

Electromagnetics:
Field Theory
Coupling

Basic Knowledge:
Antennas
ESD
Safety

Measurements and Analysis:
Test & Measurement
Test Facilities
Spectrum Analysis

Electrical Circuit Theory:
Transmission Lines
Electrical Networks
Filters
Amplifiers
Signals and Transforms

EMC Design:
Grounding & Bonding
EMC Design
EMI Prediction & Analysis

Part 2 WIRELESS CERTIFICATION SPECIFICS

General Certification Knowledge:
FCC & IC

Administration:
Test Methodology
Test Plans
Test Reports

Licensed Devices

Unlicensed Devices

RF Exposure

Optional added endorsement:
RTTE and other economies

THE NEW WIRELESS DEVICE CERTIFICATION PROFESSIONAL

This month we will have completed the details for the launch of our new Wireless Device Certification Professional certificate. This new credential is intended to recognize the special expertise required to correctly evaluate the many wireless devices that are being presented for certification in accordance with FCC and other international regulatory requirements.

The purpose of the Wireless Device Certification Professional program is to foster technical "excellence" in the evaluation and certification of wireless devices against a complexity of regulatory requirements. This approach establishes technical competency criteria for Wireless Device Certification and enforces these criteria for technical personnel performing that work. The program benefits the individual professional and the certification community as a whole by establishing a standard of excellence that will endure and extend across regional and commercial boundaries.

iNARTE Wireless Device Certification credentialing is a three step process based on education and work experience, peer endorsement and examination. Educational and work experience may be a combination of two or more years of related post secondary education combined with at least six years of applicable industrial experience, or a minimum of ten years related industrial experience. Peer and supervisory endorsements are used to substantiate the credibility of the candidate. Examinations are confined to the area of EMC fundamental knowledge and Wireless Device certification essentials. The target of



the examination is to establish that a candidate has a comprehensive knowledge in essential areas

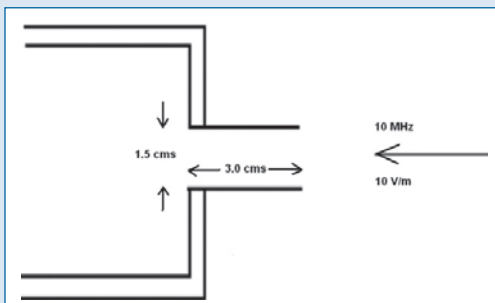
The examinations consist of two Parts. Part 1 will be given over a four hour period on the morning of the examination day. Part 2 will be given over a four hour period in the afternoon. All questions are multiple-choice and will cover both EMC Fundamentals in Part 1 and Wireless Device Certification essentials in Part 2. A passing grade for this examination is 80% average between the two Parts.

Applicants not passing an examination are not required to submit a new application form to retake it, but must notify iNARTE 45 days in advance of availability for the next examination. A candidate failing an examination may apply for re-examination at the expiration of 90 days and will be re-examined without penalty. A retesting process fee is required. Candidates may retake one or both Parts of the examination as many times as they wish. Each attempt will be matched with earlier attempts in order to determine the best combination of Part 1 and Part 2 scores. However, all applicants who retake only one Part will need to achieve the passing grade combination within 24 months, after which a new set of attempts starting with a full examination will be required. ■

QUESTION OF THE MONTH

Last month we asked:

Adding depth to an opening in a shielded enclosure can help in the overall shielding effectiveness. What is the total shielding effectiveness to a 10 MHz field with the strength 10 V/m if the only opening in the structure is 1.5 cm round with a 3cm long tube, or waveguide bonded to it?



- A) 120 dB
- B) 60 dB
- C) 90 dB
- D) 30 dB

The answer is A) 120dB

This month's question is:

Intermodulation products are a result of which of the following:

- A) Motor Brushes that arc when operated in an unshielded area.
- B) Mixing of two or more RF signals in a nonlinear junction.
- C) Transmitter primary frequencies that mix in linear junctions.
- D) Nonlinear junctions rubbing together causing intermodulation.
- E) Adding an information signal to a carrier.

(the author)

BRIAN LAWRENCE began his career in electromagnetics at Plessey Research Labs, designing "Stealth" materials for the British armed services. In 1973 he moved to the USA and established a new manufacturing plant for Plessey to provide these materials to the US Navy. In 1980 he joined the "Rayproof" organization to develop an RF Anechoic Test Chamber product line. As a result of acquisitions, Rayproof merged into Lindgren RF Enclosures, and later into ETS-Lindgren. Following a career spanning more than 40 years in the electromagnetic compatibility field, Brian retired as Managing Director of ETS-Lindgren UK in 2006. Later that year he assumed the position of Executive Director for the National Association of Radio and Telecommunications Engineers, NARTE. Now renamed iNARTE, the Association has expanded its operations and is today an affiliate of RABQSA under the overall banner of the American Society for Quality, ASQ.



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Surface Voltage and Field Strength Part I: Insulators

By definition, insulators do not have a voltage.

BY NIELS JONASSEN, sponsored by the ESD Association

This article, the first of a two-part series on measuring voltage and field strength, examines the controversial topic of an insulator's surface voltage and field strength. The discussion will include both theory and actual measurements, and will begin with a review of the most important features for a charged conductor and how these features differ for a charged insulator.

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

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Mr. Static Column
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CHARGED CONDUCTORS

Figure 1 shows an insulated conductor A with a charge q . The charge will automatically distribute itself on the surface of the conductor in such a way that the field in the interior of the conductor will be zero, the field will be perpendicular to the surface, and the integral of the field strength E from any point P in or on the conductor to a ground point G is constant and given by

$$V = \int_P^G E \cdot da \quad (1)$$

where V is the voltage or potential of the conductor.

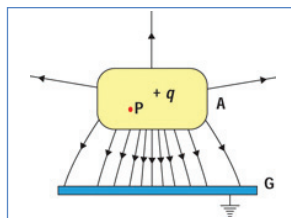


Figure 1: Charged conductor

The voltage V and the charge q are proportional, and q is usually written as

$$q = C \cdot V \quad (2)$$

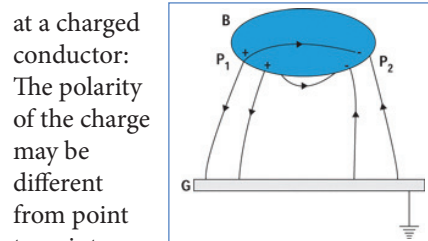
where C is the capacitance of the insulated conductor and is determined by the conductor's size and shape, and its placement relative to other conductors and ground. The charged system stores an electrostatic energy of

$$W = \frac{1}{2} C \cdot V^2 \quad (3)$$

which can be dissipated in a single discharge or current pulse.

CHARGED INSULATORS

Figure 2 shows a charged insulator. The field conditions here are very different from those at a charged conductor:



The polarity of the charge may be different from point to point, the field in the interior may be different from zero, the field is not necessarily perpendicular to the surface, and the integral of the field strength from a point on or in the insulator to ground is usually different from point to point.

In Figure 2, the integrals of the field strength for P_1 and P_2 are

$$V_{P_1} = \int_{P_1}^G E \cdot da > 0 \text{ and } V_{P_2} = \int_{P_2}^G E \cdot da < 0$$

respectively. V_{P_1} and V_{P_2} are the surface voltages (or surface potentials) of the two points. In general, the surface voltage of an insulator will vary from point to point, as will the voltage of

any point in the interior. It is therefore not possible to characterize a charged insulator with a single voltage figure. In other words, an insulator does not have a voltage.

Many people do not like to accept this simple fact, so specifics need to be discussed. There are cases in which the surface of an insulator has a constant surface voltage. But apart from such instances, there is only one situation in which all points in and on an insulator can be ascribed a well-defined (but unmeasurable) voltage. If a spherical insulator with radius R and uniform charge q (see Figure 3) is placed infinitely far (a distance much greater than R) from any conductors, the sphere would have a voltage of

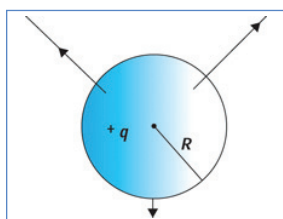


Figure 3: Uniformly surface-charged, spherical insulator

$$V_{\text{sphere}} = \frac{q}{4\pi\epsilon_0 R} \quad (4)$$

However, this very theoretical situation is the only case in which it makes sense to talk about the voltage of an insulator.

Similarly, the concept of an insulator's capacitance is meaningless. Although it is possible to get a discharge from a charged insulator, the discharge will always be partial, and the energy dissipated can neither be related to the total charge nor be related to any kind of voltage. In other words, voltage and capacitance are quantities of a conductor, not an insulator.

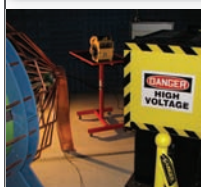
So a natural question arises: what measurements can be taken from a charged insulator? The simple answer is that the effect of the field from the charge, and sometimes the total

charge, can be measured. This article will concentrate on the direct effect of the field. As with conductors, the instruments used for measurement are field meters and noncontacting

voltmeters. Both types of instruments will distort the fields to be measured unless properly screened. Uniformly charged free insulative sheets and uniformly charged insulative sheets

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backed by a grounded conductor are the only two cases in which it is possible to make quantitatively reliable measurements of charged insulators.

UNIFORMLY CHARGED SHEETS

Figure 4 shows a uniformly charged insulative sheet. If the field strength indicated on the meter is E , the charge density s on the part of the insulator in front of the meter should be

$$\sigma = \epsilon_0 E. \quad (5)$$

If a noncontacting voltmeter is placed at a distance d from the sheet, then the surface voltage V_s indicated on the meter would be given by

$$V_s = E \cdot d = \frac{\sigma}{\epsilon_0} \cdot d \quad (6)$$

Figure 5 shows the field strength E from a free plastic sheet with a total charge q @ $0.5 \cdot 10^{-7}$ C. The area of the sheet is 21×29 cm², which gives an average charge density of

$$\sigma_{\text{avg}} = \frac{0.5 \cdot 10^{-7}}{21 \cdot 29 \cdot 10^{-4}} = 0.82 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$$

The figure shows that the field strength E is relatively constant at about $88 \text{ kV} \cdot \text{m}^{-1}$ to a distance of approximately 5–6 cm. According to Equation 5, this corresponds to a charge density of

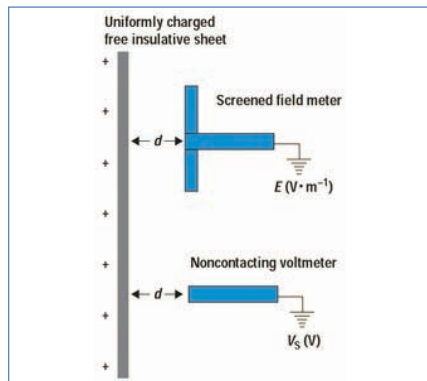


Figure 4: Static measurement on free charged sheet

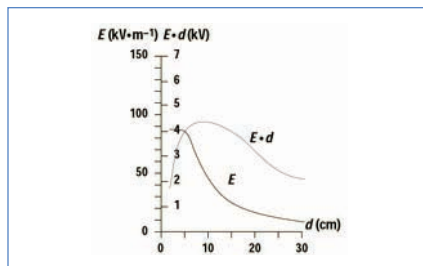


Figure 5: Field strength from and surface voltage of free plastic sheet

$s = 8.85 \cdot 10^{-12} \cdot 88 \cdot 10^3 = 0.78 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$. Considering the uncertainty of the measurements of the total charge and of the field strength, the agreement between the calculated and measured values of the charge density ($s_{\text{avg}} = 0.82 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$ versus $s = 0.78 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$) seems satisfactory.

It therefore appears that measurement of the field strength near a free charged sheet leads to information about the charge density and charge distribution on the surface. In the region where the field is homogeneous, the surface voltage of the sheet is proportional to the distance from the sheet and is measured, using Equation 6, by a noncontacting voltmeter. This measurement then leads to the surface charge density, given that the measuring distance can be estimated with reasonable accuracy. However, it should be stressed that a measurement of the surface voltage does not provide any more or better information about the charged state of the insulative sheet than a measurement of the near-surface field strength does.

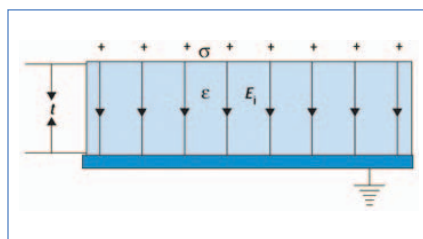


Figure 6: Uniformly charged insulator disk, backed by grounded conductor.

INSULATOR DISK

Figure 6 shows an insulator disk with permittivity ϵ and thickness t . The disk is resting on a grounded plane and has a positive charge with density s ($\text{C} \cdot \text{m}^{-2}$). If the disk is far from other conductors, the field inside the material will be given by $E_1 = s/\epsilon$, and each point on the surface will then have a voltage of

$$V_s = E_1 \cdot t = \frac{\sigma}{\epsilon} \cdot t \quad (7)$$

It should be stressed that V_s is not the voltage of the insulator disk, but only of the surface. Any point inside the insulator has a different, unmeasurable voltage.

The situation shown in Figure 6, with the disk far from conductors other than the grounded base, is of little practical interest because it excludes the presence of meters. A more common situation is shown in Figure 7, in which a grounded electrode A is parallel to the charged disk at a distance d . The field strength in the space between the charged disk and A would be given by

$$E = \frac{\sigma \cdot t}{\epsilon \cdot d + \epsilon_0 \cdot t} \quad (8)$$

The grounded plane A might typically be the place where a field meter or noncontacting voltmeter is placed, with distance d being much greater than thickness t . The charged disk can be,

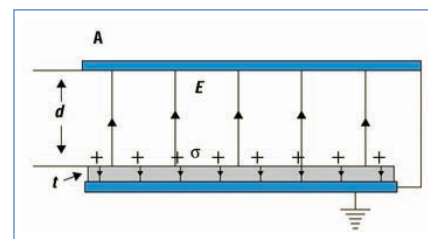


Figure 7: Uniformly charged insulator disk between grounded backing electrode and free grounded electrode.

for instance, an electret or a web. With these conditions, Equation 9 can be written as

$$E = \frac{\sigma}{\epsilon} \cdot \frac{t}{d} \quad (9)$$

The surface voltage, which is almost equal to the undisturbed value, can be written as

$$V_s = \frac{\sigma}{\epsilon} \cdot t \quad (10)$$

It appears that, under these conditions, it is possible to estimate the charge density by measuring either the field strength or the surface voltage from the charged disk, assuming the permittivity and thickness of the disk are known.

SHEET WITH GROUNDED CONDUCTOR

Figure 8 shows an experimental set-up corresponding to the conditions described in Figure 7. This could, for example, be a charged web or an electret. The charged insulator is a 1-mm plate with dimensions of

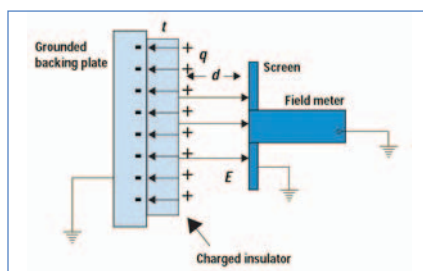


Figure 8: Uniformly charged insulator backed by a grounded conductor.

0.21 x 0.29 m². The relative permittivity (dielectric constant) of the material is $\epsilon_r \gg 2$ ($\epsilon = 1.77 \cdot 10^{-11} \text{ F}\cdot\text{m}^{-1}$). The total charge on the free surface of the insulator is $q \gg 2.7 \cdot 10^{-7} \text{ C}$, leading to an average surface charge density of $s \gg 4.4 \cdot 10^{-6} \text{ C}\cdot\text{m}^{-2}$.

In the absence of a field meter (and other grounded objects, not including the backing plate), the surface potential of each point on the surface can be calculated using Equation 7 as

$$V_s = \frac{4.4 \cdot 10^{-6}}{1.77 \cdot 10^{-11}} \cdot 10^{-3} \approx 250 \text{ V}$$

When the field meter is placed in front of a charged plate, the electric flux from the charge is shared between the field meter and the backing plate.

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Consequently, the internal field and the surface voltage will be reduced slightly, depending on how far away the meter is placed. There will also be a field E_d in the space between the charged plate and the field meter. This field is the only quantity of the charged plate that can possibly be measured.

Figure 9 shows the field strength from and surface voltage of the disk shown in Figure 8. At 5 cm, the field strength and surface potential are measured to be $E_s \gg 4.6 \text{ kV} \cdot \text{m}^{-1}$ and $V_s \gg 235 \text{ V}$, respectively. According to Equation 9, this corresponds to a charge density of

$$\sigma = \frac{\epsilon \cdot D \cdot E}{t} = \frac{1.77 \cdot 10^{-11} \cdot 5 \cdot 10^{-2} \cdot 4.6 \cdot 10^3}{10^{-3}} \approx 4.1 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$$

Comparing this with the calculated value of $s = 4.4 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$ and considering the uncertainties in the quantities involved, especially in the uniformity of the initial surface charging and the effective distance to the meter, the agreement between the calculated and measured values is surprisingly good: $4.4 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$ and $4.1 \cdot 10^{-6} \text{ C} \cdot \text{m}^{-2}$, respectively.

As shown in Figure 9, the surface voltage, $E \cdot d$, is relatively independent of the distance to the meter, and this feature will be even more pronounced in the cases of thinner insulators such as real electrets and webs, which have thicknesses on the order of 50–100 μm .

GENERAL COMMENTS

Free insulative sheets and insulative sheets backed by a grounded conductor are the only cases in which it is possible to extract reliable information from a noncontacting measurement of the charged state of an insulator. In both cases, the electric field from the charge is the deciding factor. With a free sheet (or just a relatively planar insulator), the electric field measured at a short

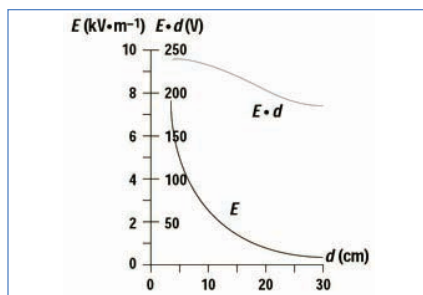


Figure 9: Field strength from and surface voltage of a uniformly charged plastic sheet backed by a grounded conductor.

distance (a few centimeters) will provide all the possible information—that is, the charge density. If a noncontacting voltmeter is used, the distance will have to be measured in order to convert the surface voltage to surface charge density. Surface voltage in itself does not provide extra information.

In the case of a sheet backed by a conductor, the surface voltage is relatively constant. If the thickness and permittivity of the material are known, then the surface voltage could be used to calculate the surface charge density. If a field meter is used, then the distance would also have to be measured. Field strength depends on the surface parameters (thickness and permittivity) in the same way surface voltage does.

Even in the well-defined situations of a free charged sheet and a backed charged sheet, a noncontacting measurement will, at best, only provide information about the charge density. Sometimes a field measurement (free charged sheet) is the most relevant, whereas at other times a direct surface-

voltage measurement (backed charged sheet) is the most relevant. However, either measurement will only lead to the charge density.

But what happens if the charged insulator is not one of the well-defined objects previously described, and the meter is just pointed toward an ordinary object? The answer can be found in Figure 10, which shows a plastic container. A screened field meter very close to the container identifies a field strength $E = +100,000 \text{ V} \cdot \text{m}^{-1}$. A noncontacting voltmeter at a distance of 2 cm (as well as the distance can be measured) identifies a surface voltage $V_s = +2 \text{ kV}$. What can be concluded from these measurements? A prudent and safe answer is that the container is positively charged.

If the situation in Figure 10 is approximated with that of Figure 4, using Equations 5 and 6, both readings would suggest that the surface charge density in front of the meters is positive and on the order of $1 \mu\text{C} \cdot \text{m}^{-2}$. This result, however, is very uncertain, especially when using a noncontacting voltmeter, because the reading is approximately inversely proportional to the measuring distance. If the measuring distance of 2 cm can be read with an accuracy of $\pm 2 \text{ mm}$, then there is already an uncertainty of 10%, regardless of meter sensitivity. If the distance is increased, then charges other than those on the surface immediately facing the meter will influence the reading and make the interpretation even more uncertain.

STATIC LOCATORS

Probably the most common way to do a fast static survey is to point a handheld meter at the suspicious item and pronounce a voltage. Often this is the only “measurement” done, and very often this is not enough.



Figure 10: Static measurement of the field strength and surface voltage on a plastic container.

The meters so used are known as *static locators*. And that is exactly what they are: instruments used to locate a static-electric field. As long as that is the only thing they are used for, everything should work fine. Static locators are scaled in volts and have a stipulated measuring range. However, the meter is not a voltmeter, meaning it doesn't react to voltage, but rather to an electric field.

If a static locator is a real field meter (e.g., a field mill) and has a scale in $V \cdot m^{-1}$ (or kV/in.), it may be used close to charged insulators to estimate the surface charge density, as explained above. If the scale is in volts, the reading may approximate the surface voltage and can, using Equation 6, lead to the surface charge density.

With both types of measurements, the results may have a high uncertainty and even errors, especially if the meters are not screened. Even if the meters are screened, there is also the influence of charges other than the ones immediately facing the meters—for instance, the charges on the other side of the insulator. The second part of this series on voltage and field strength will discuss static locators in more detail.

CONCLUSION

It is easy to determine whether an insulator is charged. Just point a suitable meter at the insulator and take a reading. If the measurement is done carefully, then the reading may provide information about how much charge is located on a unit area of the facing surface (i.e., the surface charge density, $C \cdot m^{-2}$), as well as the polarity of the charge.

However, the problem is that no meters are calibrated for this unit of measurement. The meters with the closest unit are field meters with scales in volts per meter, $V \cdot m^{-1}$. Fortunately,

the volts-per-meter measurement can be multiplied by ϵ_0 ($8.85 \cdot 10^{-12} F \cdot m^{-1}$) to arrive at the charge density.

The bad news, however, is that most meters have scales in volts. In all cases, these meters have been calibrated relative to conductors, where the concept of voltage makes sense. Used in connection with insulators, the reading may at best be an approximation of the surface voltage, which characterizes only a part of the insulator's surface, not the insulator. In this case, the reading in volts, when multiplied by ϵ_0 and divided by the measuring distance, can also lead to the surface charge density. It should be stressed that the voltage of an insulator has no meaning. All that can be found by any noncontacting measurement on a charged insulator

is the polarity of the charge and, if the measurement is done carefully, the surface charge density. ■

(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.



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Arc Flash Safety Labeling

Avoiding 9000°C Explosions

BY GEOFFREY PECKHAM

In this column we'll explore the kinds of safety markings designed to warn against electrical arc flash explosion hazards. In the United States, there are two primary documents engineers and facility owners use to determine their need to warn about arc flash hazards: the *NFPA 70 National Electrical Code (NEC)* and the *NFPA 70E Standard for Electrical Safety in the Workplace*.

The *NEC* first required arc flash safety labels in its 2002 edition and it referred to *NFPA 70E* for the actual label requirements. While the *NFPA 70E* standard requires that a label is provided to warn that an arc flash hazard exists, it does not specify exact label content. These two standards, in addition to OSHA's requirement to warn about electrical

hazards, create the need to label and warn against arc flash hazards. The *NEC* leads to what, in practice, is a two-tier approach for arc flash labeling. First, electrical panel manufacturers place a general warning which communicates the presence of an arc flash hazard and that appropriate PPE is required in accordance with the *NFPA 70E* standard (Figure 1). This

is the minimum labeling required to meet the code. The second label (Figure 2 on page 30) is more detailed and represents best practices in safety labeling for arc flash hazards. This label includes information from a specific panel in a specific location in a facility as defined by an arc flash study. It identifies the hazard severity, safe distances involved, and exact types of PPE required to avoid injury. It's a good idea to use standardized formats for this second label, though the actual content elements need to be customized for each electrical panel in each facility.

Companies often utilize outside consultants to perform full arc flash studies so hazards are defined correctly. You don't want to over-warn, such as requiring flame resistant clothing when it's not necessary. At the same time, you don't want to under-warn by mistakenly categorizing an arc flash hazard as less severe than it is. The labels that are the end result of an arc flash study are important elements in your facilities' risk reduction/safety improvement plans, as they give employees and subcontractors the information they need to know to stay safe when performing electrical maintenance procedures.

NFPA 70E states that the design of arc flash labels should comply with



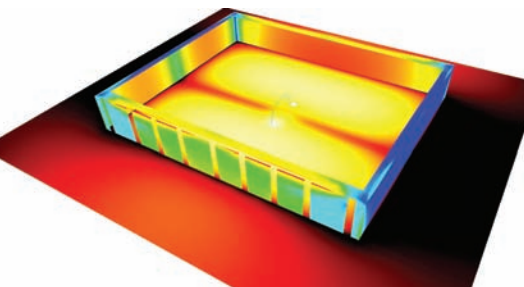
Figure 1: A general arc flash safety label (courtesy of Clarion Safety Systems © 2012) typically applied by the manufacturer of the equipment.



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CHANGING THE STANDARDS



Figure 3: Examples of standards-compliant, best practice arc flash safety labels (courtesy of Clarion Safety Systems © 2012) in use.

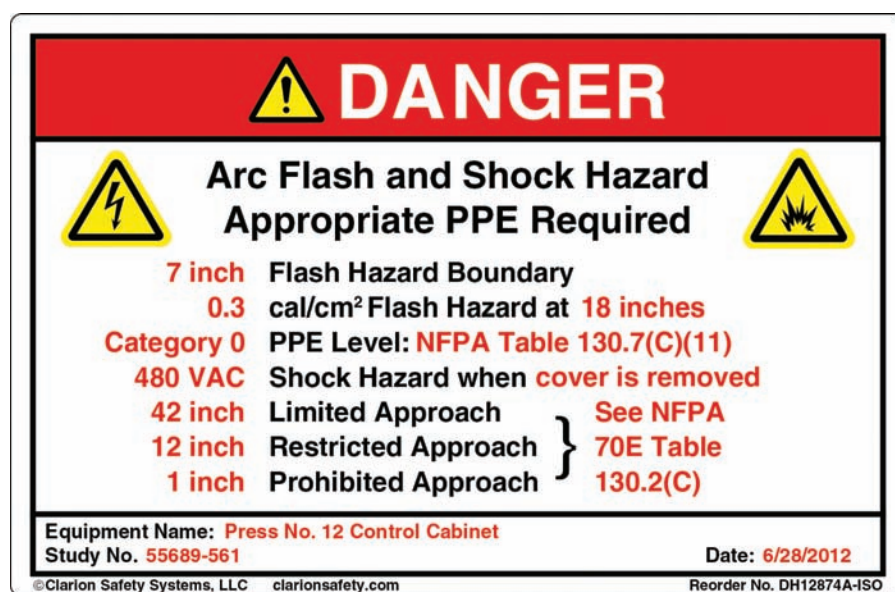



Figure 2: A specific arc flash safety label (courtesy of Clarion Safety Systems © 2012) as defined by an arc flash study typically applied by the equipment owner after an arc flash study.

the ANSI Z535.4 Standard for Product Safety Signs and Labels. This standard defines the use of signal words, colors, and formats. It also encourages the use of graphical symbols. This column is dedicated to helping engineers understand the markings that should go on their equipment. In this instance, as we're talking about arc flash labeling, the addition of graphical symbols is to be recommended because they will help bring noticeability to the marking and they'll help to communicate the message across language barriers.

When it comes to the exact symbol to be used on your arc flash labels, there is no graphic that has been standardized to specifically mean "arc flash explosion hazard." Typically the ISO 7010 warning sign for "danger – electricity" is used (see the *On Your Mark* article in the November 2011 issue of *In Compliance Magazine*).

At Clarion, we strive to create arc flash labels that comply with the latest versions of all four standards mentioned in this article: ANSI Z535, ISO 7010, NFPA 70E, and NEC (Figure 3). Combining the expertise in each standard to arrive at the proper content and format results in a label that represents today's best practice methods for communicating safety and reducing risk. 

For more information about safety signs and symbols, visit www.clarionsafety.com.

(the author)

GEOFFREY PECKHAM is president of Clarion Safety Systems and chair of both the ANSI Z535 Committee and the U.S. Technical Advisory Group to ISO Technical Committee 145- Graphical Symbols. Over the past



two decades he has played a pivotal role in the harmonization of U.S. and international standards dealing with safety signs, colors, formats and symbols.



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The Performance of Shields

BY W. MICHAEL KING

The myth: The representation of shield performance (in dB) as applied to products will be identical for EM fields developed internally to the product, compared to fields externally impinging on the shield.

The reality: The performance of the shield will probably be very different for the two field conditions, perhaps by significant performance difference.

Shielding performance essentially is a transfer function response to the propagation of electromagnetic fields that are impinging upon the shield. For shielding, the intent of the transfer function involves optimizing the *mismatch* of impedance. This mismatch may be both from the electromagnetic wave impedance compared to the shield impedance and, within the shield material itself, from the boundary of the shield surfaces compared to the “core” impedance of the material

(assuming that the material has multiple skin depths of thickness).

The *first effect* of any shield in the process of transfer functions is to mismatch the impedance of the impinging electromagnetic wave at the boundary surface of the shield. As with any impedance mismatch in a transmission line, the mismatch causes a reflection loss. The greater the ratio of impedance mismatch, the greater the reflection loss from the shield will be. When shields are thick enough

to present multiple skin depths at the frequencies of interest, and assuming that the shield metal is a “sandwich” of highly conductively plated surfaces (such as electro-tin) applied to a different material (such as cold rolled steel), an additional transfer function of loss is noted. This loss is the *second effect* of shielding and is observed as an additional inter-boundary impedance mismatch within the material itself. These mismatches set up greater shielding performance by promoting losses within the material.


As a consequence of these processes, it can be conceptualized that the ratio of the various mismatches in the transfer functions holds the key to shielding performance.

Consider that to contain/capture within a product electromagnetic waves that are sourced from the circuits and circuit boards of the product, the dimensional proximity from the sources to the shield surfaces will be relatively small (often less than 1 cm). As a process of the transfer functions and as described in our tutorial program, EMCT (Module 3), the wave impedance from the internal sources to the shield will probably be found in the region of approximately 10 to 50 ohms, (near-field, magnetic-dominant mode). Should the impedance of the shield material be approximately 5 ohms, the anticipated first effect of the reflection loss ($10 / 5$ to $50 / 5 = 2:1$ to $10:1$) will be in the range of 6 to 20 dB.

Contrast this performance against what would occur if the electromagnetic wave impedance was sourced in the far-field, tens of meters away from the product shields. Under that condition, the electromagnetic wave impedance will probably be that of the impedance

of space, approximately 377 ohms. The first effect performance of the shield will now be based on an impedance reflection ratio of about 75:1 ($377 / 5$) or 38 dB, even without considering other transfer function losses that may be evident within the material properties.

These significant differences in shield material performance also explain why shields may exhibit very different performance values when used and measured on a product, compared to the values represented by a shielding manufacturer. This is because the product may present to

the shielding surfaces a very different electromagnetic wave impedance characteristic compared to that used for evaluation of the materials themselves for "catalogue" purposes. 

(the author)

W. MICHAEL KING

is a systems design advisor who has been active in the development of over 1,000 system-product designs in a 50 year career. He serves an international client base as an independent design advisor. Many terms used for PC Board Layout, such as the "3-W Rule", the "V-plane Undercut Rule", and "ground stitching nulls", were all originated by himself. His full biography may be seen through his web site: www.SystemsEMC.com.



Significantly, he is the author of EMCT: High Speed Design Tutorial (ISBN 0-7381-3340-X) which is the source of some of the graphics used in this presentation. EMCT is available through Elliott Laboratories/NTS, co-branded with the IEEE Standards Information Network.

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NEW for 2012 is the addition of Signal Integrity (SI) topics with renowned SI expert, Dr. Eric Bogatin. There will be two separate tracks EMC and SI – with a few joint sessions.

(chairman's welcome)

Dear EMC Community,

Welcome to the 2012 IEEE International Symposium on Electromagnetic Compatibility in Pittsburgh, Pennsylvania. I would also like to extend a special welcome to the Pittsburgh Section of the IEEE and to our local Electromagnetic Compatibility Society Chapter.

Our Symposium Organizing Committee has skillfully conducted the planning and execution of the 2012 EMC Symposium with the focused goal of ensuring the most networking opportunities possible through multiple exhibits, technical programs, companion programs, and social events.

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New this year is the addition of Signal Integrity (SI) to the Global University program. Back for a second year, Henry Ott will teach the fundamentals of EMC, based on his book *Electromagnetic Compatibility Engineering*. We'll also have another special Graduate of the Last Decade (GOLD) program.

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We hope you will join us for networking, education, and the hospitality of Pittsburgh during EMC 2012.

Sincerely,



Michael J. Oliver
General Chairman
2012 IEEE International Symposium on EMC
emi@majr.com



Mike

Oliver

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Monday	7 AM	8 AM	9 AM	10 AM	11 AM	Noon	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	
	Speakers' Breakfast			Break		Lunch			Break					
	Registration Open													
		Workshops and Tutorials						Workshops and Tutorials						
					GOLD Session		Exhibitor Set Up							
										Chapter Chair Training*			Chapter Chair Dinner (until 9:00 PM)	
		Companion Hospitality Suite Open						Phipps Conservatory and Botanical Gardens						
Tuesday	7 AM	8 AM	9 AM	10 AM	11 AM	Noon	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	
	Speakers' Breakfast			Break		Lunch			Break				Welcome Reception Senator John Heinz History Center (until 9:30 PM)	
	Registration Open													
		Technical Paper Sessions			Meet Poster Paper Authors			Technical Paper Sessions						
		Poster Paper Sessions 1: Set Up Display, 9:00 AM to 10:00 AM; Meet the Author, 10:30 AM to Noon, Level 3 Foyer Outside Spirit of Pittsburgh Ballroom Display, Noon to 5:00 PM, Foyer Level 3												
		Exhibit Hall Open												
		Experiments & Demos					Experiments & Demos							
		Global EMC and SI University						Global EMC and SI University						
		Junior Technical Program												
		Companion Hospitality Suite Open												
	On The Strip and Behind the Scenes													
Wednesday	7 AM	8 AM	9 AM	10 AM	11 AM	Noon	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	
	Speakers' Breakfast			Break		Lunch			Break				Gala Event Gateway Clipper Fleet (Boat will leave from the riverside of the Convention Center) (until 9:30 PM)	
	Registration Open													
					Founders Luncheon									
					Amateur Radio Lunch									
		Technical Paper Sessions						Technical Paper Sessions						
		Exhibit Hall Open												
		Experiments & Demos					Experiments & Demos							
		Global EMC and SI University						Global EMC and SI University						
		Junior Technical Program												
	Companion Hospitality Suite Open						Carnegie Science Center							
Thursday	7 AM	8 AM	9 AM	10 AM	11 AM	Noon	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	
	Speakers' Breakfast			Break		Awards Luncheon						Gold Social Bowling Event (until 8:30 PM)		
	Registration Open													
		Technical Paper Sessions						Technical Paper Sessions						
		Exhibit Hall Open												
									EMC 2012 Wrap-Up Meeting (to 5:45 PM)		EMC BOD Meeting (until 9:30 PM)			
		Global EMC and SI University						Global EMC and SI University						
				Companion and Youth Exhibit Hall Tour										
		Companion Hospitality Suite Open												
		Fallingwater and Kentuck Knob												
Friday	7 AM	8 AM	9 AM	10 AM	11 AM	Noon	1 PM	2 PM	3 PM	4 PM	5 PM		6 PM	7 PM
	Speakers' Breakfast			Break		Lunch			Break					
	Registration Open							Workshops and Tutorials						
		Workshops and Tutorials						Westinghouse Technical Tour						
	Companion Hospitality Suite Open						Carnegie Museums of Art and Natural History							
* Monday - Chapter Chair Networking, 3:30 PM to 4:00 PM														

* Monday - Chapter Chair Networking, 3:30 PM to 4:00 PM

(Technical Program Overview)

Workshops and Tutorials

provide an opportunity to learn the basics in EMC from the experts in industry and academia.

Workshops provide an interactive format to share the subject topic with the workshop facilitator. The EMC areas to be covered include the popular series on introduction to EMC to contemporary industry topics facilitated by the EMC Society Technical Committees, Standards Working Groups and others.

Tutorials are set up in a classroom format with the lecturer providing instruction on their area of expertise.



Mr. Henry Ott will be chairing and presenting in the Tutorial Session on the Fundamentals of EMC on Monday, August 6th.

Monday, August 6

8:30 AM – Noon

- MO-AM-1 Fundamentals of EMC
- MO-AM-2 How Certain Are You About Measurement Uncertainty?
- MO-AM-3 Introduction to EMI Modeling Techniques
- MO-AM-4 Update on the Standardization Activities for Intentional Electromagnetic Interference (IEMI) Protection
- MO-AM-5 Innovations in Automotive EMC Testing

1:30 PM – 5:30 PM

- MO-PM-1 Fundamentals of EMC
- MO-PM-2 The Hype on Hybrid Antennas – Dispelling the Controversy for Qualification Testing
- MO-PM-3 How to Break Down Complex Systems into Realistic, Solvable, and Accurate Models
- MO-PM-4 Application of Reverberation Chambers
- MO-PM-5 Advanced Topics in Signal and Power Integrity

Friday, August 10

8:30 AM – Noon

- FR-AM-1 EMC Leadership Training
- FR-AM-2 Basic EMC Measurements
- FR-AM-3 Recent Developments in EMC Testing of Wireless Devices – The New Technologies Driving the Test Standards
- FR-AM-4 EMC Consultant's Toolkit
- FR-AM-5 EMCS History – Society Records and Individual Member Records – Retention, Retrieval, and Digitization

1:30 PM – 5:30 PM

- FR-PM-1 EMC Leadership Training
- FR-PM-2 Does the EMC Society Have a Role or Responsibility to Set Standards in Smart Grid?
- FR-PM-3 Fundamentals of Signal and Power Integrity
- FR-PM-4 Electromagnetic Compatibility in the Nuclear Age: Plant and Laboratory Perspective
- FR-PM-5 Advances in EMI Reduction for Power Electronics Systems

Technical Papers

are provided on Tuesday to Thursday during multiple concurrent sessions.

The papers represent the latest in technology as presented by industry, government and academia. All papers have been peer reviewed and accepted by the EMC Society's Technical Committees. The Technical Papers will be given in two formats: oral presentation sessions and poster paper sessions. Read below for the details.

The Presentation of Technical Papers and Special Sessions are aligned according to technical topic areas associated with the IEEE EMC Society Technical Committees.

Presentation of Papers Sessions

The Presentation of Papers Session is an oral briefing with charts on a digital projector of the speaker's technical paper in a theatre style room setup. We have 185 papers being accepted by the committee. The Session Chair will moderate the meeting between speaker presentations, and questions and answers with the attendees and speakers.

Special Sessions (Invited Papers)

are presented on Tuesday, Wednesday, and Thursday.

These Special Sessions may tend to be more of a tutorial nature covering all the basics or updates of that area.

Tuesday, August 7

8:30 AM – Noon

- TU-AM-1 EMC Management
- TU-AM-2 Modeling of Interconnects
- TU-AM-3 Numerical Investigation of Reverb Chambers
- TU-AM-4 Transportation Systems

1:30 PM – 5:30 PM

- TU-PM-1 Special Session Channel Characterization and Modeling for High-Speed Signaling
- TU-PM-2 Reverb and TEM
- TU-PM-3 Practical Application of Numerical Modeling
- TU-PM-4 Radiated Emissions (TC4)
- TU-PM-5 High Power Electromagnetics (Including IEMI and ESD)

Wednesday, August 8

8:30 AM – Noon

- WED-AM-1 Smart Grid
- WED-AM-2 Emissions Prediction and Testing
- WED-AM-3 Modeling of EM Pulses
- WED-AM-4 Nano Technology

1:30 PM – 5:30 PM

- WED-PM-1 Special Session – Nanotechnology for EMC
- WED-PM-2 Emissions Measurements
- WED-PM-3 Advances in Modeling Techniques
- WED-PM-4 Signal Integrity

Thursday, August 9

8:30 AM – Noon

- TH-AM-1 Special Session – Evolving Trends in Spectrum Management and Engineering
- TH-AM-2 Field Transformation
- TH-AM-3 Shielding Analysis and Application
- TH-AM-4 Shielding

1:30 PM – 5:30 PM

- TH-PM-1 Special Session – Model Validation with Feature Selective Validation (FSV)
- TH-PM-2 Antennas
- TH-PM-3 EM Environment
- TH-PM-4 Low Frequency EMC Methods and Applications Including Power Quality
- TH-PM-5 Information Leakage



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National, 1-877-222-9058
Payless, 1-800-729-5377
Thrifty, 1-800-THRIFTY

Pittsburgh PortAuthority

PortAuthority provides public transportation services throughout Pittsburgh and Allegheny County. The Authority operates, maintains, and supports bus, light rail, incline, and paratransit services.

The light rail fare is \$3.25 one way between the Pittsburgh International Airport and Downtown Pittsburgh. The light rail picks up every 15 – 20 minutes and drops you off a few blocks from your hotel. Fares are paid when boarding. You are responsible for handling your bags both on and off the vehicle.

Details can be found at www.portauthority.org or by calling 412-442-2000.

Other local transportation options can be found at www.planpittsburgh.com/get-here/transportation

(Social Events)

Welcome Reception

SENATOR JOHN HEINZ HISTORY CENTER

Tuesday, August 7 6:30 PM – 9:30 PM

From the pre-revolutionary drama of the French and Indian War to the legendary match-ups of the Super Steelers, discover 250 years of Pittsburgh history at the Senator John Heinz History Center.

An affiliate of the Smithsonian Institution, the History Center is the largest history museum in Pennsylvania. The 275,000 sq. ft. museum features six floors of long-term and changing exhibition space, including the Western Pennsylvania Sports Museum, a dynamic museum-within-a-museum, and the Library & Archives, an extensive scholarly resource documenting 250 years of life in Western Pennsylvania. The History Center presents the most compelling stories from American history with a Western Pennsylvania connection, all in an interactive environment that is perfect for visitors of all ages!

A Full Technical Registration (member, non-member, life member, retired, unemployed, or student) or a Companion Club Registration includes one ticket to the Reception and two drink coupons. All others may purchase a ticket to the Reception (which includes two drink coupons) as an add-on cost to your registration:

Adult Reception Ticket is \$65

Junior (Age 8 – 18) Reception Ticket is \$35

Children under age 8 are free, but must have a free Exhibit Hall registration badge



Evening Gala Event

GATEWAY CLIPPER FLEET MAJESTIC AND EMPRESS SHIPS

Wednesday, August 8 6:30 PM – 9:30 PM

There is no better way to see America's Most Livable City than from the decks of Majestic and Empress riverboats. Come aboard and explore the Allegheny, Monongahela, and Ohio rivers and experience an uncompromised view of beautiful landscapes that rise from the banks of the three rivers. The clean, blue waters are framed by lush foliage and award-winning architecture that make Pittsburgh one of the most scenic cities in the United States.

A Full Technical Registration (member, non-member, life member, retired, unemployed, or student) includes one ticket to the Gala and two drink coupons. All others may purchase a ticket to the Gala (which includes two drink coupons) as an add-on cost to your registration:

Adult Gala Ticket is \$85

Junior (Age 8 – 18) Gala Ticket is \$35

Children under age 8 are free, but must have a free Exhibit Hall registration badge



Photo courtesy VisitPittsburgh

(Social Events)

Chapter Chair Training Session and Dinner

Monday, August 6 3:30 PM – 9:00 PM

The Chapter Chair Training Session (3:30 PM – 6:00 PM) provides a forum for focused training to the Chapter Chairs, provides the Chapter Chairs with the opportunity to discuss their chapter issues and get group feedback, gives the Chapter Chairs the opportunity to meet Chapter Chairs from around the world, and for the Chapter Coordinator to disseminate important information from IEEE headquarters and the EMC Society Board of Directors. A Networking Session (3:30 PM – 4:00 PM) will precede the Training Session.

Dinner will be from 6:00 PM to 8:30 PM, giving the Chapter Chairs the opportunity to socialize with the other Chapter Chairs and their Angels. Besides a great meal, each Chapter Chair or their representatives will have the opportunity to share what their chapter has been doing for the past year.

After the Dinner, an interactive brainstorming session (8:30 PM – 9:00 PM) will conclude the meeting. This session is intended to provide an opportunity to exchange information and new ideas for effective chapter management, as well as discuss best practices and suggestions for future development and growth of the EMC chapters.

This is a free event open to Chapter Chairs or their representatives. Please check with your Chapter Chair, as you might be that representative for your chapter, if your Chapter Chair cannot attend this event.

Founders and Past Presidents Luncheon

Wednesday, August 8 11:30 AM – 1:30 PM

The Founders and Past Presidents Luncheon will be held at the convention center. The Luncheon is open to the Founders of the EMC Society, Past Presidents of the EMC Society, current members of the Board of Directors, and students. The luncheon is a chance for the old and the new to mix, exchange stories of experiences of the past and challenges of the future, and learn about the EMC profession.

A sit-down lunch is provided. Please indicate on the registration form that you plan to attend so there will be seating and food for you.

Awards Luncheon

Thursday, August 9 12:30 PM – 2:00 PM

The Awards Luncheon will be the last formal opportunity to gather and network with family of EMC professionals from academia, industry, government, military, and retired. The event will begin with a sit-down meal. Afterwards, the EMC Society will take time to recognize members and non-members for their contribution to the society and professional excellence.

A Full Technical Registration (member, non-member, life member, retired, unemployed, or student) or a Companion Registration includes one ticket to the Luncheon. All others may purchase a ticket to the Awards Luncheon separately:

Children under age 8 are free, but must have a free Exhibit Hall registration badge

An Adult Luncheon Ticket is \$45

A Junior (Age 8 – 18) Awards Luncheon Ticket is \$25

GOLD EMC Party

Thursday, August 9 6:30 PM – 8:30 PM

All those who are GOLD EMC-eligible, come and join us for a fun night of bowling and pizza. Mingle with the young professional crowd and see how many “turkeys” or “spares” we get.

A \$10 fee will be collected on-site. Limited to 50 attendees, so sign up early! Transportation will be provided to and from the bowling alley. Additional information will be provided in the Final Program.

Sign up during GOLD Session and Welcome Reception Check-in. Let us know if you are coming on www.facebook.com/ieeegoldemc for a head count. Raffle tickets will be distributed during the GOLD Session to only GOLD EMC members and those eligible for GOLD membership.

Stop by to visit our valued supporters.

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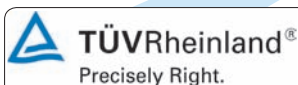
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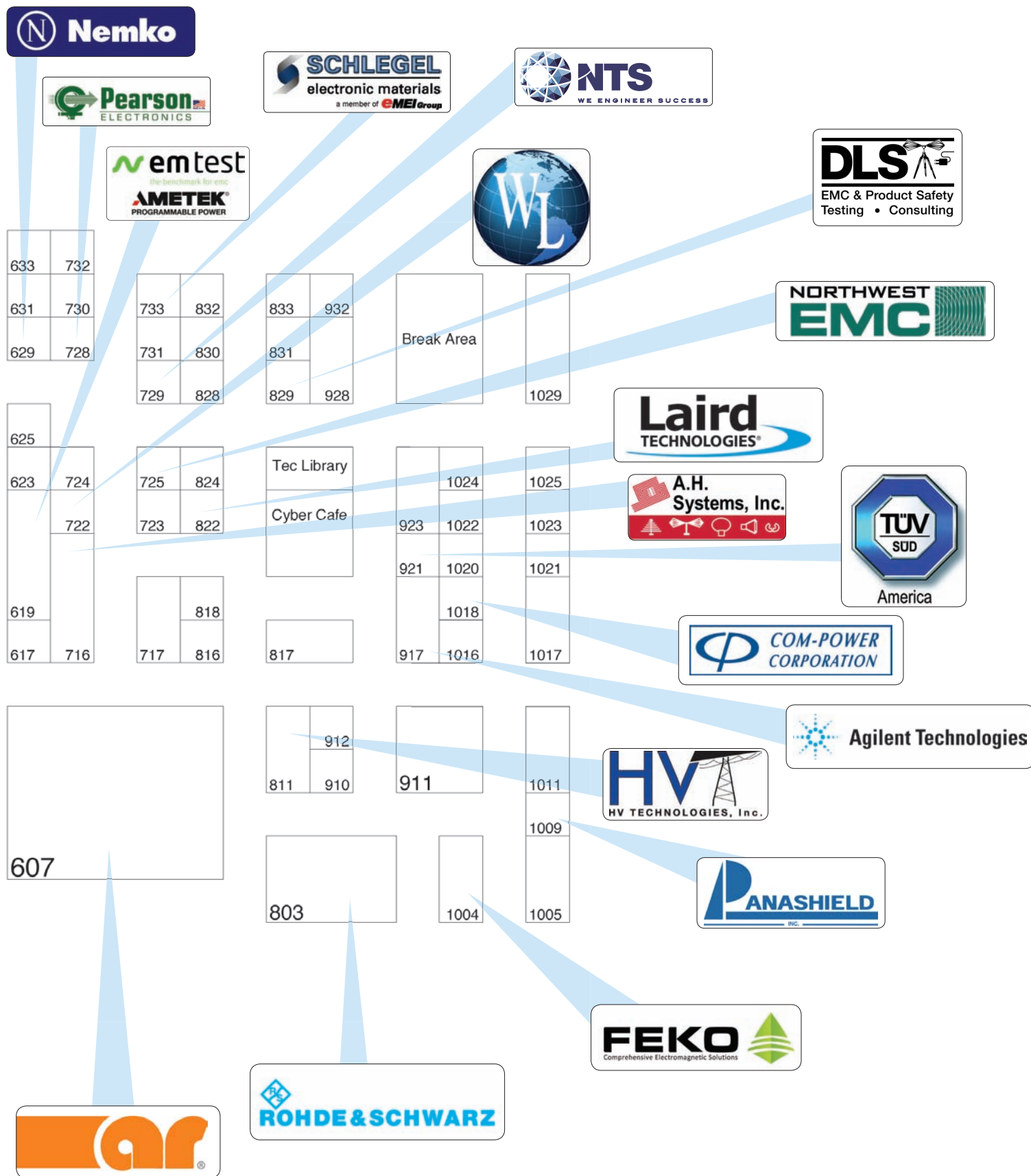
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(Exhibitor Profiles)


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Booth 716

- Manufacturer
 - Antennas and Antenna Products

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ARC Technologies, Inc.
Booth 616

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Com-Power Corporation is a leading designer and manufacturer of EMC test equipment. Since 1989, we have been supplying innovative equipment to the EMC community. We make complete test systems to perform radiated and conducted emissions. Our product line includes antennas, preamplifiers, LISNs, CDNs Comb Generators, power amplifiers and much more. Please visit our website for more details.

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(Exhibitor Profiles)

CST of America, Inc. Booth 309

- Software Development/Products



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D.L.S. Electronic Systems, Inc. Booth 829

- Testing/Certification

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www.dlsemc.com



EM Software & Systems (USA), Inc - FEKO Booth 1004

- Software Development/Products

EM Software & Systems develops the comprehensive EM analysis code, FEKO. An extensive implementation of the Method of Moments and Multi Level Fast Multipole Method allows the analysis of: EMC, Antenna Design and Placement, Dielectric bodies (SAR for RADIIAZ), radiation susceptibility of cable harness in real-world problems.

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anu@emssusa.com
www.feko.info



EM Test USA Booth 619

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 - Product Safety Compliance Equipment
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Tel: +1 202 256 1576
tom.revesz@ametek.com
www.emtest.com



ETS-Lindgren Booth 501

- Manufacturer
 - Anechoic Chambers/Materials
 - Antennas & Antenna Products
 - Filters
 - Shielding Products & Materials
 - Test & Measurement Equipment
- Software Development/Products
- Training & Seminars

ETS-Lindgren is a leading manufacturer of turn-key systems and components for EMC, RF, wireless and acoustic testing. Our RF shielded enclosures and anechoic chambers are designed for testing a wide variety of products, from mobile handsets to full size aircraft. The NEW EMCenter™ is a flexible platform that reduces system complexity and provides centralized control for making RF measurements. Our popular components include antennas; turntables; field probes, monitors, and positioners; RF and EMP/HEMP/IEMI power protection filters; as well as RF and microwave absorbers, including the new flexible FlexSorb™ absorber. Innovative software offered includes TILE!™ for automated EMC test lab management and EMQuest™ for fully automated 2- and 3-D antenna pattern measurement. Services provided include expert calibration at our A2LA accredited calibration lab and wireless testing at our CTIA Authorized Test Lab (CATL). Chamber relocation and absorber retrofit services are available upon request. Based in Cedar Park, Texas, ETS-Lindgren has ISO 9001:200 certified facilities in North America, Europe and Asia. For more information: www.ets-lindgren.com

Tel: +1 512 531 6400
info@ets-lindgren.com
www.ets-lindgren.com

(Exhibitor Profiles)


Fair-Rite Products Corp.
Booth 403

- Manufacturer
 - Antennas & Antenna Products
 - Ferrite/Suppression Products
 - Shielding Products & Materials

Fair-Rite Products Corp. manufactures a comprehensive line of ferrite components in a wide range of materials and geometries for EMI Suppression, Power Applications, and Antenna/RFID Applications. Fair-Rite is the first US soft ferrite manufacturer to receive ISO/TS 16949:2002 certification. We place the highest value on quality, engineering, and service and are dedicated to continual improvement. In addition to our standard product offering, Fair-Rite can provide custom designs and shapes to meet your specific requirements. We have an experienced team of engineers to assist you with new design and technical support. Please visit www.fair-rite.com to view our new online catalog and find contact information for customer service, applications engineers, local sales representatives, and local distributors.

Tel: +1 845 895 2055
 Toll Free: +1 888 324 7748
ferrites@fair-rite.com
www.fair-rite.com


HAEFELY EMC
Booth 429

- Manufacturer
 - Test & Measurement Equipment

HAEFELY EMC is part of HAEFELY TEST AG based in Basel, Switzerland. As a leading customer focused EMC test equipment manufacturer with a reputation for outstanding customer support and product quality, HAEFELY EMC offers a full range of conducted immunity test equipment designed to simulate the effects of interference sources on electronic, electrical and telecommunications products. Most prevalent and included in both IEC and EN product standards are the "classic" EMC tests for electrostatic discharge (ESD), electric fast transient/burst (EFT), lightning surge, magnetic fields (MF), and power line quality.

Tel: +1 845 230 9240
emcsales@hipotronics.com
www.hipotronics.com


HV TECHNOLOGIES, Inc.
Booth 811

- Manufacturer
 - Test & Measurement Equipment
 -

The staff of HV TECHNOLOGIES, Inc., in partnership with EMC Partner AG and Montena Technology, is focused on providing our clients with top quality, full compliance transient test instruments at the most competitive prices. Our staff has been supporting the EMC testing community by designing, producing, and distributing the best in high voltage transient test instruments for over two decades. When using our products, customers experience the most reliable transient test instruments with the cleanest waveforms, most accurate phase angle synchronization, and repeatable wave shapes available. This has been possible through innovative product design and the deployment of unique leading-edge technologies.

Tel: +1 703 365 2330
emcsales@hvtechnologies.com
www.hvtechnologies.com


In Compliance Magazine
Booth 417

- Publishers

In Compliance Magazine offers in-depth coverage of worldwide regulatory compliance issues for manufacturers of electronic products. Monthly technical features focus on designing and testing products to comply with domestic and international requirements. Major topics include EMC, Product Safety, Telecommunications, ESD, and Environmental Issues.

Tel: +1 978 486 4684
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This year there will be at least 117 exhibitors
 in the Symposium exhibit hall.

When you visit the show floor, please stop by to
 visit the fine companies who support
In Compliance Magazine.

Tell them we sent you!

(Exhibitor Profiles)

iNARTE Inc. Booth 300



- Associations/
Societies/
Committees

iNARTE, a non-profit organization, offers Certification Programs to validate the credentials of professional Engineers and Technicians in EMC/EMI disciplines. The purpose of iNARTE EMC Certification is to foster technical excellence in EMC engineering. Our programs establish competency criteria for EMC/EMI work. Our Certification benefits the individual practitioner and the entire EMC community by establishing a standard of excellence and recognition for those that achieve it.

Tel: +1 800 89 NARTE/ +1 252 672 0200
inarte@narte.org
www.narte.org



Laird Technologies Booth 822

- Manufacturer
 - Antennas & Antenna Products
 - Conductive Materials
 - Ferrite/Suppression Products
 - Passive Electronic Components
 - Static Control
 - Shielding Products & Materials

Laird Technologies is a global technology company focused on providing components and solutions that protect electronic devices from electromagnetic interference and heat, and that enable connectivity through wireless applications and antenna systems. Custom products are supplied to all sectors of the electronics industry including the handset, telecommunications, data transfer and information technology, automotive, aerospace, defense, consumer, medical, mining, railroad and industrial markets. Laird Technologies, a unit of Laird PLC, employs over 9,000 employees in more than 46 facilities located in 16 countries.

Tel: +1 636 898 6215
jannette.avila@lairdtech.com
www.lairdtech.com



National Technical Systems (NTS) Booth 729

- Software Development/Products
- Testing/Certification
- Training and Seminars

NTS is the largest independent provider of EMC services in North America with 8 locations to provide you with world-class product compliance services. Our state-of-the-art labs offer EMC, Product Safety, Wireless and Telecommunications engineering and compliance testing. Our expert engineers and test technicians take the time and put forth the effort to understand your business, your needs and your goals and combines this knowledge with our own compliance and testing expertise to help you create successful products.

Tel: +1 800 270 2516
info@nts.com
www.nts.com



Nemko USA, Inc. Booth 629

- Testing/Certification

Nemko contributes to a safer world by sharing knowledge and safeguarding products, environment, people and systems. Nemko creates value for the customer by providing fast and reliable global market access. With offices in 24 countries including local labs in San Diego, Dallas, Salt Lake City and Ottawa, CAN plus partner labs in every region of the US, Nemko is prepared to serve you.

Tel: +1 813 528 1261
andrew.robbs@nemko.com
www.nemko.com



Northwest EMC, Inc. Booth 725

- Testing/Certification

Northwest EMC Inc. is an independent, accredited, commercial EMC compliance test laboratory. Locations in California, Minnesota, New York, Oregon, and Washington. Facilities include FCC listed 10M, 5M, and 3M chambers with a full complement of immunity and wireless testing capabilities. Additional offerings include SAR, DFS, and Global Approvals for your worldwide marketplace. Our knowledge, experience, and strong relationships with regulatory agencies are the foundation for a seamless approval process. Let Northwest EMC serve as a single point of contact for your certification needs, and bridge the gap between your products and the world.

Tel: +1 503 943 3122
alangford@nwemc.com
www.nwemc.com



Panashield, Inc. Booth 1009

- Manufacturer
 - Anechoic Chambers/Materials
 - Shielding Products & Materials
 - Test & Measurement Equipment

Panashield designs, supplies, installs and certifies the following: RF Shielded Enclosures; EMC Chambers, Compact, 3meter, 5meter, 10meter; Military 461E and DO160 Avionics Test Chambers; Free Space Simulation Chambers; Reverberation Chambers; CISPR 25 Chambers for Automotive Testing; P3 RF Sliding Doors; Turnkey Services; Facility Relocations; Upgrades to existing facilities, including LED lighting solutions. Channel Partner with Diamond Engineering, a leader in Antenna Measurement Systems.

Tel: +1 203 866 5888
girard@panashield.com
www.panashield.com

(Exhibitor Profiles)


Pearson Electronics Inc
Booth 728

- Manufacturer
 - Test and Measurement Equipment

Pearson Electronics manufactures Precision Wide Band Current Probes used for accurate measurements of EMI, surge, lightning, pulse and other complex current wave shapes. The model 3525 has a 6 decade flat transfer impedance, 10 Hz to 10 MHz, for EMI measurements. Other probes can measure current as low as 10 microamps (20 dBμA) and frequencies as high as 200 MHz. Lightning and surge currents with amplitudes up to 500 kiloamps can be viewed with low sensitivity designs. A typical measurement is an 8x20 or 10x350 microsecond pulse. New from Pearson Electronics is the Powerline Ripple Detector, Model PRD-120, which greatly simplifies the measurement of injected ac ripple on an ac power bus. This measurement is required in MIL-STD-461 CS101, RTCA/DO-160 section 18 and MIL-HDBK-704-2 through -6.

Tel: +1 650 494 6444
 sales@pearsonelectronics.com
 www.pearsonelectronics.com


Rohde & Schwarz
Booth 803

- Manufacturer
 - Antennas and Antenna Products
 - Test and Measurement Equipment
- Software Development/Products

Rohde & Schwarz is one of the world's largest manufacturers of electronic test & measurement, communications and broadcasting equipment. With over 40 years of EMC and EMI measurement experience, Rohde & Schwarz's broad EMC & field strength test equipment product portfolio provides accurate results across a wide 3 GHz to 67 GHz frequency range.

Rohde & Schwarz not only offers EMC, EMI, EMS and EMF test equipment for pre-compliance and full-compliance measurement, but it also provides customers with complete turnkey systems. Rohde & Schwarz test solutions significantly enhance productivity and product performance by enabling precise results to be achieved when measuring complex waveforms.

For more information, visit
http://www.rohde-schwarz.us/en/products/test_and_measurement/emc_field_strength/products.

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 www.rohde-schwarz.com


Schlegel Electronic Materials, Inc.
Booth 733

Schlegel EMI Introducing Green Products
 As the inventor of the fabric over foam technology, we are looking ahead to your EMI Shielding needs. Schlegel EMI is introducing Halogen Free V0 products and Tin copper cladding. Start designing your gaskets now and you don't have to change them later due to RoHS, REACH or WEEE requirements.

Tel: +1 585 643 2000
 schlegelemi.na@schlegelemi.com
 www.schlegelemi.com


Spira Manufacturing Corp
Booth 405

- Manufacturer
 - Shielding Products and Materials

Spira Manufacturing Corporation has been serving the EMC community with quality engineered EMI/RFI shielding products for over 30 years! We are AS9100/ISO-9001 certified and offer the finest most reliable EMI/RFI shielding gaskets in the market. Spira's strength lies in our exceptional products, on-time delivery, superior customer service, and technical support. Spira's patented EMI/RFI and environmental gaskets offer excellent solutions for both cost-sensitive and high-performance applications. The unique spiral design offers extremely low compression set, long life and high shielding. Gaskets available in: groove or surface mount, EMI and Environmental protection, Honeycomb Filters, Connector-Seal Gaskets, O-Rings, Die-Cut Gaskets, and custom configurations.

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Our advertisers offer many reasons to visit their exhibit booths this year.

See a preview of what's to come — check out pages 54-59 in our Show Stoppers section!

(Exhibitor Profiles)



Advanced Test Solutions for EMC

TESEQ, Inc.
Booth 409

- Manufacturer
 - Antennas and Antenna Products
 - Test and Measurement Equipment
- Software Development/Products

Teseq, Inc. was formerly known as Schaffner Test Systems, until a management buyout was finalized in November 2006. The company provides EMC instrumentation and test Systems for radiated and conducted interference in automotive, consumer electronics, telecommunications, medical, aerospace and defense industries. It has approximately 130 employees and has been accredited to perform calibration services according to ISO 17025 at its Edison, NJ laboratory. Teseq is the only pulsed immunity manufacturer in North America with an accredited calibration lab.

Tel: +1 732 417 0501
usasales@teseq.com
www.teseq.com



TestEquipment.com, Inc.
Booth 509

TestEquipment.com is designed to serve the test equipment user by combining multi-vendor equipment and service purchasing activities with custom test equipment management portals to support all test equipment requirements. Users purchase test equipment and services, maintain asset records and documentation, and access test equipment industry news and community features via a single source. TestEquipment.com will bring test equipment users, manufacturers, and service providers together by providing a single platform to purchase and sell test equipment, and test equipment services.

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Thermo Fisher Scientific
Booth 322

- Manufacturer
 - Product Safety Compliance Equipment
 - Test & Measurement Equipment
- Testing/Certification

Thermo Fisher Scientific provides a family of EMC immunity test systems to meet the broad range of tests requirements and budgets for organizations worldwide. Instead of a mix-match set of testers, you are selecting a well thought-out, integrated array of instrumentation, with expansion capabilities that will not sink into obsolescence as tests and standards continue to evolve. Now offering ISO/IEC 17025 Accredited Calibrations!

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TÜV Rheinland of North America
Booth 401

- Testing/Certification

TÜV Rheinland is uniquely qualified to help its clients get their products to market quickly. Customers can choose conveniently located EMC labs equipped with 5 and 10 meter chambers to handle a variety of products. As an EMC Notified Body (CAB) and international service provider, we offer a flexible, competent service to help you meet the requirements of the EMC directive 2004/108/EC as well as FCC and Industry Canada requirements. For wireless radio compliance needs, TÜV Rheinland is a TCB for the U.S. and an FCB for Canada and can provide the wireless product certifications required.

***All TÜV Rheinland's EMC labs are 17025:2005 accredited, FCC listed, VCCI registered, IC recognized and our Pleasanton CA lab carries both WiFi & Zigbee accreditations.

Tel: +1 978 266 9500
krussian@us.tuv.com
www.tuv.com/us



America

TÜV SÜD America Inc.
Booth 921

- Testing/Certification
- Training & Seminars

TÜV SÜD America offers EMC and Wireless (Radio) testing and certification services for the aerospace, commercial, medical, and automotive industries. Our NVLAP, A2LA, and AEMCLRP-accredited laboratories can perform testing to FCC, Industry Canada, European, MIL-STD-461, RTCA/DO-160, GM, Ford, Honda, Nissan, Toyota, Hyundai, and many other test specifications. Additionally we provide HIRF, environmental, mechanical and electrical safety testing, and certification services.

Tel: +1 248 670 0200
info@tuvam.com
www.TÜVamerica.com



Washington Laboratories, Ltd
Booth 722

- Testing/Certification
- Training & Seminars

Washington Laboratories provides testing, training, engineering and support for the electronics industry. Specialities include wireless, nuclear EMC, MIL-STD-461, IEC, CE Marking and international approvals for equipment manufacturers, with a full spectrum of EMC, Wireless, Environmental and Product Safety offerings.

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IN COMPLIANCE
Magazine

(Show Stoppers)

We bring you an opportunity to learn about what's new and what you have to look forward to when you stop by our advertisers' booths for a visit in Pittsburgh this year.

Advanced Test Equipment Rentals

find us at **Booth 517**

Since 1981, Advanced Test Equipment Rentals (ATEC) has shown its commitment to providing quality customer service by meeting our customer's equipment rental needs. ATEC supplies complete testing solutions for EMC, Defense, Telecom, Power Quality, Environmental and similar testing applications. Our custom solutions, flexible rental terms, and quality customer support differentiates us from our competitors as a complete solution for all test and measurement needs.

Celebrating 30+ years in business, ATEC has become the leading experts in EMC test applications and have accrued the largest inventory of EMC equipment in the industry.

As a leading provider of test and measurement equipment, Advanced Test Equipment Rentals has established solid relationships with industry leading manufacturers worldwide. As a result, our company is able to provide a wide variety of equipment from the unique and unusual to the most cutting-edge products on the market today.

Please visit Advanced Test Equipment Rentals, booth #517, to meet our friendly and knowledgeable staff and enter our raffle for a chance to win a fabulous prize. We hope to see you at EMC 2012!

AR

find us at **Booth 607**

What has AR done for you lately? Stop by Booth #607 and see!

We've exceeded old power limits with our new 16kw, 10 kHz - 225 MHz amplifier and are breaking down barriers with our new dual band solid-state amplifiers. These amplifiers offer the reliability of solid-state from 1 -18 GHz in one package. Our new DSP EMI Receiver covers 20 Hz to 18 GHz and features amazing speed and incredible accuracy.

A new family of solid-state microwave amplifiers provides power up to 500 watts covering 1 – 2.5 GHz; making them excellent replacements for traveling-wave tube amplifiers. We're giving you more power in our 0.8 – 4.2 GHz solid-state microwave amplifiers – up to 1200 watts! There will be live demonstrations of our EMC test software, EMI receiver, conducted immunity test systems and more.

Don't forget to test your AR knowledge and be entered into our daily prize drawings. There are 4 chances to win each day!

ARC Technologies, Inc.

find us at **Booth 616**

At ARC Technologies it's all about the "fillers" we put in our materials that make them perform the way they do. So no matter what your EMI or RF related problem maybe, we can offer a solution. We are the best in the business and offer:

- Materials Tuned to Your Frequency Specification
- Injection Molded Absorber for Lids, Covers,

- Enclosures & Housings
- EMI / RF Absorbing Cable Coating & Heat Shrink Tubing (new)
- Simple and Effective Cut EMI / RF
- Absorber Sheet Material Converted To Your Drawing Covering All Frequency Ranges!
- Free Engineering and Consultation Services for Our Valued Customers

CST of America, Inc.

find us at **Booth 309**

CST will be presenting the latest developments of CST STUDIO SUITE® at booth 309.

Bi-directional transient Field/Cable co-simulation

In many applications, such as lightning strike as well as other EMC susceptibility and emission scenarios, it is necessary to include in the 3D model an accurate representation of the often complex cable bundles which can be both inside and outside of any shielding enclosure. Due to the large aspect ratio which can exist between the enclosures (e.g. a car, a plane) and the cross sections of the individual conductors in the cable, this can be a very challenging problem. The improved integration of the TLM solver of CST MICROWAVE STUDIO® (CST MWS®), formerly known as CST MICROSTRIPES, enables the bi-directional transient co-simulation with CST CABLE STUDIO® (CST CS®). which is an. Stop by at our booth to learn more about this effective way to meet the challenge of different scale in simulation.

(Show Stoppers)

D.L.S. Electronic Systems, Inc.*find us at* **Booth 829**

Pick up your 10% discount coupon at Booth 829 and take advantage of the D.L.S. Combination Package Discount specifically for IEEE EMC Symposium attendees.

D.L.S. will offer a 10% discount coupon on any new compliance testing project that combines two or more of the following D.L.S. Compliance Services:

- EMC and Environmental
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- Product Safety and Environmental
- Qi Compliance and EMC
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- Qi compliance and Environmental

The coupon is redeemable for up to \$1000 total discount for the next 30 days.

D.L.S. is the largest independent testing facility under one roof in North America, specializing in compliance projects for EMC, Product Safety, Environmental, and Qi Compliance for Wireless Power Consortium. Led by the largest iNARTE-certified engineering staff in the industry, they are ready to assist with design consultation, troubleshooting, or mitigation, offering real time solutions from experienced compliance professionals. Included are devices for the Military, Avionics, Commercial, Medical, and Industrial marketplace, including MIL STD 461, MIL STD 810, RTCA DO 160, FCC, IC, CE, IEC, ETSI, EN, WPC, UL-cUL and other global standards.

We welcome the opportunity to work with you on your next project. Find out firsthand the difference a certified iNARTE engineering staff can make with respect to your compliance testing needs.

EM Software & Systems (USA), Inc - FEKO*find us at* **Booth 1004**

FEKO is a comprehensive electromagnetic simulation software tool, based on state of the art computational electromagnetics (CEM) techniques enabling users to solve a wide range of electromagnetic problems. The multiple solution techniques available within FEKO make it applicable to a wide range of problems for a large array of industries.

Typical applications include **EMC** (analysis of diverse problems including shielding effectiveness of an enclosure, cable coupling analysis in complex environments, e.g. wiring in a car, radiation hazard analysis), **Antennas** (analysis of horns, microstrip patches, wire, reflector, conformal & broadband antennas and arrays), **Antenna placement** (analysis of radiation patterns, hazard zones, etc. with antennas placed on large structures, e.g. ships, aircrafts armored car) **Bio-electromagnetics** (analysis of homogeneous or non-homogeneous bodies, SAR extraction), **RF components** (analysis of waveguide structures, e.g. filter, slotted antennas, directional couplers) **3D EM circuits:** analysis of microstrip filters, couplers, inductors Radomes (analysis of multiple dielectric layers in a large structure) **Scattering problems** (RCS analyses).

Please visit the FEKO (www.feko.info) booth # 1004-1006 at the EMC symposium for more information, interesting demonstrations, brochures & articles.

EM Test USA*find us at* **Booth 619**

Come by booth 619 to see the latest in Conducted Immunity test solutions for Automotive, Hybrid & Electric Vehicle, Green Energy Test Solutions, including new Harmonics & Flicker Test Solutions for Energy Regeneration systems which both consume and deliver energy to the grid. All the latest products including IEC & ANSI conducted immunity (Surge, Burst, Dips & Interrupts, ESD, Conducted RF and Harmonics/Flicker), MIL & Avionics Power Input Test, and Automotive test solutions. will be on hand with demos displayed on two 60 inch monitors for comfortable viewing by all

Factory experts will be available to answer all your questions about the latest changes to the standards and demonstrate the latest new products. Meet our new technical manager for North America, with 27 years of experience in Conduct Immunity, to learn all about our rapidly expanding North American Service facility capabilities in San Diego.

In business since 1987, EM Test is an international company with several fully accredited 17025 calibration labs, plus sales offices and distributors around the world providing local support, training and service. Please come by Booth 619 so we can get reintroduced. You will be glad you did.

(Show Stoppers)

ETS-Lindgren

find us at **Booth 501**

Stop by Booth 501 and see what ETS-Lindgren is doing to simplify EMC testing!

- Imagine seven specialized RF test instruments in a rack space just 3U high, all under centralized control. That's just the beginning of what's offered by the new EMCenter™ flexible RF test platform. Stop by and see this amazing system demonstrated.
- Release 6.0 of TILE!™ adds more capability to this already powerful EMC lab management software. Come in for a demonstration.
- Don't miss our new antenna tower with boresight option, specifically designed to operate in today's smaller chambers.
- Visit our antenna tree display and see the latest crop of new antennas and enhanced favorites.
- Pick up a free sample of our flexible EMC absorber, FlexSorb™ -- the absorber that "Bends Without Breaking". While supplies last.
- Get info and sign up for our new hands-on MIL-STD 461F and Wireless classes.

And there's more! See it all in Booth 501 at the Symposium!

Fair-Rite Products Corp.

find us at **Booth 403**

Fair-Rite Products Corp is Powered UP!

Our expanded Power/Inductive Materials and Components line for transformer, inverter and inductor applications is stocked and ready for delivery! We now offer THREE new materials, 95, 97 & 98 in industry standard shapes and sizes. Our expanded line provides low losses and optimum use of given volume of ferrite material for power/inductive designs up to 750Khz. The added shapes permit

simplified construction of common mode EMI filters without toroidal winding complexity.

Additionally, Fair-Rite has also created a High Frequency Toroid Kit for inductive applications operating at a frequency of 1MHz and above. The kit contains eight sizes in four materials from a 6mm OD to 61mm OD. The materials are selected for optimized performance over a specified frequency range for power conversion and low loss applications. These toroids and materials can be utilized for broadband transformers and high frequency chokes as well. The toroid shape offers an ideal geometry for potential users to evaluate material relative to their electrical requirements.

In addition to our standard product offering, Fair-Rite can provide custom designs and shapes to meet your specific requirements. We have an experienced team of engineers to assist you with new design and technical support.

HV TECHNOLOGIES, Inc.

find us at **Booth 811**

Stop by we have the answers!

What do the new standards mean to your testing?

New standards for EFT and Surge put new verification requirements on your test equipment. Make sure you have what you need to be ready. Come talk with us we have the answers you need about upcoming conducted immunity requirements.

- IEC 61000-4-4 and IEC 61000-4-5 Edition 3 have been released or soon will be.
- MIL-STD-461G is in committee with many additions on the horizon. Be prepared.
- New requirements for Smart Grid.

CE Mark Applications

- TRA3000 the most versatile generator on the market

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New Technologies need testing too

- Smart grid communication & Power meters
- Solar panels and DC-AC Inverters
- Electric vehicle and charging stations
- Protective relays

MIL-STD

- EMP Test Systems
- CS115, CS116

Whatever your application is, stop by our booth to discuss how our quality solutions can work best for you. We have the largest range of transient products offered by one supplier.

National Technical Systems (NTS)

find us at **Booth 729**

NTS is recognized worldwide as an industry leading provider of Electromagnetic Compatibility (EMC) engineering, and compliance testing services in the Military/Defense, Aerospace, Telecommunications, Consumer Product and Energy industry segments.

NTS operates the largest network of A2LA accredited EMC laboratories than any other company in North America with locations from coast to coast. We offer the broadest range of capabilities to test your products for compliance towards applicable EMC domestic and international regulatory and industry requirements.

Our EMC/EMI Subject Matter Experts can offer your company integrated design, analysis, testing and evaluation services, reducing your product

(Show Stoppers)

development costs and accelerating your time to market.

We operate modern, world class facilities staffed by highly experienced EMC engineers and technicians, all trained in the usage of modern test and measurement equipment. Not only does NTS provide testing services, we also provide services on both ends of the product development cycle; from the point of product conception to worldwide market access.

Our Program Managers and EMC/EMI Subject Matter Experts will work closely with you and your team, conducting technical design reviews to determine your exact challenges, needs and requirements. For more information, visit NTS on the web at www.nts.com or stop by Booth 729 at the IEEE EMC Symposium to speak with one of our experts.

Northwest EMC, Inc.

find us at **Booth 725**

Since 1992, Northwest EMC Inc. has been assisting product manufacturers access the worldwide marketplace. With state-of-the-art facilities, we are able to maximize your testing dollars and decrease project costs. We're located California, Minnesota, New York, Oregon, and Washington. Facilities include FCC listed 10M, 5M, and 3M chambers with a full complement of immunity and wireless testing capabilities.

With our newest addition opening this fall in Bothell, Washington, we will add MIL-STD 461, and RTCA DO 160 to our extensive list of offerings, which currently include SAR, DFS, Automotive, and Global Approvals.

Northwest EMC selected the leader in SAR evaluation systems, SPEAG to provide the fastest and most accurate measurement tool. Our SAR measurement system is located in a semi-anechoic chamber providing an

ambient free environment that also eliminates reflections.

Our knowledge, experience, and strong relationships with regulatory agencies are the foundation for a seamless approval process. Let Northwest EMC serve as a single point of contact for your certification needs, and bridge the gap between your products and the world.

Visit Northwest EMC at booth 725 to see what we can do for you, and obtain the latest information regarding our newest addition. See you in Pittsburgh!

Panashield, Inc.

find us at **Booth 1009**

Panashield continues to bring new solutions to the EMC marketplace, with this year in Pittsburgh being no exception.

We will be exhibiting the new Diamond Engineering DRG Horn, which Panashield will be distributing.

This Horn breaks the mold for what has been the industry solution for more than 25 years.

- Broadband - 700 MHz to 26 GHz
- Increased Monotonic Gain – Superior to all existing Broadband DRGHs
- Improved Beam performance – No flaring at higher frequencies
- Custom Configurations available – Using Diamond's Single Antenna Mirror method, custom designs can be quickly configured

Panashield will also be displaying their improved LED panel lighting system and new anechoic absorbers meeting the latest international standards.

Stop by and say hello to your friends on the Panashield Team – the Team that brings the highest level of quality products and customer service to the EMC industry.

Pearson Electronics Inc

find us at **Booth 728**

Pearson Electronics is pleased to introduce the new Powerline Ripple Detector, Model PRD-120, which greatly simplifies the measurement of injected audio ripple on an ac power bus in measurements such as MIL-STD-461 CS101. We will be demonstrating the PRD-120's ability to make CS101 much easier, accurately measuring low-level audio ripple voltage on a 115 Vac 60 Hz power bus. In conjunction with a spectrum analyzer, the PRD-120 separates the injected ripple from the power waveform in the frequency domain allowing for accurate measurements of the injected waveform. The PRD-120 is a simplified, cost efficient way to monitor the entire frequency range in MIL-STD-461 CS101, RTCA/DO-160 section 18 and MIL-HDBK-704-2 through -6.

We will also have our Precision Wide Band Current Probes on display that are used for accurate measurements of EMI, surge, lightning, pulse and other complex current wave shapes. We will be demonstrating the performance of several probes to assist with various measurements required by the MIL-STD-461 specification. The Pearson model 3525 will be compared to other passive EMI probes to demonstrate its efficiency and its 6 decade flat transfer impedance, 10 Hz to 10 MHz, best in the industry. This probe is a great choice to meet the 30 Hz to 10 kHz frequency requirement for CE101. Stop by booth 728 to see these great demos and to also learn about our free current probe give away.

(Show Stoppers)

Rigol Technologies

New Spectrum Analyzer with All-Digital IF Technology Redefines the Product Category!

The new DSA815 Spectrum Analyzer from Rigol Technologies redefines the product category by setting new standards for performance and price. Compliance testing has become a critical task in today's design process with each compliance lab trip potentially costing thousands of dollars. The DSA815 can help you verify and debug boards and products before sending to a lab, saving significant time and money... and it pays for itself by saving a single trip to the compliance lab.

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(Show Stoppers)

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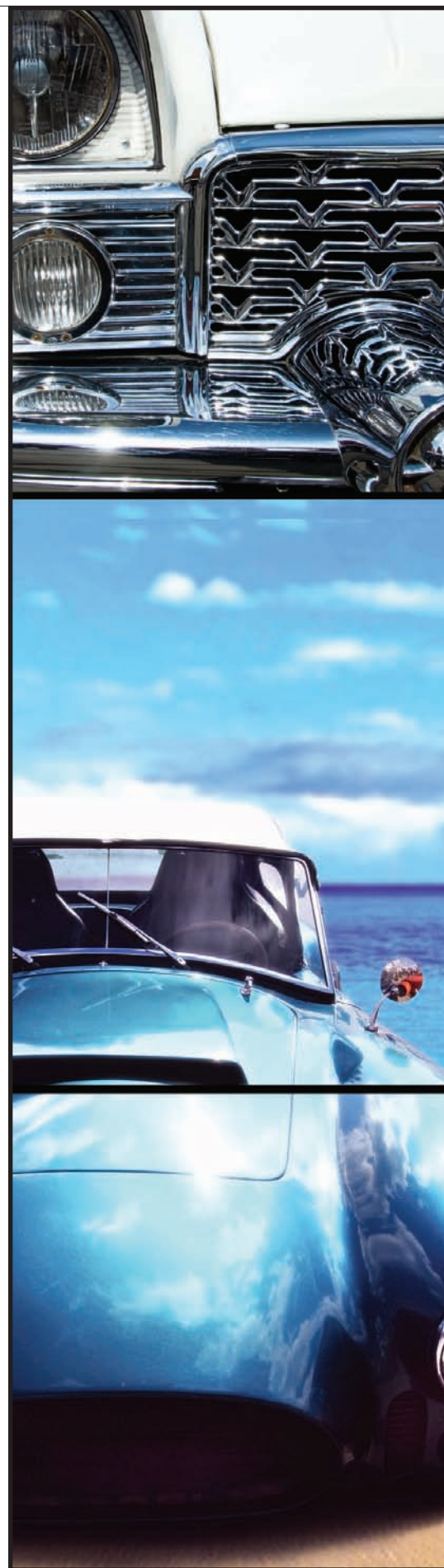
The Evolution of EMC Testing for Electrified Powertrains in Automotive Vehicles

A brief history of automotive EMC testing and standards development

BY ROB KADO, JIM MUCCIOLI, DALE SANDERS AND TERRY NORTH

From the time when automotive vehicles were essentially mechanical with spark ignition the only electrical system, through the many decades that brought the development of electrical, electronic and computer controlled automotive systems, the need for and methods of automotive testing have evolved along with the vehicles. At one time, electrical testing was sufficient. But with the dawn of the digital computer era, compatibility became a major issue. Those pesky clocked systems are inherently noise producers and are also subject to immunity issues. During the 70's, industry experience included the development of advanced fuel management systems, then in progress to meet new exhaust emission standards, but the technology at the time was limited to analog controls. By the 80's, however, the digital revolution

was well underway, bringing digitally controlled fuel injection systems and many other applications that pushed the envelope of EMC concerns. The automotive official equipment manufacturers (OEM) recognized this challenge and began to develop EMC testing and evaluation capability. Initially, there were no applicable standards tailored for vehicle EMC, so the OEMs developed internal procedures that eventually became published as EMC requirements for both vehicle and component validation. Vehicles present a particularly challenging EMC immunity profile as they are numerous and versatile, being able to reach radio frequency (RF) exposure locations not accessible to most other products. Where most consumer electronics may be exposed to RF fields of a few volts per meter, vehicles face much greater threats and





must be validated accordingly. Over the years, automotive OEMs have made extensive use of road trips to RF transmitter and other high RF field sites to map the vehicle EMC environment, and have adapted their requirements and test methods to effectively protect vehicle electronics from these environmental threats.

One key example to illustrate this point is the introduction of vehicle passive

restraint systems in the 80's. At that time, not all automotive OEMs had full vehicle EMC test facilities, however, they were aware of the potential immunity risks that electro-explosive systems presented and were fully committed to an exhaustive evaluation for EMC at both the component and vehicle levels. In past experience, in order to adequately validate this new technology, the standard component test methodologies were

implemented and several new ones were developed in order to provide a greater diagnostic capability to predict system performance before the system was fully integrated. To evaluate the vehicle immunity profile, use was made of the military facilities at White Sands Missile Range, NM, which had the capability of generating high-level RF fields over the electromagnetic spectrum from long wave to microwave. On the test vehicles, the electro-explosive devices that trigger the passive restraint system deployment were instrumented with state-of-the-art monitoring capability so the amount of coupled RF current at each test frequency could be monitored. Due to this exhaustive evaluation and the experience gained, it was possible to establish good correlation between vehicle test validation methods and corresponding component validation procedures. This thorough analysis and evaluation led to a successful launch of this new technology without the adverse reactions that might have otherwise occurred. The EMC test methodologies that were put in place by vehicle OEMs became the basis for future EMC standards. Over the years, the automotive OEMs have worked with SAE, ISO, CISPR and IEC to develop workable EMC standards that reflect the real world EMC environment and the need to provide vehicles that can operate reliably in this environment. These cooperative efforts are ongoing.

VEHICLE EMC TESTING

An important element in the design and development of today's complex vehicles is assuring the compatibility of the electrical system and its numerous subsystems with itself and the environment in which it is used. To assure electrical system compatibility, we must understand and control the (RF) emission and immunity characteristics of all components and systems in the vehicle. This also includes fully characterizing these systems with regard to their immunity



Figure 1: A vehicle positioned in a vehicle TEM cell

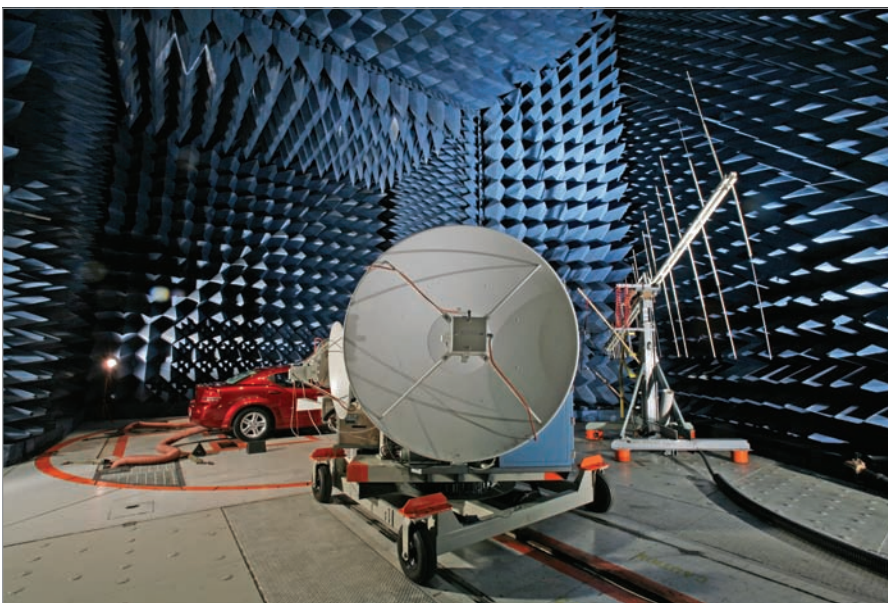


Figure 2: Vehicle in an anechoic chamber

to electrostatic discharge (ESD) and other transient voltages. Furthermore, inductive components, such as motors and solenoids, must be evaluated to determine their potential to generate transient voltages within the vehicle's electrical system.

Vehicle EMC testing can be broken down to three major categories: immunity, emissions, and ESD/transients. In the following sections, we will describe in more detail how each is tested and the types of facilities required.

RF Immunity

In the presence of high electromagnetic fields created by radio transmitters (whether portable, mounted on the vehicle or roadside installations), the electronic subsystems on the vehicle could malfunction, cease to function temporarily, or experience a catastrophic failure. Furthermore, as electronics in general increase in complexity and the threat of interference increases, today we have much more spectral content generated with respect to cell phone use, radio/television broadcast, aftermarket electronics and the standard electrical content of vehicles. Testing for RF immunity not only covers external sources or devices, but also the actual in-vehicle electronics interfering with each other.

The general frequency range covered for immunity is 10 kHz – 4 GHz, with the capability of testing to 18 GHz when known threats exist. Along with this, the capability exists to generate the various types of modulation to simulate modulation used by standard real-world devices.

For the lower frequency range of 10 kHz – 30 MHz, a transverse electromagnetic mode (TEM) cell (Figure 1) or transmission line system (TLS) is typically used. In both cases, the field is created from an overhead structure and kept uniform/

homogenous around the vehicle while various functions are monitored using shielded video cameras, wheel speed sensors and fiber optics for vehicle bus traffic and diagnostics. Both test methodologies are similar in that power is created using an RF amplifier (usually 10kW power) through a transmission line acting as an antenna radiating an RF field up to 200 V/m, depending on the specification. For the vehicle in the TEM cell shown in Figure 1, the metal plate above the vehicle is the septum or radiating antenna. A RF absorber is placed in specific locations in the TEM cell to help mitigate high voltage standing wave ratio (VSWR) situations.

For the mid to upper frequency range of 30 MHz – 800 MHz, an anechoic chamber is used. The vehicle and, in some cases, the antennae are on turntables as multiple sides of the

vehicle must be tested based on harness routing and module location. As with all immunity testing, monitoring such as cameras and fiber optics are used that are not affected by the RF being applied. Figure 2 shows a typical anechoic chamber with a vehicle on the turntable; note also that various antennae can be used to apply the fields. For these frequency ranges, depending on the equipment used, 1kW to 10kW is required to generate fields up to 200 V/m.

For the high frequency range of 800 MHz – 18 GHz, an anechoic or reverberation chamber is used. The advantage of a reverb chamber is that a single sweep is performed and testing is done; often with an anechoic chamber the testing takes much longer as the high frequency causes a very narrow beam width. The narrow beam width requires multiple positions of testing to



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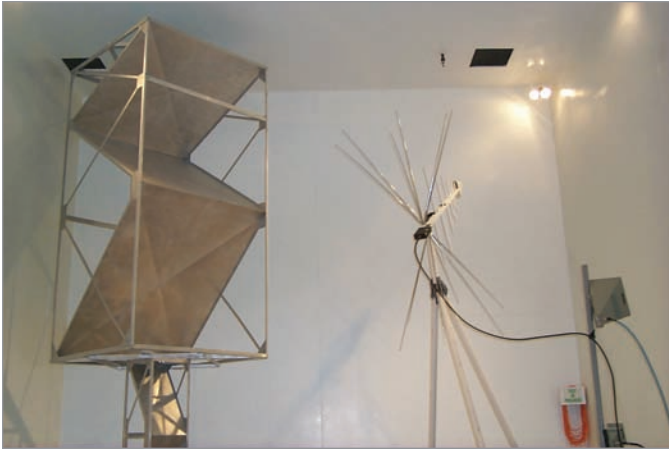


Figure 3: Typical paddle/stirrer (left) in a reverb chamber and two radiating antennae (right)



Figure 4: Example of a vehicle in a reverb chamber

cover the entire vehicle and ensure all areas are exposed to the RF field. In a reverb chamber, the field is generated and stirred with paddles to provide full exposure to the field surrounding the entire vehicle in a single sweep. Figures 3 and 4 show a typical reverb chamber with a vehicle and a closer shot of the paddles used for stirring the field. Another advantage of a reverb chamber is that much less power is required to create high field strengths of 200 V/m.

Another type of vehicle RF immunity testing is the testing of on-board transmitters. This test simulates the effect of radios being installed and used in a vehicle such as CBs, ham radios and more common devices



Figure 5: Example of on-board transmitter testing

such as cell phones or walkie-talkies. The testing consists of outfitting a vehicle with the various antennae both internal and external to the vehicle (e.g. roof top or bumper installation) and broadcasting at the various frequency and power levels while monitoring for disruption of normal vehicle operation. Figure 5 shows an example of antennae placement for on-board transmitter testing in a vehicle.

RF Emissions

The second major part of EMC testing is emissions; measuring the amount of noise a component and its wiring/apparatus puts out while in normal operation. This testing reveals potential interference, not only with other on-board electronics, but also with



Figure 6: Vehicle in an anechoic chamber for RF emissions testing



Figure 7: Example of magnetic field probe measurement

adjacent vehicles and other electronics/ installations in the real world.

To protect for on-board receivers and other electronics, testing is performed per CISPR 25. The vehicle is tested in an anechoic chamber and the on-board antennae of the vehicle are used to measure their applicable fields; for other frequency bands, magnetic mount antennae are placed in the standard installation locations and used for measurement. Figure 6 shows an example of a vehicle in such an anechoic chamber.

To protect for off-board receivers and installations, testing is performed per CISPR 12; the main difference is the antennae used are set at a 3 or 10m distance from the vehicle. This testing is also performed either in an anechoic chamber or open area test site (OATS).

To further validate these results; especially for AM/FM radio bands, radio noise evaluation testing is performed. During this testing, levels of injected power at the various frequencies are broadcast while the different subsystems are operated to evaluate reception.

In addition to RF emissions and as a result of new electrified powertrain vehicles, magnetic field emissions testing is also required. This testing is performed using special magnetic field probes and tested per International Commission on Non-ionizing Radiation Protection (ICNIRP) to limit human exposure to such fields. The testing is performed in various locations, mainly throughout the interior of the vehicle where a human being would be. Figure 7 shows an example of a probe measuring magnetic

fields in the engine compartment of a vehicle.

Other Types of Vehicle EMC Testing

There are other various types of EMC testing that occur on a vehicle such as (ESD), conducted transient emissions (CTE) and electrical tests. ESD is the simulation of discharge that occurs normally between a human and some part of the vehicle; this can be from entry, exit, or simply attempting to push a button or reach for the door handle. CTE is a measurement of the voltage transient that occurs when an inductive load such as a motor, solenoid or actuator is switched. Finally, various electrical tests are performed, such as load dump and reverse battery, to simulate these potential events.

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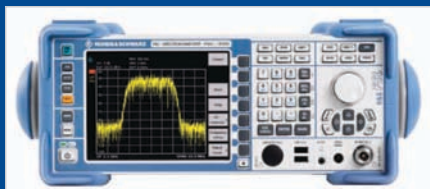
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As can be seen, vehicle EMC testing is very in-depth and costly. The photos provided here are from the Chrysler EMC Facility which is valued at over 30 Million USD. With electrified powertrain emerging as a new technology in vehicles, the challenges for EMC increase. With such vehicles, new considerations such as testing while the vehicle is plugged into its charger, regenerative braking and, finally, operation cycles on a charged battery versus test time (some test runs can take in excess of five hours) are part of the validation process. The specifications are evolving as well; Figure 8 shows a set-up diagram for an electric vehicle to be tested while charging. As the specifications continue to be established and evolve to meet changing product requirements, the industry will adapt and evolve as well, as it always has in the past.

AUTOMOTIVE COMPONENT/ MODULE TESTING

Similar to vehicle EMC testing, automotive component testing is categorically broken down into threetypes: emissions, immunity and

ESD/transients. EMC requirements and test set-ups for automotive components are established by International Standards and OEM specifications that have been derived directly from vehicle testing and real-world experiences/measurements. Components that undergo EMC testing to established OEM component requirements provide a high confidence level of EMC (emissions, immunity and ESD/transients) performance when integrated into a vehicle or into a vehicle system. This is a significant distinction from other industries for several reasons:

1. All electronic products sold in the United States are required by law to be compliant to FCC Part 15. However, FCC Part 15 only addresses RF emission levels of an electronic product. Automotive OEMs at both the vehicle and component level require immunity and ESD/transient testing, as well as emissions. It should also be noted that automotive OEM emissions levels are much more severe than FCC requirements.
2. Vehicle operating environments, thus their requirements, are generally much harsher for automotive components than other electronic products sold in other industries. For example, vehicles are expected to operate safely in a wide range of operating temperatures and different weather conditions, as well as under exposure to varying sources of electromagnetic fields (natural and manmade), all of which impact electric components and design.
3. Automotive component EMC tests, conditions, set-ups and facilities have been developed specifically for correlation to vehicle environments. Compliance to automotive OEM component EMC requirements is considered as a pre-qualification. Components must also comply with vehicle EMC requirements when installed in a vehicle. As such, automotive components are given a functional and operational impact assignment as part of the pass/fail test criteria. This assessment is similar to what other safety critical industries are starting to adopt using International Standards such as ISO 26262. See Reference 1.

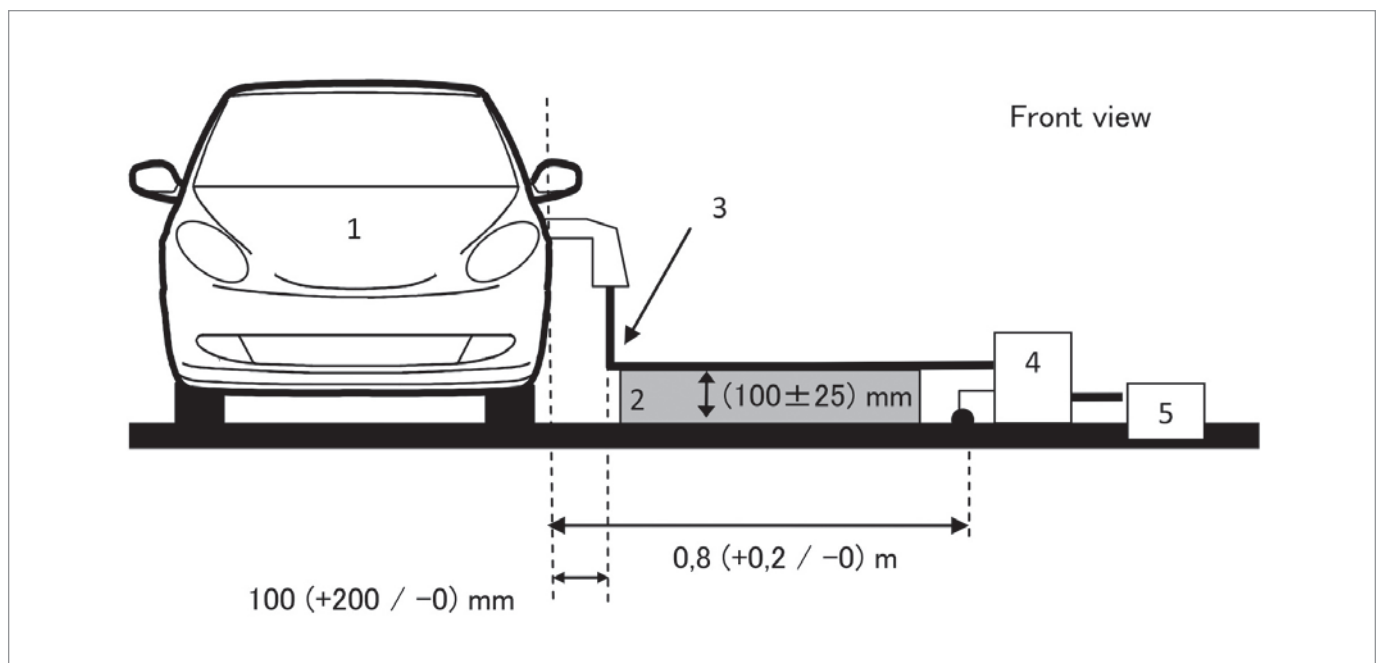


Figure 8: Example of a vehicle set-up while plugged in for charging

WIRELESS AND ENERGY STAR WORKSHOP: ALL YOU NEED TO KNOW!

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DATES

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8:30 am - to 5:00 pm daily

LOCATION

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781-290-5600

ABOUT THE SEMINAR

Join the experts with American Certification Body and Washington Laboratories and TÜV Rheinland for a comprehensive overview of methods and requirements for the latest Wireless Device Approvals. This seminar will cover methods of testing, evaluation and certification requirements for commercial equipment with demands for EMC compliance. We'll provide specific focus on radio regulations compliance for products bound for global markets.



Learn the specific requirements of the FCC Rules and Regulations including recent interpretations and policies and the impact of the new edition of ANSI C63.4 and the recently-adopted ANSI C63.10. This seminar is a two-day comprehensive presentation on wireless device approvals processes and methods.

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WHO SHOULD ATTEND

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SEMINAR OVERVIEW - Specific topics include:

Explanation of new technologies	Measurement methods: power, averaging techniques, duty cycle correction, occupied bandwidth and spurious emissions
Energy Star	Dynamic range considerations
The latest requirements and changes from FCC, IC and Europe	Certification documentation, reporting and data requirements
Practical testing techniques	Test accreditation, including calibration, uncertainties and engineer proficiency
Testing methodologies for radio transmitter devices	
Extending the frequency range beyond the coax medium (external mixing)	

COURSE OUTLINE

Wireless and Energy Star Workshop: All You Need To Know

Wed September 19, 2012

8:00 AM Registration
8:30 AM Introduction and overview of course
9:00 AM Radio Regulations (FCC/IC)
9:30 AM Break
10:00 AM Measurement and Certification requirements
11:15 AM Permissive changes
12:00 PM Lunch
1:00 PM Modular approvals
2:00 PM Break
2:30 PM New Technologies
3:30 PM RF Exposure, Maximum Permissible Exposure (MPE)
4:30 PM Questions and Answers

Thur September 20, 2012

8:30 AM ENERGY STAR® Overview
9:30 AM TV and Display Requirements
10:00 AM Break
10:15 AM Audio Video Products
11:00 AM Measurement Methods of ENERGY STAR®
12:00 PM Lunch
1:00 PM Product approvals for Overseas Markets
3:00 PM Break
3:30 PM Japan and China Certification Requirements
4:30 PM RTTED Approval for European market
4:30 PM Questions and Answers

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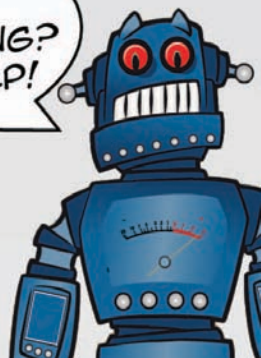
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The EMC systems engineering methodology integrates all requirements and objectives; additionally it facilitates the identification and specification of unknown or hidden requirements leaving behind a traceable, repeatable, documented path of engineering effort and decisions.

THE AUTOMOTIVE EMC DESIGN, REQUIREMENTS, VERIFICATION, AND VALIDATION PROCESS

The history and emphasis the automotive industry places on EMC (emissions, immunity, ESD/transients), from vehicle to individual components, requires a comprehensive process which comprises a collaboration of OEM and tier suppliers, as well as multiple engineering disciplines. To manage the EMC design, requirements, verification and validation process, a system engineering approach is typically used.

THE SYSTEMS ENGINEERING PROCESS AS APPLIED TO AUTOMOTIVE EMC

See References 2, 3, 4, 5 and 6.

The EMC systems engineering methodology integrates all requirements and objectives; additionally it facilitates the identification and specification of unknown or hidden requirements leaving behind a traceable, repeatable, documented path of engineering effort and decisions. Below is a high-level description of this approach that is used in the automotive industry.

The EMC system engineering process starts with OEMs and tier suppliers defining the following concepts for components, system architecture and vehicle integration:

- **System** – a set of components acting together to achieve a set of common objectives via the accomplishment of a set of tasks.
- **System behavior** – a sequence of functions or tasks, with inputs and outputs, which must be performed to achieve a specific objective.
- **Requirements** – mandates that something must be accomplished, transformed, produced or provided. The attributes of a good requirement are that it is unambiguous, understandable, traceable, correct, concise, unique and verifiable.
- **Traceability** – in reference to requirements; a requirement is said to be traceable if one can identify its source. The source may be a higher-level requirement or a source document defining its existence. An example would be if a component-level requirement (weight, reliability) is traceable back to a vehicle-level requirement
- **Operational concept** – an operational concept is a shared vision from the perspective of the users and development participants of how the system will be developed, produced, deployed, trained, operated, maintained, refined and retired to meet the operational needs and objectives.

It is recommended that a background study based on the following questions should be considered in preparation for the systems engineering process:

System requirements

- Has the need for the system or product been established and justified?
- Has the overall system technical design approach been justified through a feasibility analysis?
- Has the mission for the system been defined through scenarios or profiles?
- Have all basis system performance parameters been defined (technical performance measures)?
- Has the system or product lifecycle been defined (design, development, test and evaluation, production and/or construction, distribution, operational use, sustaining support, retirement and disposal)?
- Has the planned operational deployment and distribution been defined (customer requirements, quantity, distribution schedule)?
- Has the operational environment been defined in terms of temperature extremes, humidity, vibration and shock, storage, transportation, and handling? A dynamic scenario is desired.

System trade-off studies

- Have trade-off evaluations and analyses been accomplished to support major design decisions?
- Have all feasible alternatives been considered in trade-off studies?
- Have such analyses been accomplished with lifecycle considerations in mind (decisions based on lifecycle impacts)?
- Have system trade-off studies been adequately documented?

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Once the above concepts have been defined and the background study performed, the six-step design process is applied as illustrated in Figures 9, 10, 11 and 12.

Step 1 - Bound the system for EMC

- Identify all external items.
- Establish interactions.
- Create system context diagram.

Step 2 - Identify the source of requirements

- Collect requirements.
- Sort requirements by classification.

Step 3 - Discover and understand requirements

- Discover system-, subsystem- and component-level requirements.
- Brainstorm scenarios.
- Benchmark competition.

- Use behavior models to:
 - discover “hidden” interface requirements.
 - resolve conflicts between models and scenarios.

Step 4 - Create alternatives

- List performance and operational objectives.
- Prioritize requirements with weighting factors.
- Synthesize physical architecture to support each alternative.
- Perform trade-off between candidate architectural solutions that satisfy the requirements.
- Collect the results in a derived set of requirements based on the chosen solution.
- Compare the various alternatives, rank them and select the best approach.
- Evaluate candidate architectures using measures of effectiveness.

Step 5 - Select the best solution

- Compare proposed systems implementation.
- Select the *best* solution.

Step 6 - Validate best solution

- Define validation plan
- Link to design requirements at each level (vehicle, system, component)
- Verify all requirements. (mandatory)
- Plan for verification starting early and continuously at the system level.
- Requirements Trace requirements forward to verification and link verification back to the requirements at all levels.
- Verification methods are:
 - inspection
 - test
 - demonstration
 - analysis, which may include simulation

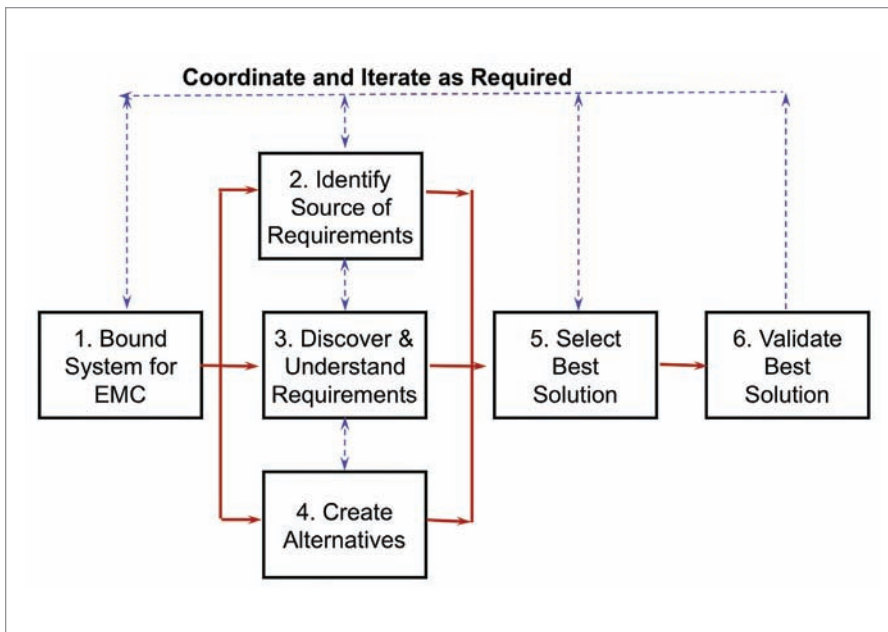


Figure 9: Six step system engineering process for EMC

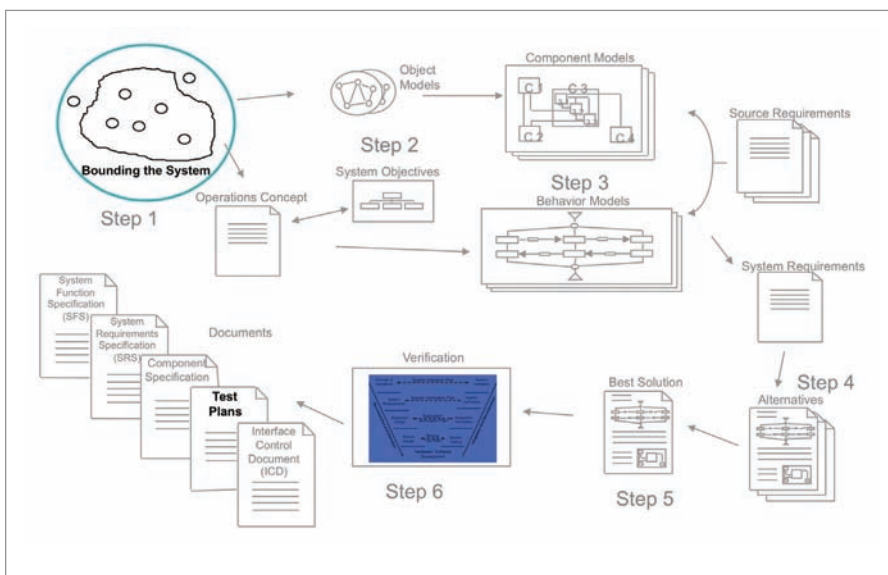


Figure 10: Data is generated and linked throughout the process

System engineering process summary

- The EMC systems engineering process methodology integrates all requirements and objectives, and facilitates the identification and specification of unknown or hidden requirements.
- The systems engineering process leaves behind a traceable, repeatable, documented path of engineering effort and decisions.

THE IMPORTANCE OF EMC TEST PLANS AS GOVERNING DOCUMENTATION

See References 2, 3, 4, 5 and 6.

As automotive engineers work through the six-step design process, many documents are generated. For EMC, the most important document is the EMC test plan. Most OEM in North America provide a template to follow when generating this document. When properly completed, the EMC test plan provides a traceable link of not just the EMC tests performed and test parameters, but also documentation of the operating modes/states, justification of performance criteria, component uses in vehicles and systems, a

component's mechanical and electrical interfaces, as well as any deviations and assumptions required for individual test circumstances.

Elements of a good EMC test plan to consider for any device-under-test (DUT) (component or vehicle) should describe or answer the following information:

1. DUT part number and revision
2. DUT subassemblies such as PCB, hardware and software revision

3. DUT manufacturing/assembly location and suppliers
4. DUT customer and production release date
5. DUT releasing/program engineer
6. DUT EMC test plan revision history
7. Applicable EMC test standards (OEM or international)
8. EMC test facility, location, contact and accreditations

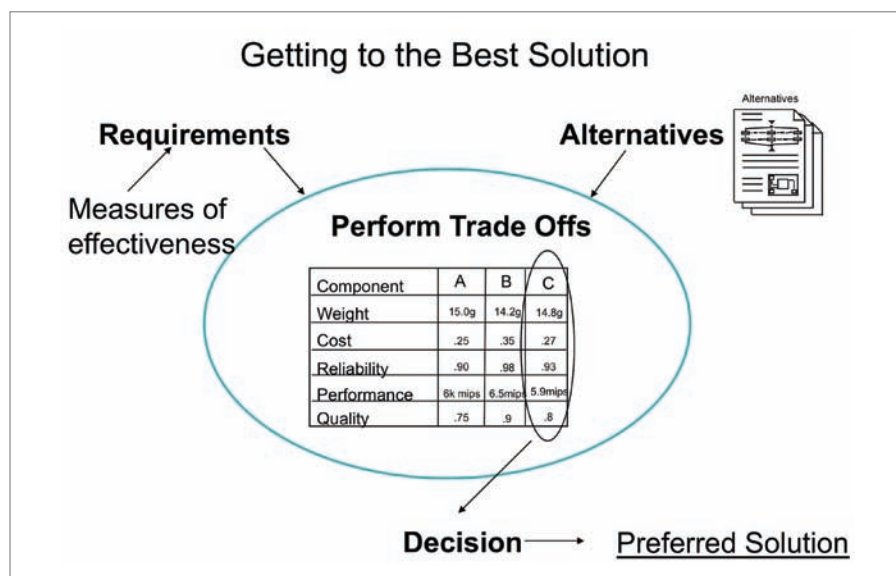


Figure 11

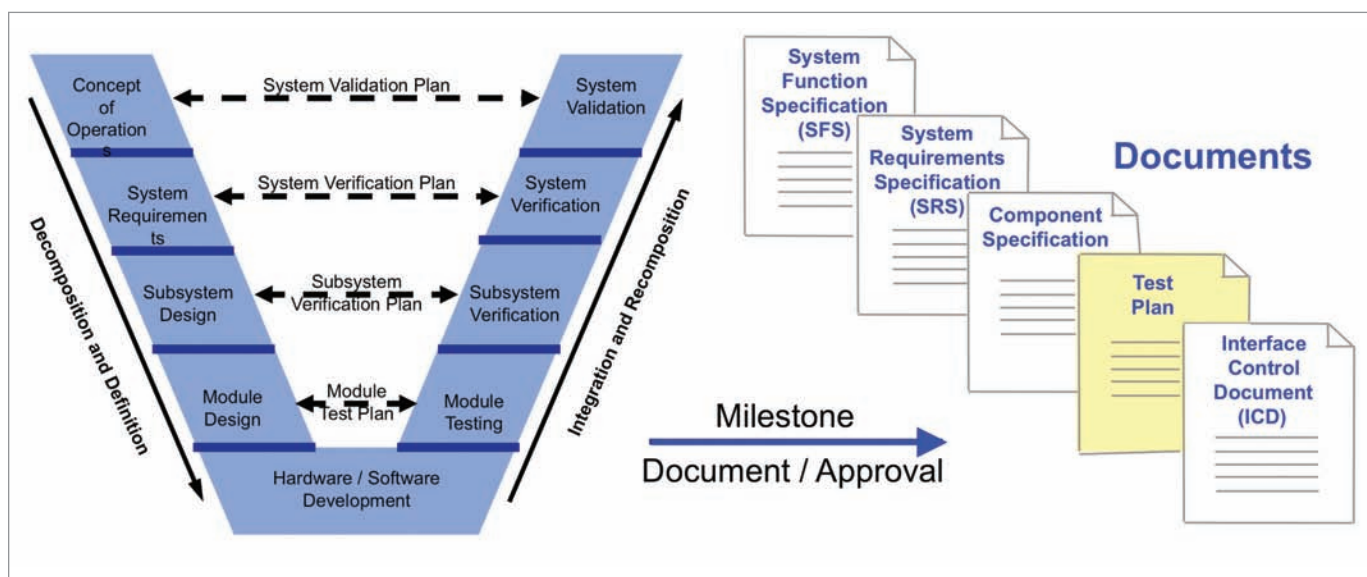


Figure 12: The "Big V" - validation and verification

9. Type of EMC test report requested: engineering development, sign-off design validation or sign-off production verification
10. OEM/customer sign-off (if applicable)
11. DUT description and intended use
 - a. DUT and DUT family introduction and functional description
- b. DUT description and sample selection
- c. DUT electrical and mechanical schematics, layout and diagrams
- d. DUT software functional description of operation
- e. DUT bill-of-materials (BOM)
- f. DUT operating modes
- g. DUT electrical and mechanical inputs, outputs, power requirements, loads and monitoring requirements
- h. DUT calibration procedures
12. Required loads, harness and support equipment needed to operate DUT
13. For each individual EMC test, the following should be noted or referenced:
 - a. test modes
 - b. environmental conditions
 - c. grounding schemes and requirements
 - d. harness requirements
 - e. applicable loads and monitoring equipment
 - f. power supply and signals
 - g. functional and operational requirements
 - h. test deviations
 - i. pass/fail criteria
 - j. instructions if an anomaly is observed
 - k. any DUT safety precautions or procedures

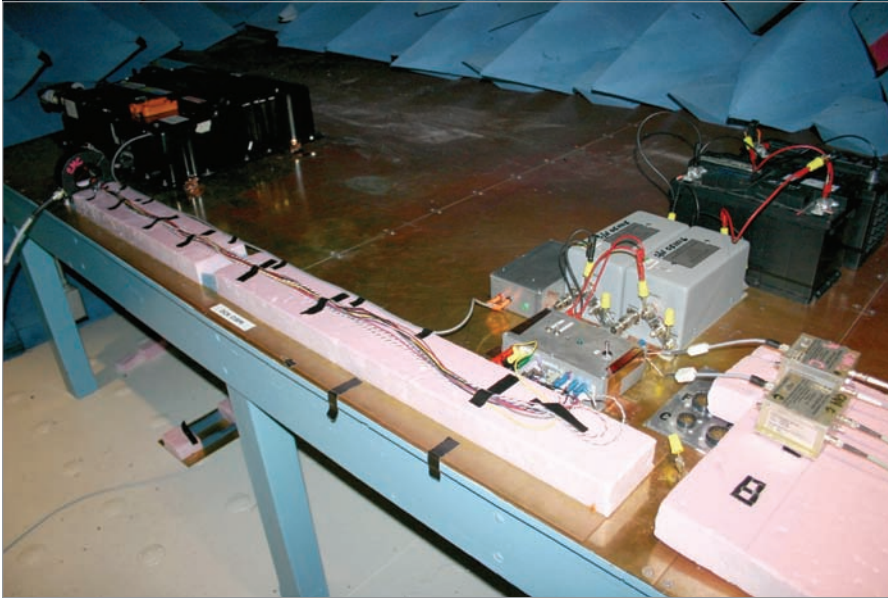


Figure 13: ESS bench setup for CISPR25 Radiated Emissions/ISO 11452-2 radiated immunity

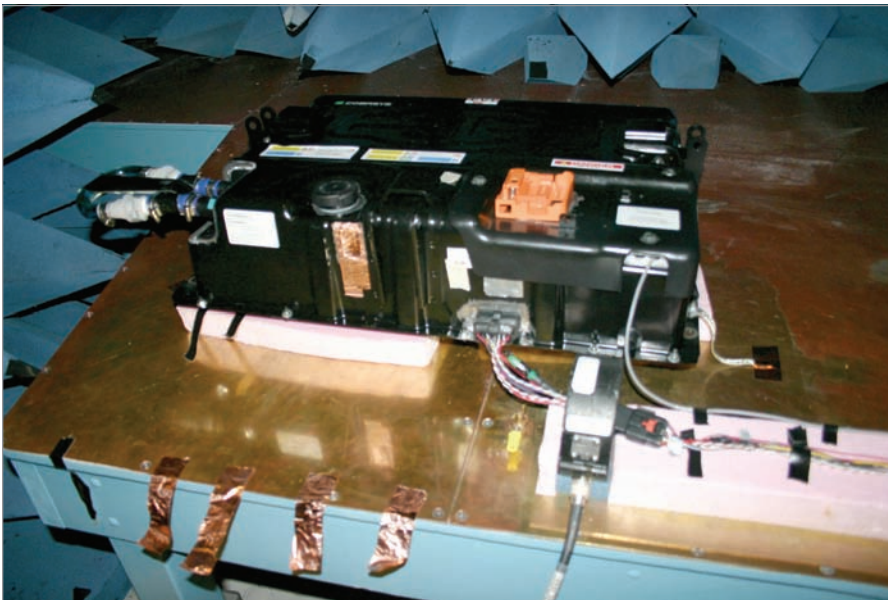


Figure 14: ESS (close-up) on a copper ground plane for CISPR25 radiated emissions/ISO 11452-2 radiated immunity testing

THE EMC TEST PLAN AND ELECTRIFIED POWER-TRAIN TECHNOLOGY

See References 2, 3, 4, 5 and 6.

As test standards evolve and adapt to new technologies in the automotive industry, the overall vehicle requirement remains essentially the same. For example, the emerging electrified powertrain technology has not had a substantial impact for vehicle EMC emissions, immunity and transient requirements; however, it has increased the importance of the EMC test plan for systems such as the energy storage system (ESS) which is a large part of the electrified powertrain architecture. ESSs have come to encompass several competing electric vehicle (EV) and hybrid electric vehicle (HEV) architectures. In turn,

the ESS contains multiple sub-systems in addition to just battery cells.

The ESS and its sub-systems include design variables such as high-voltage DC-to-DC power converters, battery cell charging/discharging schemes, varying numbers of battery cells, shapes and technology, cooling schemes (liquid and/or air), diagnostic sensors (thermal, voltage, current, etc.), overall ESS physical shapes, sizes and weight, as well as on-board vehicle orientations.

When writing an EMC test plan for ESS, collaboration with the EMC test facility is a good idea. The size and weight of the ESS alone can cause an issue when testing. For example, an ESS can range from 8 cubic feet to more than 64 cubic feet in size and weigh 700 to 2500 or more pounds. EMC test facility chambers and ground planes need to be able to handle the weight as well as be able to safely move the ESS in and out of the chamber. Also, thought should be given to the orientations of the ESS needed for emissions and immunity testing, with consideration given to maintaining minimum clearances per the international or OEM standards used for testing. Some examples are shown in Figures 13, 14 and 15.

Another aspect the EMC test plan should clearly specify is the monitoring requirements of the ESS. It is not uncommon that input/output requirements to monitor an ESS are double or triple that of a normal automotive component and may require special software that interfaces to software running the EMC test, so when/if an observed anomaly occurs during a test cycle, the test parameters are known.

Finally, with regards to the ESS, the EMC test plan should note the high-voltage (HV) power requirements, charging procedure and safety operation procedure for working with the HV. The goal of the EMC test plan is to provide for safe operation,

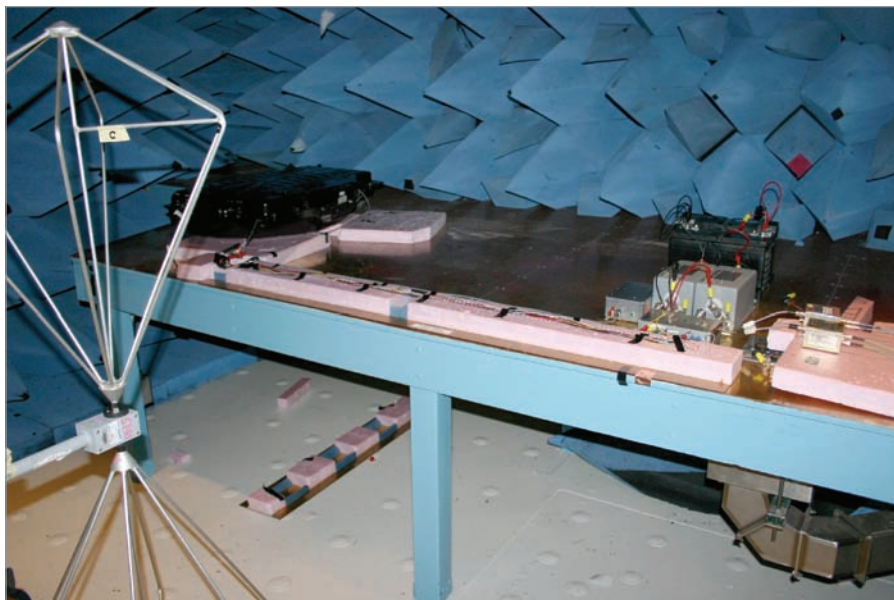


Figure 15: ESS CISPR25 radiated emissions/ISO 11452-2 radiated immunity bench setup with bi-conical antenna

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reduced test down-time and a traceable document for future testing and product development.

SUMMARY

The authors have presented a brief history of the development of methodologies by automotive OEM to effectively validate new technologies and the cooperative role OEM have played in the generation of new EMC standards, including an overview of vehicle and component EMC testing. The advantage of the system engineering process in providing an organized and traceable method to meet the challenges of validating new technologies was presented, along with a practical approach to apply this method to a particular product. The importance of EMC test plans, particularly for complicated systems and new technologies, was stressed along with some useful guidelines for developing an effective test plan. Finally, the need for an EMC test plan to meet the particular challenges of validating electrified powertrain technology was described. ■

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Conductors and “Conductive Paths”

What Is Really Happening

(And why should anyone care?)

BY MARK STEFFKA

When people are asked what is the most commonly used component in electrical or electronic circuits, the typical answers are “Well, of course everyone knows its resistors”, or “It must be capacitors”, and even sometimes “Nothing operates without transistors”.

In fact, none of those answers are correct; the *real* answer is that *conductors* are the most common type of component. Obviously, without conductors there would be no such thing as circuits. Even though conductors are the basic component of electrical circuits, there is surprisingly little consideration of the physics involved in conductors (outside of textbooks) and there seems to be even less emphasis on considering the characteristics of conductive structures (such as “chassis grounds”) when those conductors and conductive assemblies are used for the critical current return paths in a circuit. Perhaps this is because wires just don’t seem that exciting! Ironically, successful EMC engineering requires just such an understanding!

This article will refresh (or perhaps initiate) the reader’s knowledge and

understanding of key aspects of conductors and conductive paths by looking at a number of topics, including:

- history of conductors.
- fundamentals of electrical energy propagation.
- types of wire conductors.
- models and characteristics of transmission lines.
- use of assemblies as conductive paths.

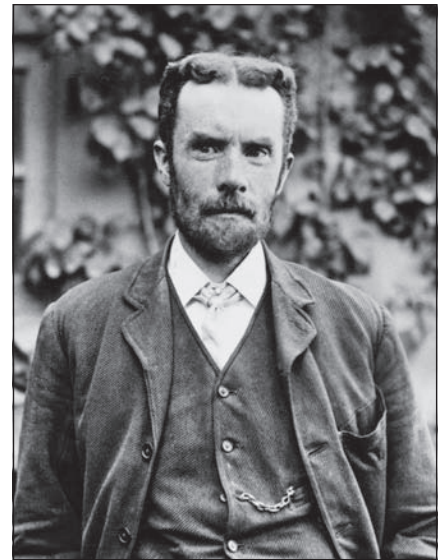
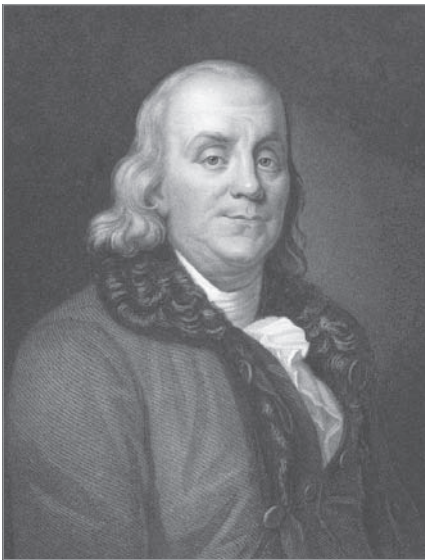
HISTORY OF CONDUCTORS

Although wire made from conductive materials (such as iron or copper) has been in use for perhaps thousands of years, it was used as a mechanical component. It was not until a few hundreds of years ago (during the 1700s) that it was first used as a method to define a path for electrical current

flow. Some of those first electrical uses were for protection of wooden structures in colonial America by the attachment of the conductive wire to iron “rods” placed on buildings to (hopefully!) provide a path for lightning strikes to be safely conducted to the earth instead of across the structure (which many times caused fires). The use of wire for this purpose (and the invention of the associated lightning rods) has been attributed to Benjamin Franklin.

During the early 19th century, as interest and worldwide fascination into “electrical flow” grew, Michael Faraday was among the first to perform empirical experiments to understand properties of conductors.

As the 1800s progressed, more uses for electricity were developed, including power distribution and communication



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Figure 1: Pioneers in the use of conductors, Benjamin Franklin, Michael Faraday and Oliver Heaviside

(telegraph systems). As these systems became more complex, physically large, and capital intensive, there was an increasing desire to more fully understand these interconnection methods. As a result, Oliver Heaviside developed a number of important concepts and inventions during the 1880s, including transmission line theory and the “coaxial” style cable that we see today.

WHAT IS THE PURPOSE OF A CONDUCTOR?

From the evolution of wires for lightning protection to power and signal distribution, and even to today, it can be seen that there is only one purpose of a conductor. That purpose is to provide an intended path for propagation of electromagnetic energy.

Therefore, a conductor is used to:

- provide power or signal(s) to where it's needed.
- divert energy from where it's NOT desired (such as in lightning grounds or surge suppression).

That intended path of electromagnetic energy is via “conduction”, as described by Professor Maxwell (in addition to his theory of “displacement current”, such as the current that “flows” through a capacitor).

In order to understand how energy is conducted from a source to a load, we start with the concept of the “idealized” energy transfer loop (as shown in Figure 2).

“IDEALIZED” ENERGY TRANSFER LOOP

The figure shows the source of the power (or signal), represented by the “generator”. On the other side of the figure is the load (which can be represented by an impedance). The process of transferring the energy from the source to the load is via the conduction path, defined by the solid lines on the diagram). This transfer is typically explained as being similar to a current in water, in that there is a “current flow” along one conductor, while the other conductor functions as a “current return”. While this view is not incorrect, sometimes it is better to visualize the energy as an electromagnetic wave being guided from the source to the load.

CONNECTION PATH IMPEDANCE

Using the idealized energy transfer loop leads (unfortunately) to assumptions in system and circuit design that the conductive path is always characterized by a simple zero impedance connection. The problem is that in actual circuit construction, although conductive materials are used, these materials

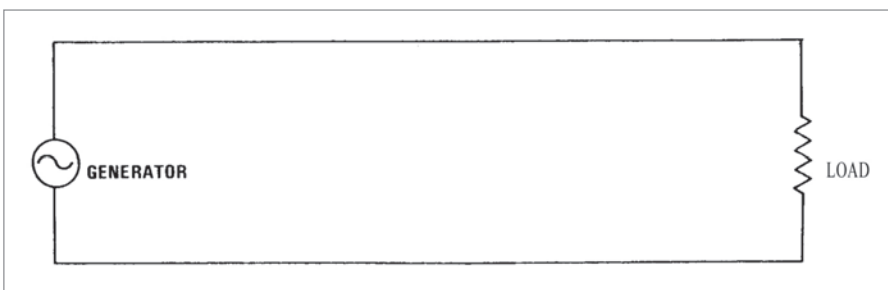


Figure 2: Schematic of basic or “ideal” energy transfer loop

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in reality have “non-zero” physical parameters (such as thickness, width, and material resistivity). Depending upon the physical size of the conductor(s), these actually need to be defined as having relevant volume or surface resistivity as shown in Figure 3. For volume resistivity, it is common to utilize a unit volume, such as a cube of equal dimensions in the X, Y, and Z directions. For surface resistivity (when the thickness of the material is

significantly less than the other dimensions) an X and Y dimension is used.

The way we typically establish conductive paths from sources to load is to use wires of various diameters (called “gauges”). Figure 4 shows various wire geometries and the common method for identifying the wire diameter. The resistance of wire is a function of both its material and physical dimension (typically diameter

is expressed in “MIL”, which is equal to 0.001 inch).

By using physical dimensions and material characteristics, it becomes a straightforward process to determine the resistance of any wire. This is shown below.

Calculation of the Resistance of Wires

- Resistance (R), is determined by ρ (rho), length (L), and cross sectional area (A).
- Example showing resistance for 1,000 feet of wire of 10,400 circular mils.

Given: $\rho = 10.37$ ohms

$L = 1,000$ ft

$A = 10,400$ circular mils

Solution:

$$R = \rho \frac{L}{A} = 10.37 \times \frac{1,000}{10,400}$$

$$= 1 \text{ ohm (approximately)}$$

In this example, the 1,000-foot wire has a resistance of 1 ohm. It can be seen that if the length is doubled, the resistance will also double. This makes sense. An interesting observation can be made at this point, however, and that is if the cross-sectional area of the wire decreases (gets smaller), the resistance of the wire increases!

WIRE SIZE (“GAUGE”)

In order to provide consistency in wire selection and application, it is typically manufactured in sizes numbered according to the American Wire Gauge (AWG) tables. These tables show wire sizes from 0000 gauge (which is a 460.0 mil diameter for solid wire) to 40 gauge (3.1 mil diameter for solid wire). Of particular note is the fact that, according to these tables, a *wire* is a single rod or filament of drawn metal. Of course another type of wire is actually a number of solid

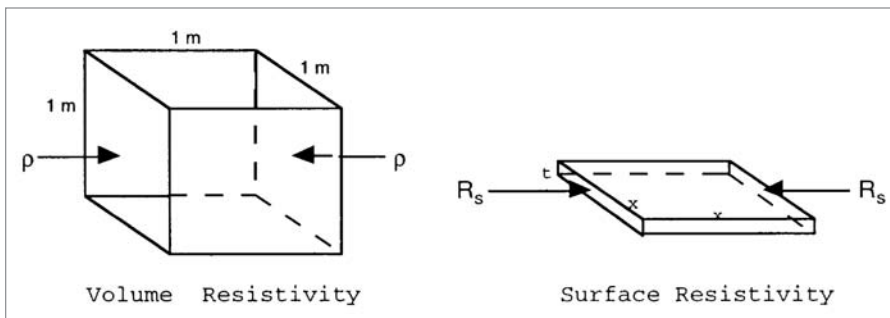


Figure 3: Defining the actual relevant volume and surface resistivity of a conductor

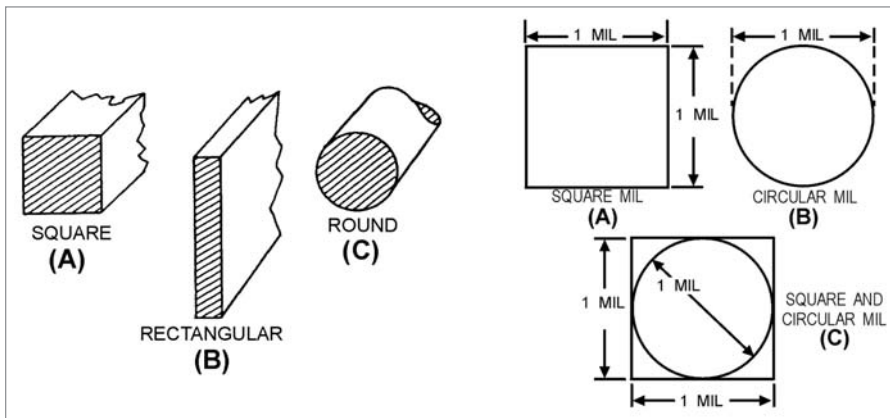


Figure 4: Various geometries of wire and methods for determining gauge

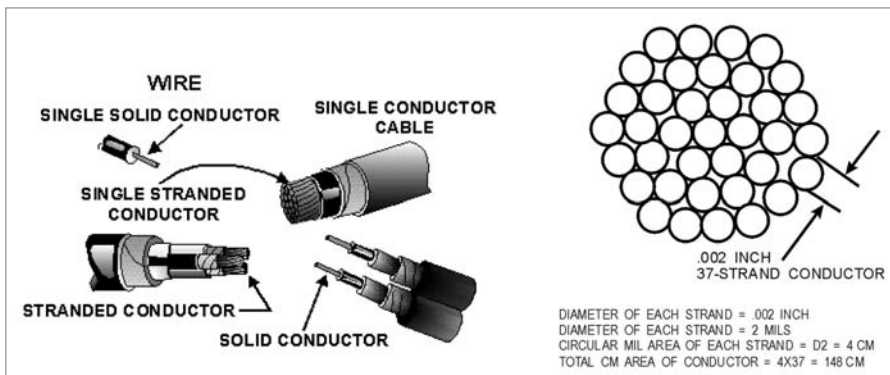


Figure 5: Illustration of both wire and cable conductors

wires bound together to function as a single wire. This more correctly is known as a *stranded conductor* or a cable. Table 1 shows DC parameters of typical cables of various AWG sizes. Figure 5 shows the difference between a single conductor wire and a stranded-conductor “wire”.

Why do we have both solid and stranded “wires” (conductors)? It turns out that each has its own advantages that would make the selection of one or the other optimum for a particular application.

In the case of solid wires, they have the following attributes:

- cost-effective.
- high mechanical integrity (keeps form).
- smaller diameter for equivalent “gauge”.

Stranded wires, on the other hand would be used when the following characteristics are desired:

- flexibility.
- reduced “noise” (due to lower inductance compared with a similar length of solid wire).

- redundancy (some broken solid wires will not affect functionality).

In the same way we can define solid wire sizes, we also define physical dimensions for stranded conductors. *An interesting point is that the diameter for “gauge equivalent” solid and stranded*

DC Parameters of Some Standard Cables

Size (AWG)	Diameter (mils)	DC Resistance (Ohms/1000 ft)
No. 12	80.81	1.588
No. 8	128.5	0.6282
No. 2	257.6	0.1563
1/0	324.9	0.09827

Table 1: Table showing DC resistance of different wires by gauge and diameter

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Wire Gauge	Wire Diameter (mils)	
	Solid	Stranded
4/0	460.1	522.0 (427 × 23) 522.0 (259 × 21)
3/0	409.6	464.0 (427 × 24) 464.0 (259 × 23)
2/0	364.8	414.0 (259 × 23) 414.0 (133 × 20)
1/0	324.9	368.0 (259 × 24) 368.0 (133 × 21)
1	289.3	328.0 (2109 × 34) 328.0 (817 × 30)
2	257.6	292.0 (2646 × 36) 292.0 (665 × 30)
4	204.3	232.0 (1666 × 36)
6	162.0	184.0 (1050 × 36) 184.0 (259 × 30)
8	128.5	147.0 (655 × 36)
10	101.9	116.0 (105 × 30) 115.0 (37 × 26)
12	80.0	95.0 (165 × 34) 96.0 (7 × 20)

Table 2: Table equating solid wire gauge to stranded cable

conductors are NOT the same! This is due to the fact that the stranded wires have some amount of open space between them when contained in one bundle (because the wires are circular). This can be seen in the cross-section of the stranded conductor in Figure 5.

Shown is a table for examples of both solid and stranded wires (Table 2). The table is used in the following manner:

- the entry for the wire gauge 12 shows a SOLID wire diameter of 80.0 mils.
- Stranded wire with a 12 gauge can be obtained by combining either 165 solid wires of 34 gauge (165 x 34) or 7 wires of 20 gauge (7 x 20).

EMC ASPECTS OF WIRES

While important, DC characteristics of wires are not the primary characteristics of concern in EMC work. The important elements to consider are:

- lines on a schematic (or connections in SPICE) that represent the “ideal” characteristics.
- frequencies of interest in EMC work that require an understanding of “non-ideal” behaviors.

A key consideration when using wires (or any type of conductor) with non-DC current is that there is AC impedance that increases with frequency due to the skin effect phenomenon. The skin effect causes a reduction in the cross-sectional area through which the current flows and, as we saw in a previous equation, the cross-sectional area decreases when the resistance increases. The same condition is a contributor to AC impedance. This is shown in the following figure and equation (Figure 6).

In addition, both the AC resistance and reactance of a conductor vary with frequency as a result of the skin effect, and are reflected in the resistance ratio factor (X).

DC RESISTANCE, AC RESISTANCE, AND INDUCTIVE REACTANCE

If the fact that AC resistance can dominate DC resistance isn't bad enough, since the wires are part of

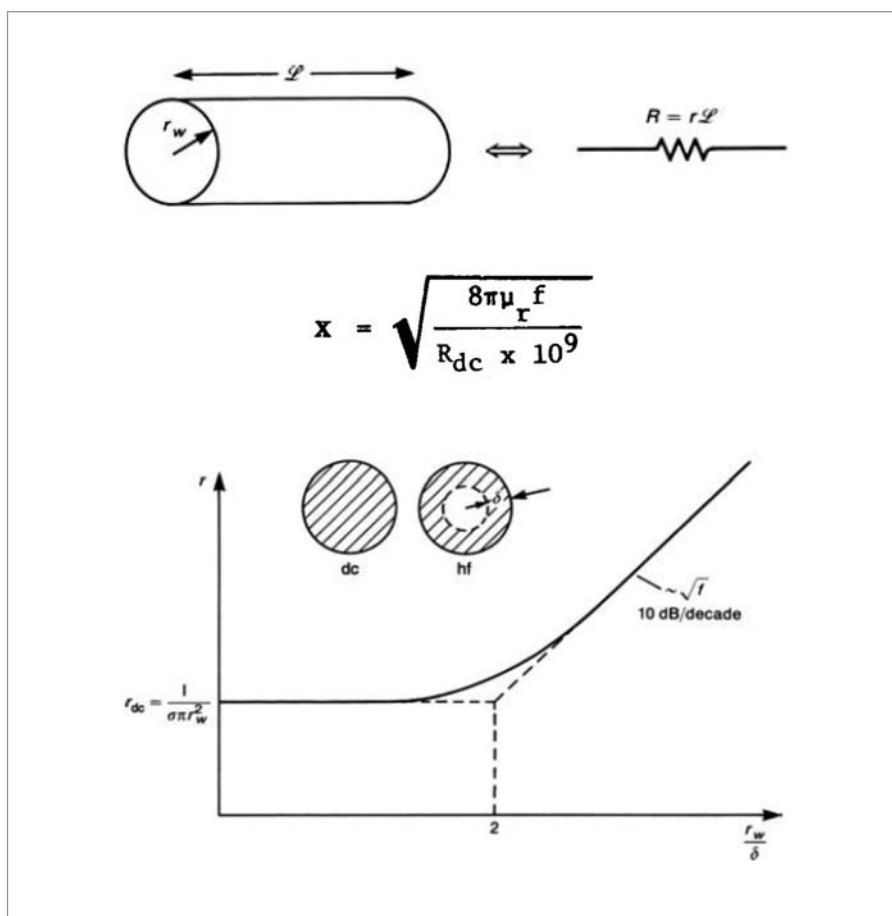
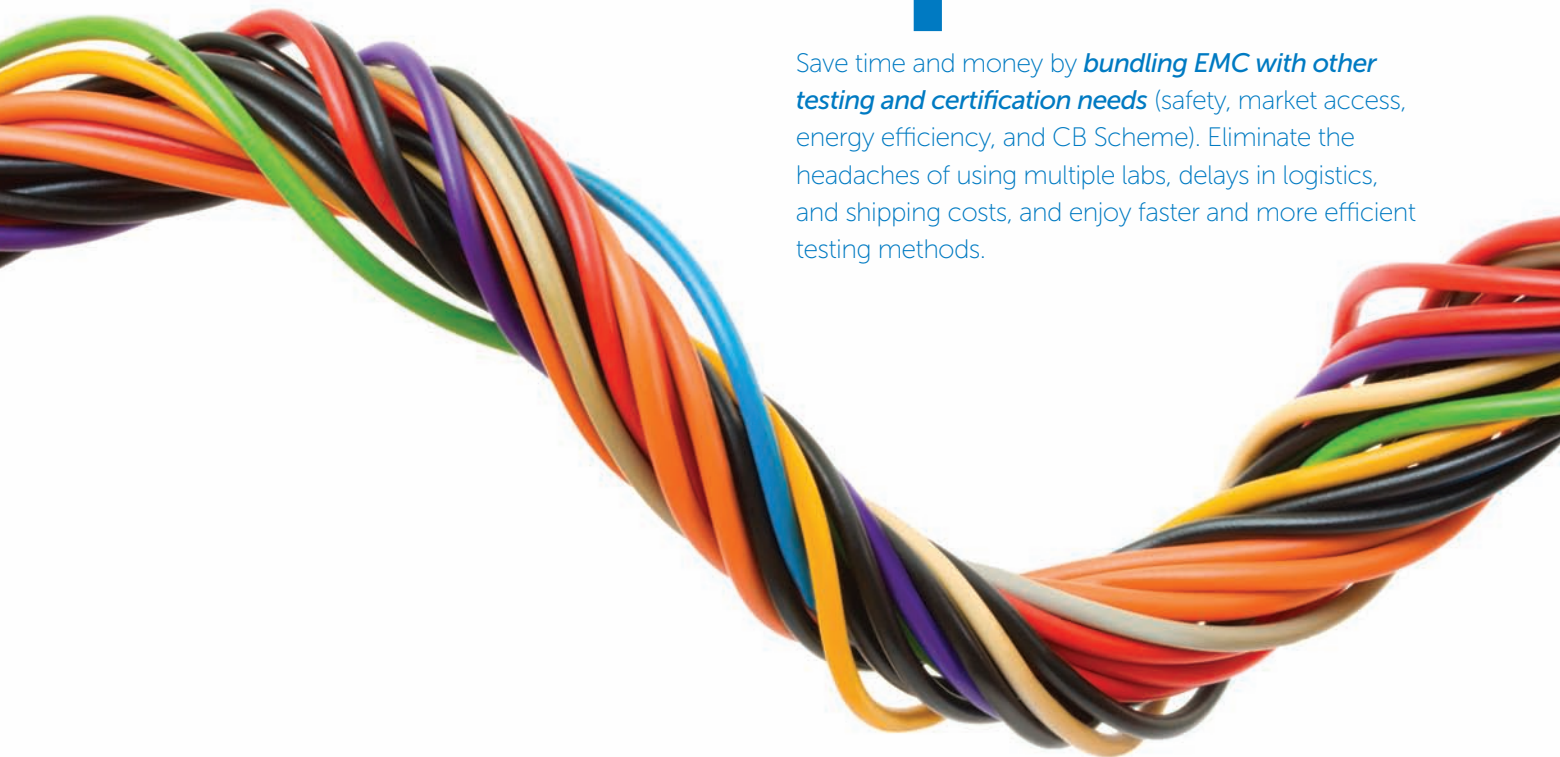


Figure 6: AC impedance of a conductor is composed of two parts: the DC resistance and the AC resistance (once the wire radius exceeds approximately two skin depths)

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a current loop, they also have self-inductance and result in even higher impedance.

Table 3 summarizes these effects. It may even be startling that at only 1 MHz, the AC resistance is an order of magnitude greater than the DC

resistance and the inductive reactance (X_L) is hundreds of times the AC resistance!

Figure 7 shows the relationship between wire length, diameter, and self inductance. We can see that:

- impedance of short wires increases significantly due to inductance.
- even “small” values of inductance (a few micro-Henries) have high impedance at EMC frequencies (due to $X = j\omega L$).

Now that we have investigated the properties of single-strand wires, let’s look at the characteristics of stranded wires.

It turns out that an approximation can be made in that the resistance (and to a certain degree, self inductance -- ignoring the effects of mutual inductance) of the stranded wire can be modeled as the resistance (inductance) of each strand divided by the number of strands (as each strand is effectively in parallel with the others). Interestingly, this was first empirically observed by Michael Faraday making the simple observation of “sparks” created in a circuit. When the same parallel wires were spread out, the “sparks” were less – without any change to the length of the wire bundle. Of course, we now know that fewer “sparks” mean less series inductance. Faraday’s observation is recorded as follows:

Copper wire $\frac{1}{32}$ of inch in diameter. Six lengths of five feet each, soldered at ends to piece of copper plate so as form terminations, and these amalgamated. When this bundle was used to connect the electro-motor it gave but very feeble spark on breaking contact, but the spark was sensibly better when the wires are held together so as to act laterally than when they were opened out from each other, thus showing lateral action.

Made a larger bundle of the same fine copper wire. There were 20 lengths of 18 feet 2 inches each and the thick terminal pieces of copper wire 6 inches long and $\frac{1}{8}$ of inch thick.

This bundle he compared with a length of 19 feet 6 inches of a single copper wire $\frac{1}{8}$ inch in diameter,

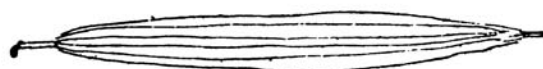


FIG. 13.

having about equal sectional area. The latter gave decidedly the largest sparks on breaking circuit.

Size AWG	Length (Ft)	R_{dc} (Ω)	R_{ac} (Ω)	L (μH)	X_L (Ω)	Z (Ω)
No. 12	100	0.1588	1.23	60.9	382.65	382.65
No. 2	100	0.0156	0.387	53.8	338.03	338.03
1.0	100	0.0098	0.307	52.44	329.49	329.49

Table 3: Comparison of AC resistance, DC resistance and inductive reactance for different wire gauges

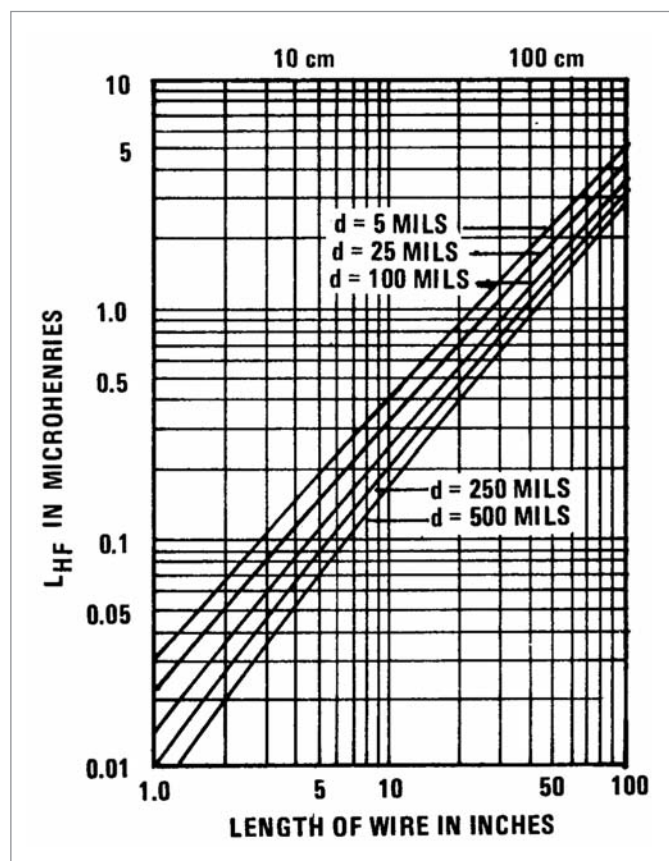


Figure 7: Relationships between wire length, diameter, and self inductance

WIRING FOR COMMUNICATION

As the 1800s continued, the “state-of-the-art” communications systems became the telegraph, and later the telephone, systems. As the infrastructure was developed and built for these, there became a need to understand, in detail, the physics of conductors (which were now called transmission lines). It was discovered that long distance communication paths had unique characteristics that hadn’t been seen before (Figure 8). This was because these installations were the first widespread development of large systems utilizing interconnecting conductors (wiring). This led to the development of the “Telegrapher’s Equations” (discussed later) that became the basis for transmission line theory.

...AND THEN IT HAPPENED – THE FIRST (AND STILL THE ONLY TRUE) GROUND CONNECTION!

As the telecommunications boom of the 1800’s continued, more and more wire was needed to construct the systems. From this need, one fundamental of all electrical engineering procedures was born, the discovery that by using the earth as a current return path, only half the amount of wire was

needed! Thus, the term “ground” was coined for electrical connections (Figure 9)!

current, thereby saving the expense of another line wire and also avoiding the additional resistance introduced thereby. The resistance of the ground-return path GG is negligible in comparison with the resistance of the line wire, for in nearly all cases it is less than one ohm. This low resistance is due to the enormous cross-sectional area of the earth path, although the conductivity of the earth’s crust is poor. Recent experiments, made by Löwy, indicate that the specific resistance of a variety of rocks is greater than 10^8 ohms per centimeter cube, depending upon the amount of moisture in them. To attain low earth resistances it is

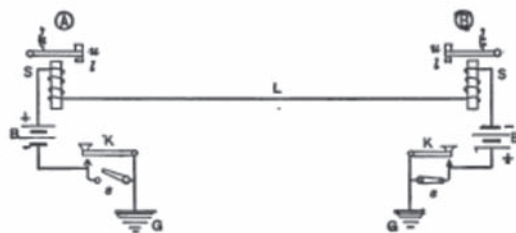


Figure 9: Early reference of the term “ground-return”

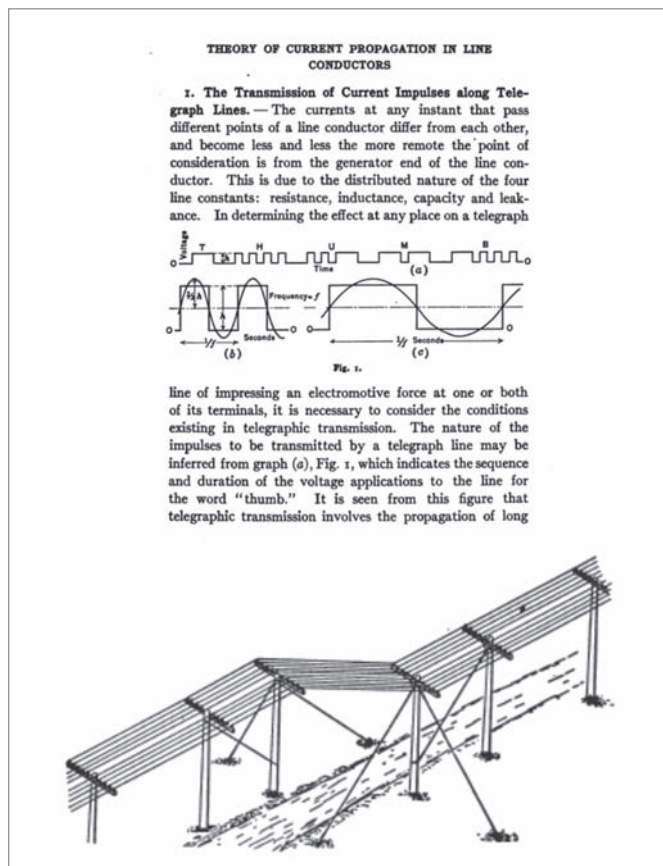


Figure 8: Requirements of early electronic communications led to new understanding of conductors

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ANALYSIS OF THE GROUND RETURN

This practice for long distance telephone and telegraph connection was possible due to a unique physical relationship of the geometry and conductivity of the earth. It turns

out that, rather than being a return path with a significant variation in impedance, the resistance reached an asymptotic limit just over 4 ohms (Figure 10).

This was due to the large area through which current could flow (similar to parallel wires) and, ironically, the resistance of the ground connection was much lower than the long signal wires. This further established the belief that a ground connection was a low impedance path (compared to the rest of the circuits).

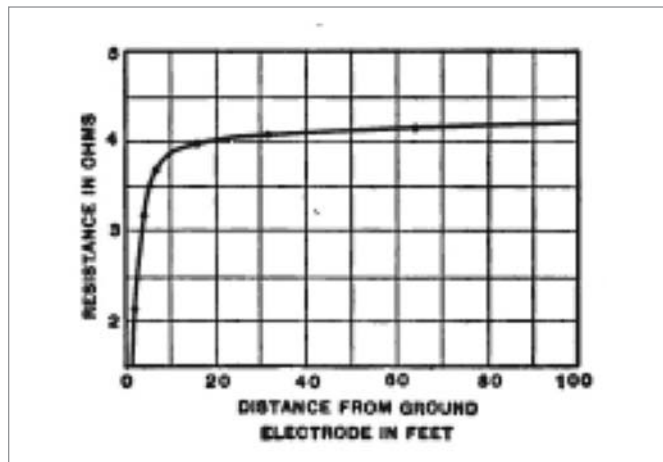


Figure 10: Graph showing the leveling off of resistance in a ground connection

HEAVISIDE'S DISCOVERIES: THE TELEGRAPHER'S EQUATIONS

An interesting phenomenon then occurred as the (telegraph) message signal speeds increased. It was discovered that some of the transmission lines caused signals to be affected and changed at the receiving end from their original characteristics at the sending end.

Heaviside then investigated Faraday's observations of inductance, referenced Maxwell's work, and from that work he developed the "Telegrapher's Equations" which revealed how line characteristics affected signal propagation. This became the basis for all transmission line engineering.

This was amazing an insight. Heaviside realized that the use of two conductors in the telegraph transmission line resulted in the capacitive and inductive

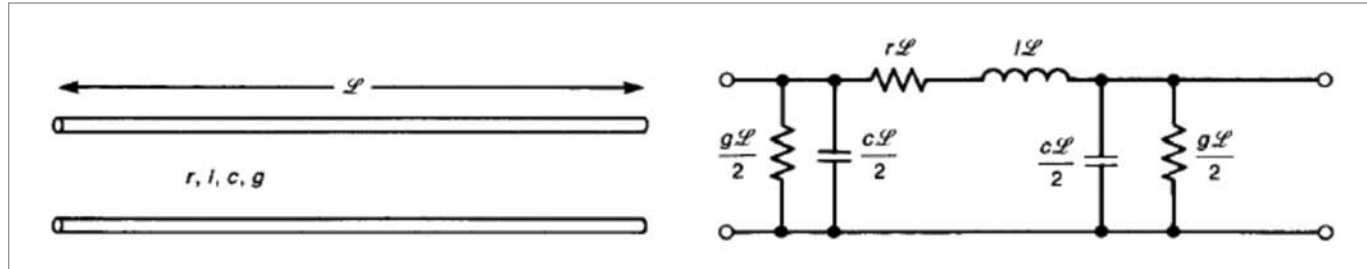


Figure 11: Heaviside realized that capacitance and inductance are continuous along the length of a pair of conductors, and can be represented as "lumped" or "distributed"

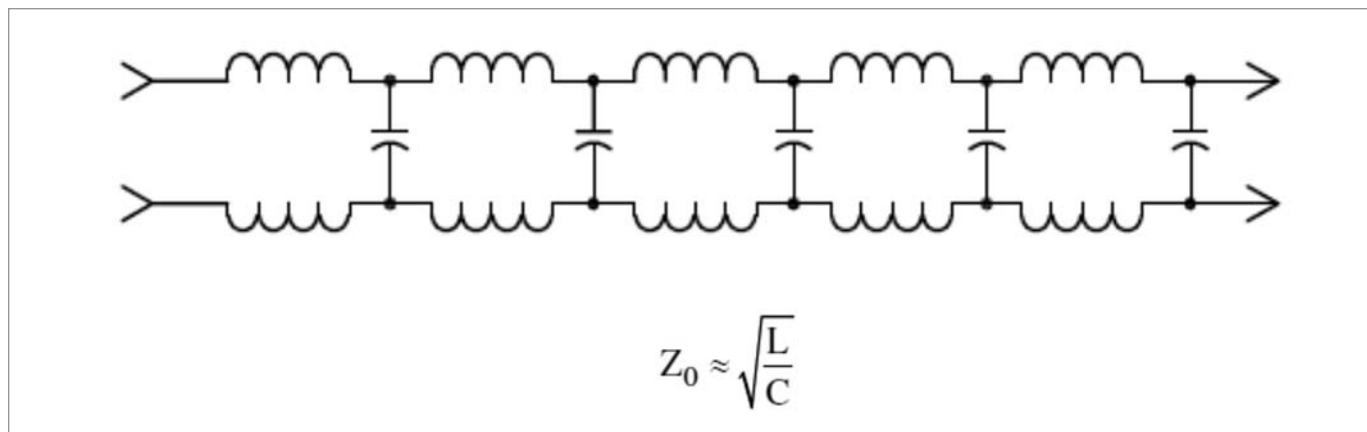


Figure 12: Diagram and equation for the Transmission Line Model

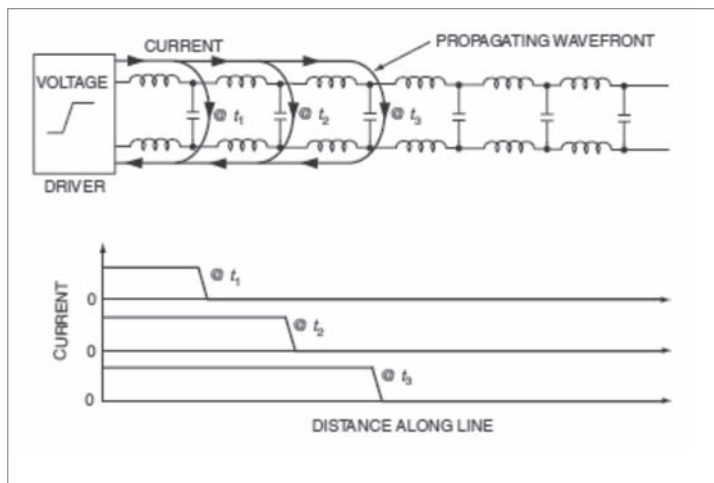


Figure 13: Illustration of how energy propagates along a line (courtesy of Henry Ott, page 218 of *Electromagnetic Compatibility Engineering*)

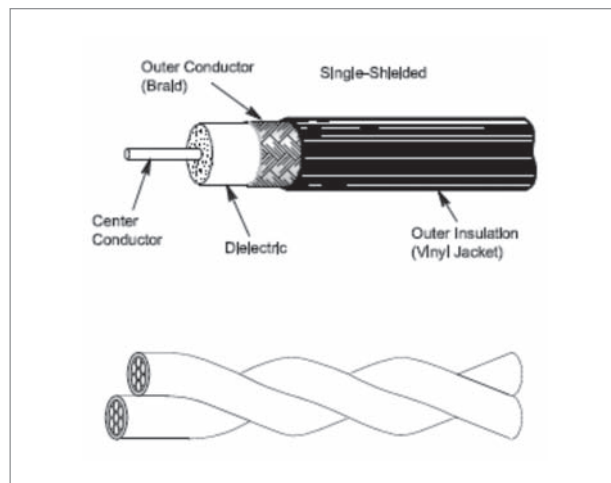


Figure 14: A coaxial line is shown on the top and a twisted wire pair is shown on the bottom.

properties of the line. (This had not been recognized before.) He correctly understood that the capacitance and inductance are continuous along the length of the pair of conductors and therefore could be represented as either lumped or distributed components along the transmission line (Figure 11).

We now refer to Heaviside's work as the discovery of the Transmission Line Model (Figure 12). Most importantly, this discovery allowed for the describing of a transmission in term of its characteristic impedance (Z_0), which is a function of the distributed inductance and capacitance along the line and which makes it independent of line length!

THE TRANSMISSION LINE MODEL

- Model that utilizes a line of distributed inductance and capacitance.
- Model that shows a line can be represented by a surge (or characteristic) impedance, ignoring small dielectric losses.

TRANSMISSION LINE SIGNAL PROPAGATION

Key to transmission line theory is the ability to understand how energy,

whether it's "power" or "signal", propagates along the line. A very good visualization of this is shown in Figure 13.

As can be seen, the propagation essential takes place by the current flow through the line series inductance and the "charging" of the effective parallel capacitors. Since there is a time constant associated with the charging of the capacitors, this causes the propagation speed to be reduced compared to the traditional "speed of light" electromagnetic wave propagation through air/vacuum. The effect of this reduction in propagation speed is known as "velocity factor" and varies based upon the values of the inductance and capacitance (which is determined both by transmission line geometry and material used in the transmission line construction).

EXAMPLES OF COMMON TRANSMISSION LINES

Today's transmission lines are typically either coaxial or "twisted wire pair" (TWP) (Figure 14). Coaxial cable is used for shielding electrical fields and TWP is used for magnetic field shielding from emissions from either the transmission lines or from external interference.

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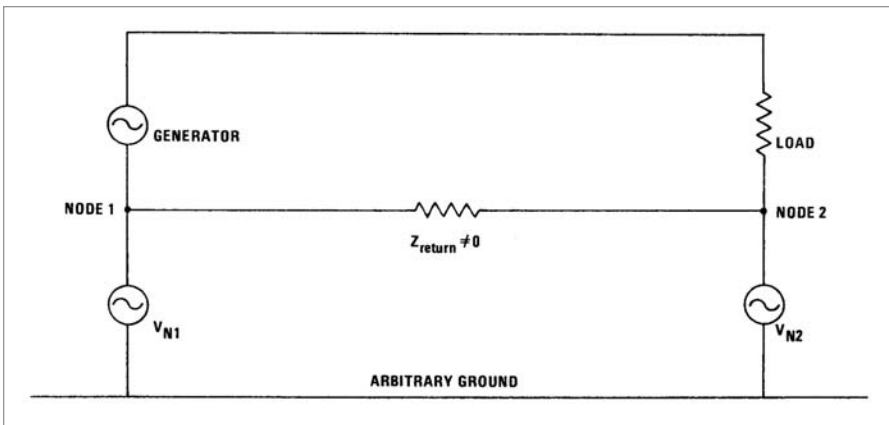


Figure 15

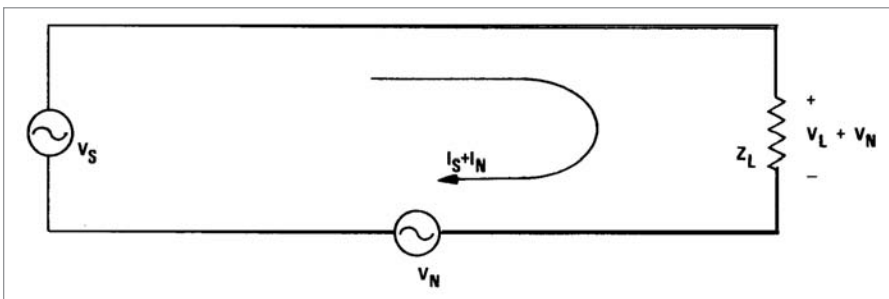


Figure 16

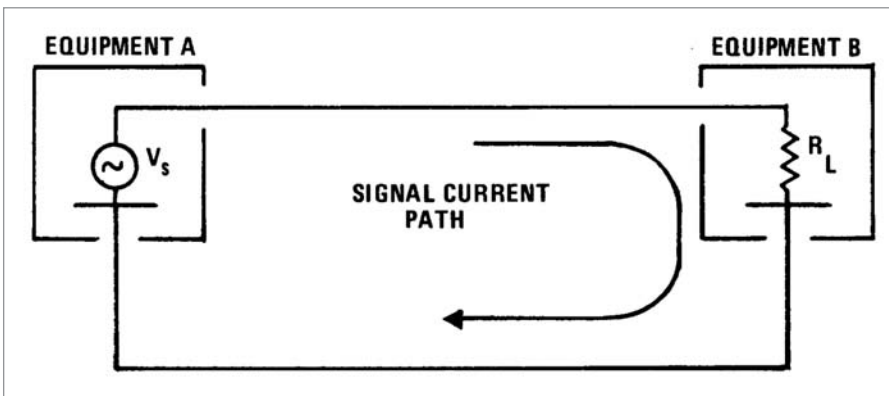


Figure 17: Schematic of a signal return

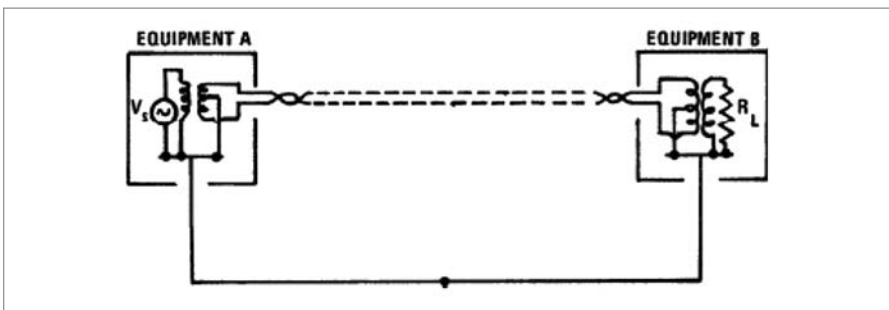


Figure 18: Isolation of signal return from the conductive path

OTHER TYPES OF CONDUCTIVE PATHS

A common practice is to utilize the metal chassis or enclosure as a conductive path (typically called “case grounding”) for either signal or power return. There are a number of reasons that this is done including:

- minimization of wiring costs (similar to telegraph “grounding”).
- resolve of component/system EMC problems.

Unfortunately, due to the fact that the impedance of the “ground” path is unknown, this results in the actual energy transfer loop being quite different from the “idealized” (previously discussed). The actual loop is shown in the Figure 15.

Implications of Practice

From that figure, it is easily seen that using the chassis or enclosure as an electrical return path would result in “ground” impedance being undefined and something other than the assumed zero (0) ohms. This impedance is comprised of two terms, the resistance (due to material and frequency) and inductance (due to geometry). Unfortunately, this would *not* be evident from looking at the schematic for the system and result equivalent circuit from this practice is shown in Figure 16.

Actual “Grounding”!

Since the chassis conductive path is very small (compared to earth) – there may be significant path impedance (Figure 16), resulting in unexplained “ground shift” conditions.

Signal “Grounding”

Connecting the signal return to the conductive chassis can cause undesired results due to impedance in the signal current path and/or the presence of other return currents (Figure 17).


Signal Return – Best Practice

The best solution is to isolate the signal return from conductive paths that are not well controlled or may have interfering currents on them (Figure 18).

SUMMARY

There are undeniable realities of conductors that we need to be conscious of when working with circuits:

- Real conductors have properties of resistance and inductance that need to be considered.
- Conductors are the defined paths for the propagation of electrical energy.
- Wires can be either solid or stranded, with each having advantages and disadvantages.
- Transmission lines have inductance and capacitance that determine their characteristics.

And the moral is that any conductive path needs to be evaluated – not just assumed! 

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This article is based on a presentation made during the "Fundamentals" workshop at the 2011 IEEE EMC Symposium and is an example of the type of material discussed at Fundamentals sessions.

(the author)

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Site Attenuation Measurements Using External Source Control

A method of determining the performance of an open area test site (OATS) or an anechoic chamber is to perform a site attenuation measurement. The process used is to step a signal source at the transmitting antenna and use a receiver or spectrum analyzer at the receiving antenna. The two are stepped together to give a set of data that shows the performance of the test site or chamber. ANSI C63.4 outlines the process for performing normalized site attenuation (NSA) measurements. In these measurements, the spectrum analyzer controls the signal source.

BY DENNIS HANDLON

The design of today's anechoic chamber is aimed at emulating open area test sites. Performance in the chamber is evaluated using two antennas, a receiver or spectrum analyzer and a signal source. The measurements are made in two steps. First the cable connecting the source to the transmit antenna is connected to the cable that connects the signal analyzer to the receive antenna and a series of values are measured by stepping the source and receiver or signal analyzer in ~10% steps. The through-line measurement is referred

to as V_{direct} and the measurement made using the antenna is called V_{site} . ANSI requires that a chamber must be within +/- 4dB of the ideal site attenuation. In ANSI C63.4, the ideal normalized site attenuate is shown in tabular form. The graph in Figure 1 shows the ideal normalized site attenuation measurement. The formula for performing site attenuation measurements is $A_N = V_{\text{Direct}} - V_{\text{Site}} - AF_R - AF_T - \Delta AF_{\text{TOT}}$. ΔAF_{TOT} is assumed to be 0 at a 10 meter distance from receive to transmit antenna.





With the receiver controlling the external source the measurement system can be swept over the entire range of interest. The max hold feature of the receiver allows the recording

of the highest level signals. In order to obtain a graph of the chamber or OATS true performance, the receiving antenna must be swept from one meter to four meter height. The loss of the

two antennas must be removed from the measurement and the result is normalized to the direct measurement.

UPDATED APPROACH TO SITE ATTENUATION MEASUREMENTS

Since the signal source is separate from the receiver, unlike signal analyzers that have a built-in tracking generator, the source can be placed near the transmit antenna to reduce cable loss, thereby improving the signal to noise performance of the measurement. Also, the cables that are connected as a through-line are shorter, reducing cable loss. Once the level of the through-line is established and placed into the trace for normalization, the cables can be connected to the two antennas that are placed at 10 meters apart. Figure 2 shows the typical interconnection between the source and the EMI receiver.

The transmit center of the antenna is fixed at one meter above the ground

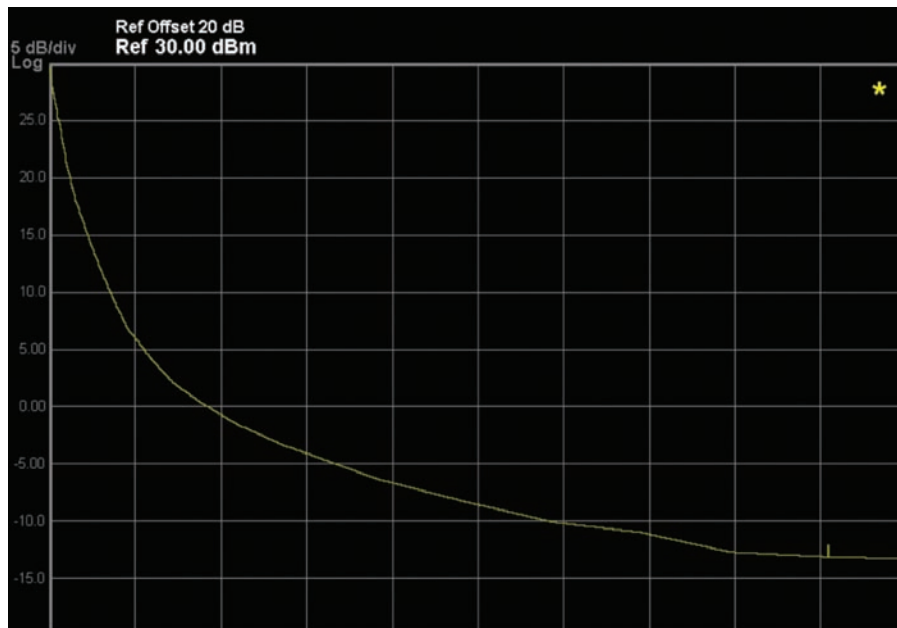


Figure 1: Theoretical normalized site attenuation 30 MHz to 1 GHz.

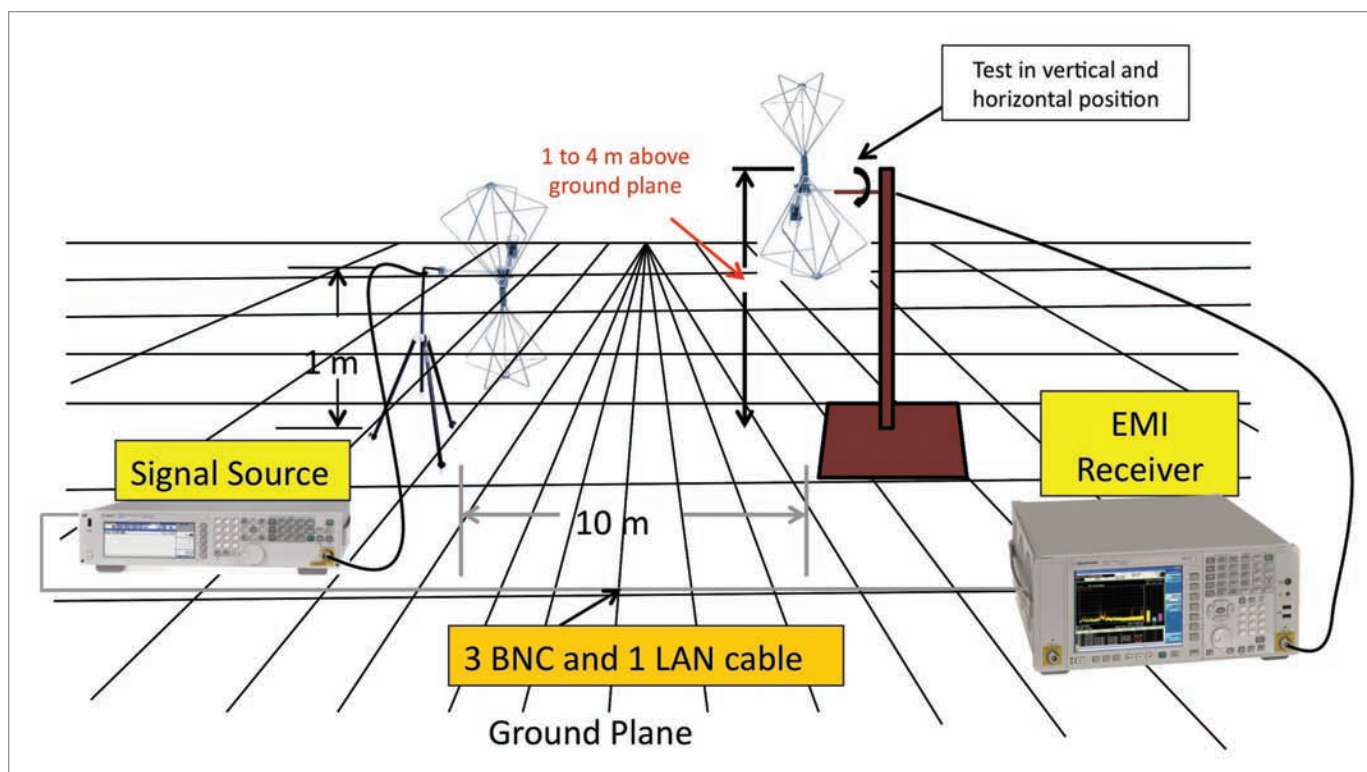


Figure 2: Typical external source control layout

In order to use an external source located at a distance to the EMI receiver, some connections need to be made. Communication between the source and the receiver can be accomplished using USB, GPIB or LAN.

plane. The receive antenna is moved from 1 meter to 4 meters above the ground plane. At the same time, the signal source and EMI receiver is swept over the frequency range that the antennas are designed for and calibrated over. It is important that the antennas are calibrated correctly, that is, the calibrated antenna factors completed by the manufacture are very close to the actual relationship between the field at the plane of the antenna and the voltage out of the antenna that the antenna experiences at a specific frequency. If this is not, the case then the actual normalized site attenuation calculation may not be close to the theoretical site attenuation. In order to pass the normalized site attenuation, the measured values must fall within +/- 4 dB of the theoretical site attenuation.

In order to use an external source located at a distance to the EMI receiver, some connections need to be made. First, the frequency references need to be tied together to insure frequency tracking. Communication between the source and the receiver can be accomplished using USB, GPIB or LAN. In this case we will use LAN. Communication between the source and receiver includes start/stop frequency and amplitude levels. The other connections can include triggering to insure that the source and receiver step together over the frequency range.

The next consideration is the resolution bandwidth to be used for the test. It is important that there are no gaps in the data collection. If the bandwidth is narrower than the step size of the

frequency steps, then dropouts or signal spikes can be missed. The total

number of steps used in this case is 1601.

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Modern signal analyzers or EMI receivers are able to compensate for the response of broadband antennas.

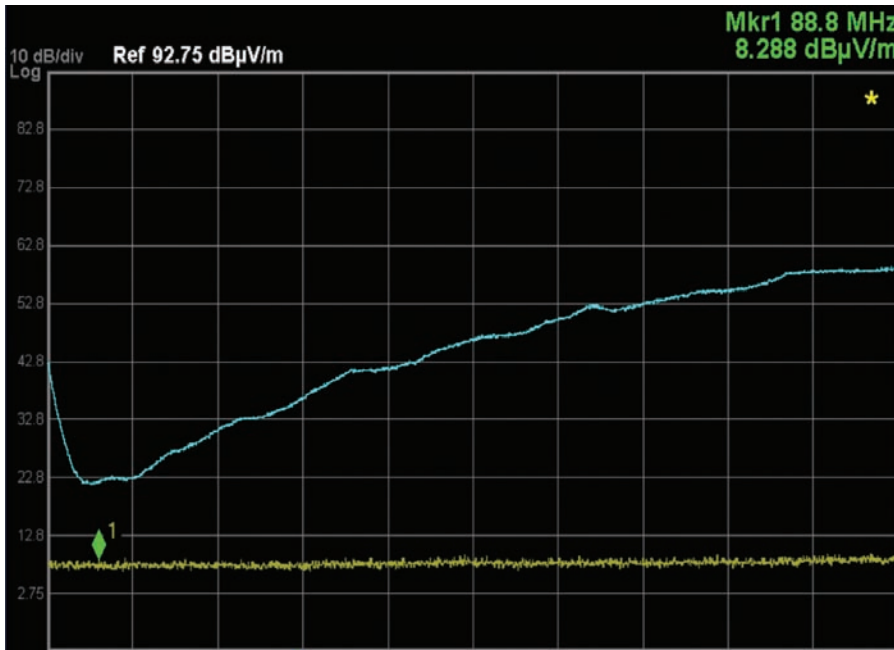


Figure 3: The yellow line is the noise floor and blue line is the noise floor corrected for both antennas

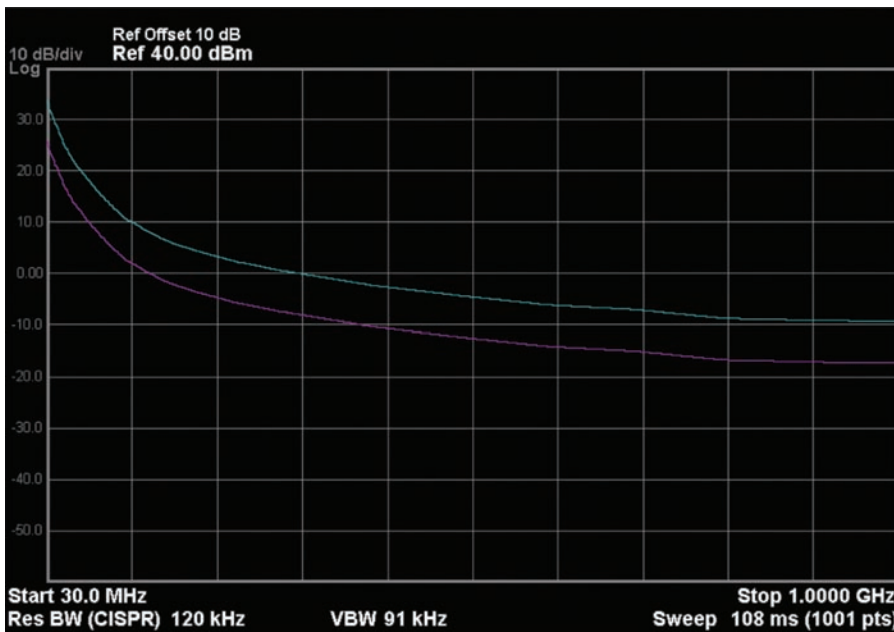


Figure 4: NSA limits

CORRECTING FOR ANTENNA FACTORS

Modern signal analyzers or EMI receivers are able to compensate for the response of broadband antennas. Antenna manufacturers send the calibration data for the antennas which are then loaded into a correction factor editor. Since the site attenuation measurements require two antennas, the easiest way to correct for both antennas is to add the corrections together and place it into the corrections editor. The typical correction for a broadband antenna ranges between 7 dB and 25 dB. Adding the two together gives a correction of 14 dB to 50 dB. In order to meet site attenuation requirements, antennas to be used must have the corrections as accurately characterized as possible. A trace showing only the correction factor for the combination of the antennas is shown in Figure 3. The corrected noise floor is the antenna factors added to the noise floor.

With the antennas in the horizontal polarization, sweep the antenna tower between 1 meter and 4 meters with the signal analyzer or EMI receiver in the max hold trace configuration. The result is a corrected trace that shows the site attenuation over the frequency range of interest.

CHOOSING THE BANDWIDTH

There is a trade-off between the number of data points, sensitivity and dynamic range. Choosing the correct bandwidth can help solve some of the issues. In order to avoid missing spikes and dropouts of signals, it is

Now that the antennas are in place and the source frequency range is set correctly for the broadband antennas used, the measurement can be started.

recommended that the bandwidth be at least 200 kHz, because the maximum number of points is 1601 when using an external source. The minimum bandwidth step size would be 168 kHz to allow a bandwidth per point. The video bandwidth should be equal or greater than the resolution bandwidth.

NORMALIZING TO A THROUGH-LINE MEASUREMENT

The cable connected to the transmit antenna and the cable connected to the

receive antenna are connected together with a high quality barrel connector (very low loss) and the frequency responses of the two cables are measured using the combination of the external source and the receiver. The amplitude values versus frequency are subtracted from the corrected values of the site measurements when using the antennas.

NORMALIZED SITE ATTENUATION LIMITS

In Figure 4, a continuous plot of the theoretical normalized site attenuation

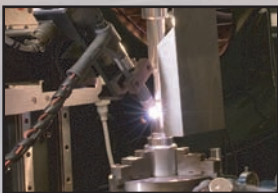
is displayed. The limit as stated earlier was +/- 4 dB. A linear plot of the limits is shown. The goal in the swept tune NSA is to have all the values fall within the limit shown.

PERFORMING SITE MEASUREMENTS

Now that the antennas are in place and the source frequency range is set correctly for the broadband antennas used, the measurement can be started. The antennas are placed in the horizontal position.

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The receive antenna is moved slowly from 1 meter to 4 meters. The source/receiver combination is swept much faster than the antenna is moved so that at least 20 sweeps are taken while the antenna is moved through its range. The trace mod is maximum hold so that only the highest values

are maintained on the display. These maximum values relate to the highest signal strength received by the receiving antenna. These maximum values are a result of the combination of the reflected and line-of-sight signals. The theoretical normalized site attenuation measurements take into account the

reflections from the ground plane. What the theoretical NSA does not take into account are the reflections from absorber lined areas such as the ceiling or the back walls.

An open area test site usually does not have these additional reflective problems unless there is a reflective surface within the area that may influence the overall measurements. One of the open area test sites that I was involved with had a cyclone fence 50 yards off the center line, which did affect the measurements. When the fence was moving in the wind we did see a couple of tenths of a dB change.

DEALING WITH THE TRACE DATA

Let's analyze the trace that is on the display after the maximum signals have been captured. Since the data was captured in a chamber, there are no large ambient signals to obscure the measured data. The first item to note is that the data is corrected for the loss of the two antennas used for the measurement. An important point to note is that the correction factors used for the antennas must be as accurate as possible. One or two dB of error in the correction factors will cause the same level of errors in the site attenuation measurement.

The trace data was stored as a .csv file and then displayed on the results shown in Figure 5. The .csv file allows closer inspection of individual frequency points.

Once the normalization is performed, the errors will be removed since the systematic errors are in both the site attenuation measurements and through-line measurement. None systematic errors, such as thermal drift and some aging phenomenon, are not removed through normalization. However, allowing the source and receiver to warm up and stabilize will greatly reduce non systematic errors.

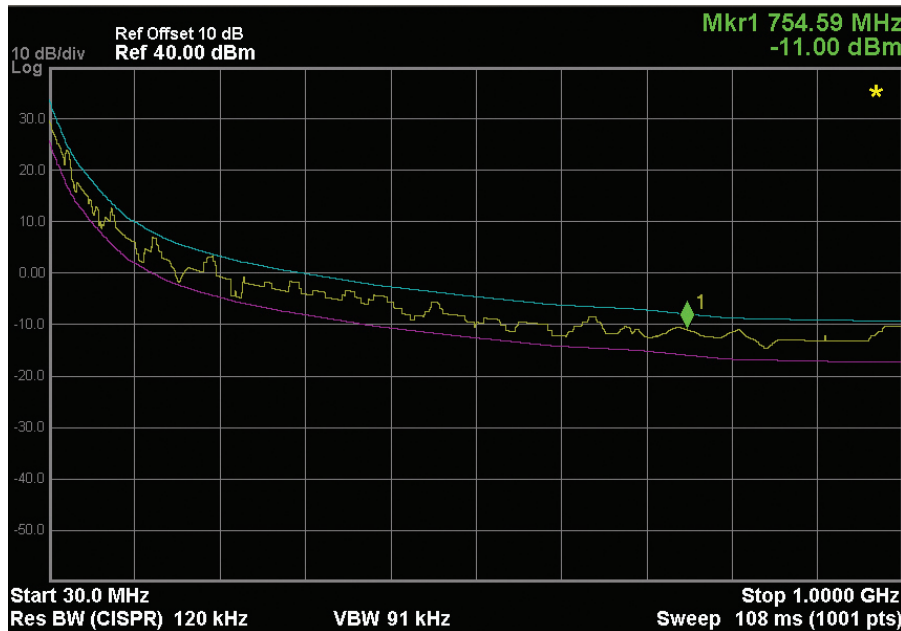


Figure 5: Final results of normalized trace data

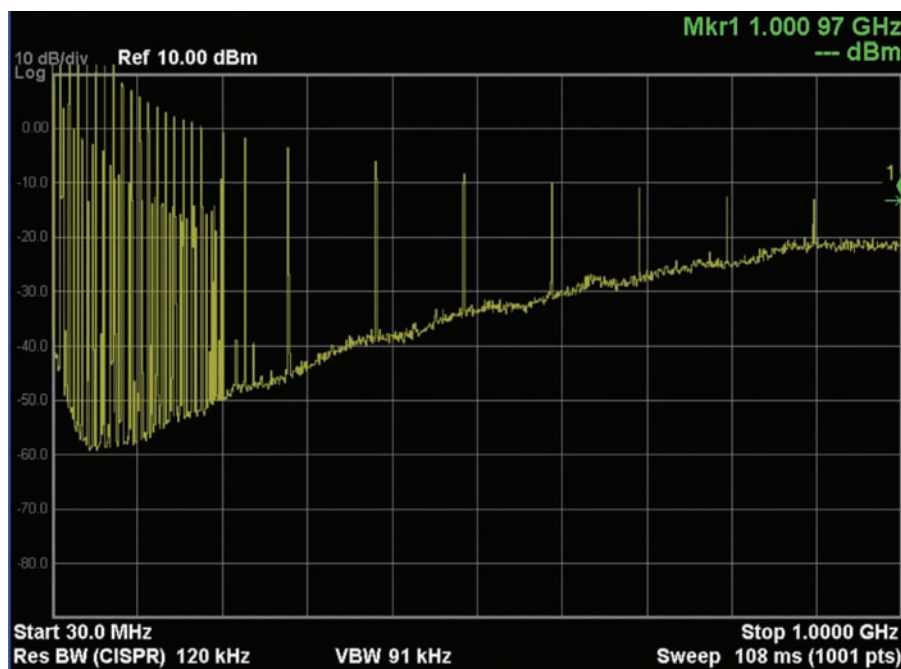


Figure 6: Measured fixed frequency points as described in ANSI C63.4

COMPARISON TO THEORETICAL SITE ATTENUATION MEASUREMENTS

Since the theoretical attenuation for an ideal site is a group of fixed-frequency data points, another plot was made using those fixed frequency plot points. The data is from a ten meter chamber. The power of the source driving the transmit antenna was adjusted so that the loss in the higher frequencies is still above the correction factor for both antennas. As an example, the total corrections of the two antennas at 900 MHz is 49.8 dB and the theoretical normalized site attenuation is -12.8 dB. The overall power needs to be high enough to be above the corrected noise floor to get an accurate amplitude reading without added noise to the measured signal.

The signals in the plot in Figure 6 were measured using the marker function and placed in Table 1. The digital IF of the signal analyzer or EMI receiver allows the user to measure signal anywhere on the screen without compromising accuracy, even signals that are off the top of the display are measured accurately.

SITE ATTENUATION MEASUREMENTS ABOVE 1 GHZ

The above discussion focused on site attenuation measurements from 30 to 1 GHz. As the testing moves higher in frequency, it is even more important to have the signal source and receiver as close to the antennas as possible because of signal attenuation in cabling. If amplifiers are used to improve performance at these higher frequencies, they also must be included in the overall loss/gain profile. The amplifier gain versus frequency must be well understood. This characterization

can be accomplished using a network analyzer. Use the external source applied for site attenuation to characterize the amplifiers and associated cabling, and place the results in correction factor arrays, available in most EMI receivers or signal analyzers.

SUMMARY

The use of an external signal source controlled by a signal analyzer will greatly improve the process of performing site attenuation measurements. Shorter cables reduces signal loss because the source is at the transmit antenna, which is increasingly important as the test frequencies go higher. The frequency and the amplitude of the source can be controlled by the signal analyzer. It is very important to set the ideal signal level to perform site attenuation measurements over the desired frequency range. As seen before, there is a trade-off between noise floor, signal level and bandwidth. The total number of data points must be considered to establish the needed overlap between steps or points. I recommend that the signal level be at least 8 to 10 dB above the indicated noise, which means adjustment of bandwidth/signal level to avoid overloading the input mixer of the receiver or signal analyzer. ■

Frequency	Theoretical value in dB	Measured value in dB
30 MHz	29.8	29.7
40 MHz	24.9	25.1
50 MHz	21.1	20.9
60 MHz	18.1	18.0
70 MHz	15.5	15.6
80 MHz	13.3	13.5
90 MHz	11.4	11.6
100 MHz	9.7	11.3
110 MHz	8.3	8.1
120 MHz	7.0	6.6
130 MHz	5.9	5.7
140 MHz	4.8	4.6
150 MHz	3.9	3.8
160 MHz	3.0	2.8
170 MHz	2.4	2.1
180 MHz	1.7	1.5
190 MHz	1.2	1.0
200 MHz	0.6	0.4
250 MHz	-1.6	-1.8
300 MHz	-3.3	-3.5
400 MHz	-5.9	-6.3
500 MHz	-7.9	-8.3
600 MHz	-9.5	-10.1
700 MHz	-10.8	-11.0
800 MHz	-12	-12.7
900 MHz	-12.8	-13.1
1 GHz	-13.8	-13.3

Table 1: Fixed frequency theoretical NSA versus measured values

(the author)

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Thermal Testing: A Primer

BY HOMI AHMADI

Thermal testing, also known as heat testing, is one of the most critical tests required by the majority of regulatory safety standards in determining the safety of a product.

Excessive heat is the number one enemy in any electrical or electronic circuit. Designers are perpetually trying to improve the way to reduce heat or partially cool their products because they are being asked to design products with higher power density into smaller sizes, while operating temperatures of components or devices have not changed greatly over the past few decades. This means that component temperatures must be well controlled to avoid any failure and to increase the reliability of the product.

This article will cover basic fundamentals for thermal measurement and provide some of the methodology used to arrive at accurate measurements.

CHOOSING A THERMOCOUPLE

Accurate temperature measurement of components can be challenging. An important tool used in thermal

measurement is the thermocouple, one of the most accurate and repeatable.

Although there are many devices or methods used for measuring temperature, thermocouples are one of the simplest and most commonly used sensors. Having said that, using an infrared camera can quickly help identify any hot spot.

Thermocouples consist of two wires of dissimilar metals, joined near the measurement point or junction (Figure 1). The output is a small DC voltage measured between the two wires. This differential voltage is then converted to a temperature using specially designed equipment such as a chart recorder or data logger.

There are over a dozen different types of thermocouples commonly used in

various industries. Most of these have been given internationally recognized letter designator types, such as B, C, D, E, G, J, K, L, M, N, P, R, S, T, and U.

Types J, K, and T are among the most commonly used thermocouple types in the electronic industry due to their ease of use, low cost, and availability. Each thermocouple has its own temperature range and accuracy. For example, the range for type J thermocouples is -210°C to $+750^{\circ}\text{C}$, while for type T the range is -100°C to $+350^{\circ}\text{C}$; for this reason, they are used for different applications. These temperature ranges are approximate because manufacturers state slightly different numbers. They also have different color codes. For example, in North America a type J is white and

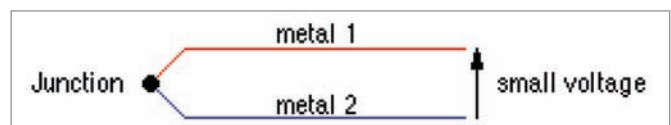


Figure 1: Thermocouple composition

A good weld has a small tip with a very small amount of wire stripped, whereas a poor weld shows the opposite.

red, but in the rest of the world a type J is typically black and white.

The following is a list of recommendation that must be considered before taking any thermal measurements:

- Choose the thermocouple based on your application — expected temperature, environment, abrasion, oil, etc. For example, if you are measuring temperature of a component in a furnace, it is best to use a type C thermocouple.
- Ensure that the chart recorder or data logger is compatible with the thermocouple wiring. If you are using type K, ensure that the data logger is also set to type K. An incorrect setting will result in measurement errors.
- Visually and physically check the outer jacket for any obvious damage by running the thermocouple wires through your hand and feeling for any possible damage.
- Visually check the tip. The smaller the weld tip, the more accurate the results will be. Figure 2 illustrates two different weld tips.
- A good weld has a small tip with a very small amount of wire stripped, whereas a poor weld shows the opposite.
- Check each thermocouple for its functionality. Valuable time can be wasted if the thermocouple is damaged or is not functioning correctly after it is affixed to a component. One of the easiest methods is to hold each thermocouple between your thumb and index finger for a few seconds. The thermocouple should read your body temperature (37°C).
- Take care when using thermocouples in a noisy environment or when attaching them to windings of a transformer. Thermocouples typically have no shielding and can be susceptible to EMI noise. Measuring magnetic temperature can be tricky, in particular when measuring switching transformers. The closer the thermocouple tip is to the windings, the more accurate the results are. However, it is best if the thermocouple tip is not touching the magnet wires directly since some of the windings carry high voltages and this may damage the data logger if it comes in contact with the thermocouple. The safest approach is placing the thermocouple tip on insulation tape, which covers the winding. One of the best ways to overcome an electrical noise problem is to use a thermocouple with shielded leads and connectors or to rout it away from noisy circuits.
- Ensure that a thermocouple is calibrated.
- When repairing and welding a thermocouple, it is critical that the weld tip is carefully checked to ensure the weld is secure and that the thermocouple is recalibrated prior to use.
- Avoid using a thermocouple with long lead length. High resistance in the wire may lead to errors. Use an appropriate extension wire and adapter, if longer length is needed.
- Avoid performing thermal testing in an uncontrolled environment, high traffic area, or areas exposed to any air-conditioning. Excessive air movement will impact the final results.

MEASURING TECHNIQUES

The following factors may affect the final results:

- Position of the thermocouple: Critical when measuring temperature on the winding of a choke or transformer. The results are more accurate the closer the thermocouple is placed to the windings.
- Use of excessive glue or cement: Extra volume and mass can assist heat transfer, in particular when temperatures are close to their limits. Use an exact dose of adhesive. When using adhesive, ensure that the



Figure 2: Good weld vs. poor weld

adhesive possesses a high thermal conductivity.

- Obstruction of the airstream around the thermocouple wires.
- Equipment voltage: Temperature results usually vary as the input voltage to the equipment changes. For example, some units run hotter at 90 V_{ac}, while others may run hotter at 264 V_{ac}. It is recommended that the input voltage source is as stable as practical. Any small variations in input voltage will result in variations in temperature. Ensure voltage tolerances are taken into consideration, as each safety standard uses different tolerance percentages.
- Equipment load: Equipment load plays a crucial role in the final thermal results. In the majority of the cases, the higher the load, the higher the temperature on individual

components. Most product safety standards require the equipment under test (EUT) to be loaded to its maximum normal operating load during the heating test.

- Local ambient conditions: As mentioned before, it is important that the thermal test is performed in a controlled environment. If there is excessive air movement, then the final results cannot be considered as accurate. One of the simplest solutions is to conduct tests in a corner of the lab where there is less traffic and there is no air-conditioning blowing cold air directly on the EUT.
- Stabilization or thermal equilibrium: In certain instances, engineers record the final data after a certain time, such as after one or two hours of operation. Since different products behave differently and reach their

maximum temperature at different times, it is important to record the final data ONLY after the EUT has reached thermal equilibrium.

It would be helpful to explain what thermal stability is. A temperature is determined to be constant or stabilized when the graph on a chart recorder or data logger is shown to be flat without any temperature rise and shows three successive readings are within 1°C of each other when taken at 30-minute intervals. Unfortunately, there is no harmonized standard that defines thermal stability and each standard has its own definition. The most important point to bear in mind is that temperature rise is always an exponential curve. Therefore the easiest method is to use a chart recorder or data logger simply because the curve as temperature becomes stable is readily visible.

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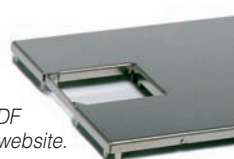
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Figures 3 and 4 illustrate respectively measurements where thermal equilibrium has been achieved and where complete thermal stability has not been achieved.

DOCUMENTING THE RESULTS

Before publishing the final results, take the following steps:

- Review the raw data to ensure that nothing unusual stands out. Use engineering judgment. For example if the body temperature of an metallic oxide varistor (MOV) is lower than that of the printed circuit board (PCB) on which it is mounted, the data should be checked again.
- Compare the test data to previous test data that has been done on the

same product to find out if they all follow similar patterns.

- For almost each measurement of data, there is a limit to which the data is compared. These limits can be derived from verifiable sources such as product safety standards, component manufacturer data sheets, internal procedures, etc.

Tables 1 and 2, from IEC 60950-1, show the limits for some components.

- Prepare the final report by tabulating the data, correcting it to the corresponding T_{mra} (manufacturer recommended ambient), and include the limits for each component where possible.
- Prepare a complete report and ensure that all details (such as input voltage, load condition, amount and direction of any forced airflow, duration of test, and any other parameters that may be beneficial to the reader) are clearly documented.

COMPUTING TEMPERATURES

Typically manufacturers market their products much higher than 25°C. Based on the manufacturer's recommended ambient temperature, also known as T_{mra} , either the limits or the measured temperatures must be corrected accordingly.

The formula below shows how to make the adjustment:

$$T < T_{max} + T_{amb} - T_{ma}$$

Where:

T = measured temperature

T_{max} = maximum limit allowed

T_{amb} = local ambient

T_{ma} = maximum ambient temp permitted by the manufacturer.

Example

An electrolytic capacitor is measured to be 63°C at a room ambient of 23°C.

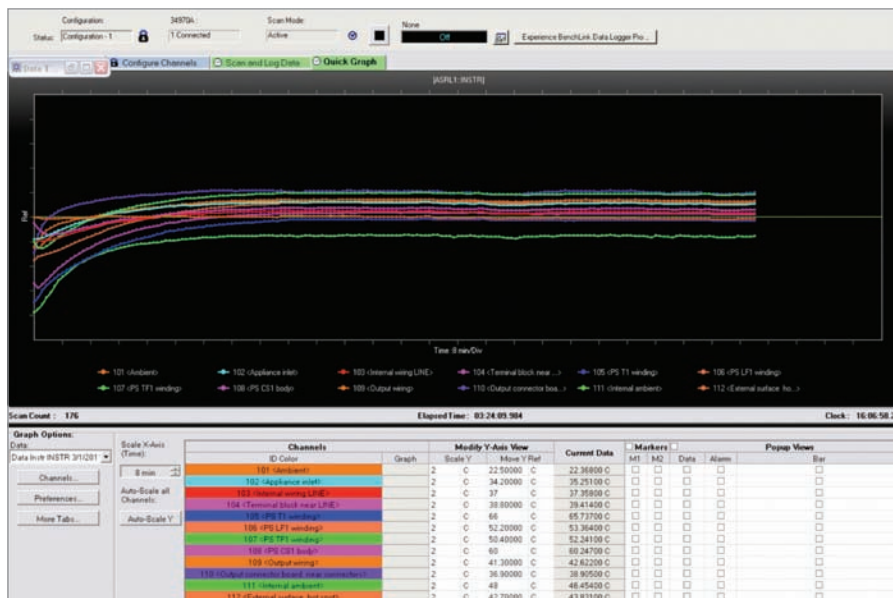


Figure 3: Example showing thermally stable measurements

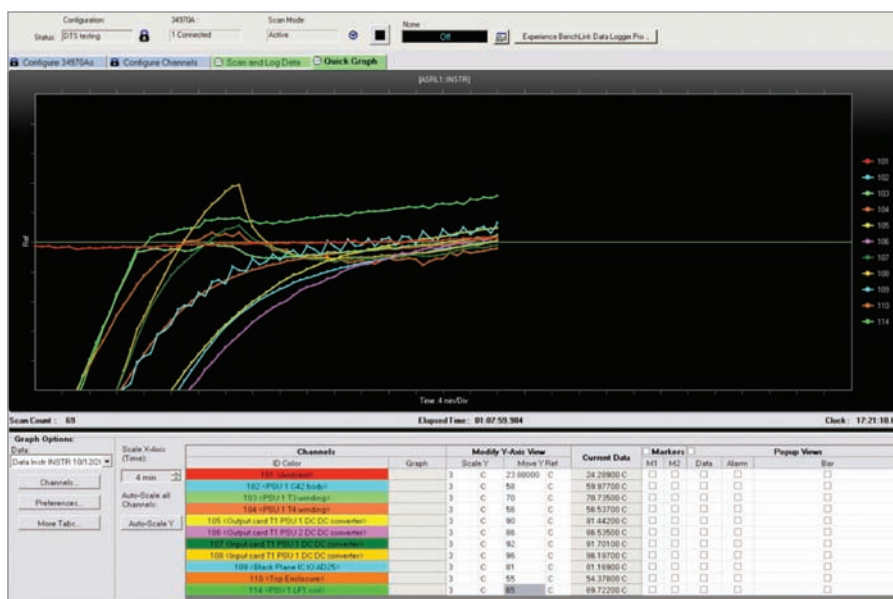


Figure 4: Example showing unstable temperatures

The capacitor is rated for 105°C and the manufacturer needs to qualify this product to 50°C operation. Does this component meet the required limits?

Using the above formula:

$$63 < 105 + 23 - 50$$

$$63 < 78$$

The component meets its permitted limit.

If the T_{mra} is higher than 25°C, then the manufacturer has the choice of:

- Testing it on the bench in the lab and then mathematically correcting the temperatures as shown using the formula above
- Testing the product in an elevated environment, such as a heating oven

An oven is used when there is a specific request or the lab environment is unstable. When testing in an oven, accurately document the oven air temperature, level of oven air circulation, oven humidity, and sample placement. Additionally, an oven is used when

the product is temperature controlled as stated in Clause 1.4.12.2 of IEC 60950-1, 2nd Ed. Most test agencies and standards allow both methods.

If the T_{mra} is 50°C or less, it is recommended that the testing is done on the bench. If the T_{mra} is higher than 50°C, then it is recommended that the testing is done in an oven.

Testing in an oven is typically exponential, where testing on the bench is typically linear when mathematically corrected.

Part	Maximum temperature (T_{max}) °C
Insulation, including winding insulation: <ul style="list-style-type: none"> – of Class 105 material (A) – of Class 120 material (E) – of Class 130 material (B) – of Class 155 material (F) – of Class 180 material (H) – of Class 200 material – of Class 220 material – of Class 250 material 	100 ^{a b c} 115 ^{a b c} 120 ^{a b c} 140 ^{a b c} 165 ^{a b c} 180 ^{a b} 200 ^{a b} 225 ^{a b}
Rubber or PVC insulation of internal and external wiring, including power supply cords: <ul style="list-style-type: none"> – without temperature marking – with temperature marking 	75 ^d Temperature marking
Other thermoplastic insulation	See e
Terminals, including earthing terminals for external earthing conductors of STATIONARY EQUIPMENT, unless provided with a NON-DETACHABLE POWER SUPPLY CORD	85
Parts in contact with a flammable liquid	See 4.3.12
Components	See 1.5.1
<p>a If the temperature of a winding is determined by thermocouples, these values are reduced by 10 °C, except in the case of</p> <ul style="list-style-type: none"> – a motor, or – a winding with embedded thermocouples. <p>b For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature.</p> <p>c The designations A to H, formerly assigned in IEC 60085 to thermal classes 105 to 180, are given in parentheses.</p> <p>d If there is no marking on the wire, the marking on the wire spool or the temperature rating assigned by the wire manufacturer is considered acceptable.</p> <p>e It is not possible to specify maximum permitted temperatures for thermoplastic materials, due to their wide variety. These shall pass the tests specified in 4.5.5.</p>	

Table 1: Temperature, limits, materials, and components

Parts in OPERATOR ACCESS ARE AS	Maximum temperature (T_{max}) °C		
	Metal	Glass, porcelain and vitreous material	Plastic and rubber ^b
Handles, knobs, grips, etc., held or touched for short periods only	60	70	85
Handles, knobs, grips, etc., continuously held in normal use	55	65	75x
External surfaces of equipment that may be touched ^a	70	80	95
Parts inside the equipment that may be touched ^c	70	80	95

a Temperatures up to 100 °C are permitted on the following parts:

- areas on the external surface of equipment that have no dimension exceeding 50mm, and that are not likely to be touched in normal use; and
- a part of equipment requiring heat for the intended function (for example, a document laminator), provided that this condition is obvious to the USER. A warning shall be marked on the equipment in a prominent position adjacent to the hot part.

 The warning shall be either

- the symbol (IEC 60417-5041 (DB:2002-10));
- or the following or similar wording

WARNING
HOT SURFACE DO NOT TOUCH

 b For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature.
 c Temperatures exceeding the limits are permitted provided that the following conditions are met:

- unintentional contact with such a part is unlikely; and
- the part has a marking indicating that this part is hot. It is permitted to use the following symbol (IEC 60417-5041 (DB:2002-10)) to provide this information.

Table 2: Touch temperature limits

TC Locations	Bench °C	Bench Adjusted to 50°C	Oven at 50°C
T3 windings	78.48	105.61	92.57
L24 winding	99.16	126.29	112.1
PCB next to Q9	91.36	118.73	104.56
CR32	63.84	90.97	77.73
PCB next to U19	50.02	77.15	65.59
Q40 body	77.40	104.53	91.19
Ambient	22.87		48.98

Table 3: Bench vs. Oven testing

Table 3 shows the temperature results of an information technology equipment (ITE) product that was tested both on a bench as well as in an oven.

Looking at Table 3, it is clear that testing on the bench and then mathematically correcting the values to the manufacturer's stated T_{mra} is much harsher than when it is tested in a heating oven that was set to T_{mra} .

DETERMINING LINEAR FEET PER MINUTE

Another issue that designers sometimes face relating to thermal testing is the terminology used in some of power

supply specifications. Some power supply manufacturers use the term cubic feet per minute (CFM), while others may use linear feet per minute (LFM) when a supply requires forced air cooling. CFM is a measurement of volume while LFM is a measurement of velocity. Most fan manufacturers use CFM, while board designers prefer to use LFM as this makes calculating thermal derating curve or power dissipation much easier.

LFM is equivalent to CFM divided by the cross-sectional area of interest.

The larger the cross-sectional area, the smaller the LFM for a given CFM, as shown in the formula below:

$$\text{LFM} = \text{CFM} / \text{area (ft}^2\text{)}$$

Where:

area is the cross-sectional area of the opening which typically happens to be the fan box size in square feet.

if the fan is square, then the cross-sectional area is $L \times W$.

if the fan is circular, then the cross-sectional area is πr^2 .

Example:

A fan measures 40 x 40 mm and has a CFM of 5.2, then the LFM is calculated as:

$$1 \text{ mm} = 0.00328 \text{ ft.}$$

$$40 \text{ mm} = 0.1312 \text{ ft.}$$

$$40 \text{ mm}^2 = 0.0172 \text{ ft}^2$$

$$\text{LFM} = 5.2 / 0.0172$$

$$\text{LFM} = 302 \text{ ft/min}$$

REFERENCES

1. 60950-1: 2005 Information Technology Equipment - Safety - Part 1: General Requirements, <http://www.omega.com>

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ESD Electronic Design Automation Checks

Part 1: Outlining the essential requirements of the ESD verification flow

BY MICHAEL G. KHAZHINSKY

The verification of electrostatic discharge (ESD) protection in a complex integrated circuit (IC) design is extremely challenging. Leading-edge designs have many supply domains and voltage levels for different functional parts like radio frequency (RF), digital and high voltage blocks, making ESD checking a complex and error prone task. Relying on manual verification alone poses a significant risk of missing design flaws, which can be very costly during manufacturing and in the field. Consequently, automated ESD checking is highly desired in today's design flow. This article outlines the essential requirements of the ESD verification flow as defined by the ESD Association (ESDA) Electronic Design Automation (EDA) Tool Working Group [1].

Figure 1 illustrates the timeline and main stages for an example design

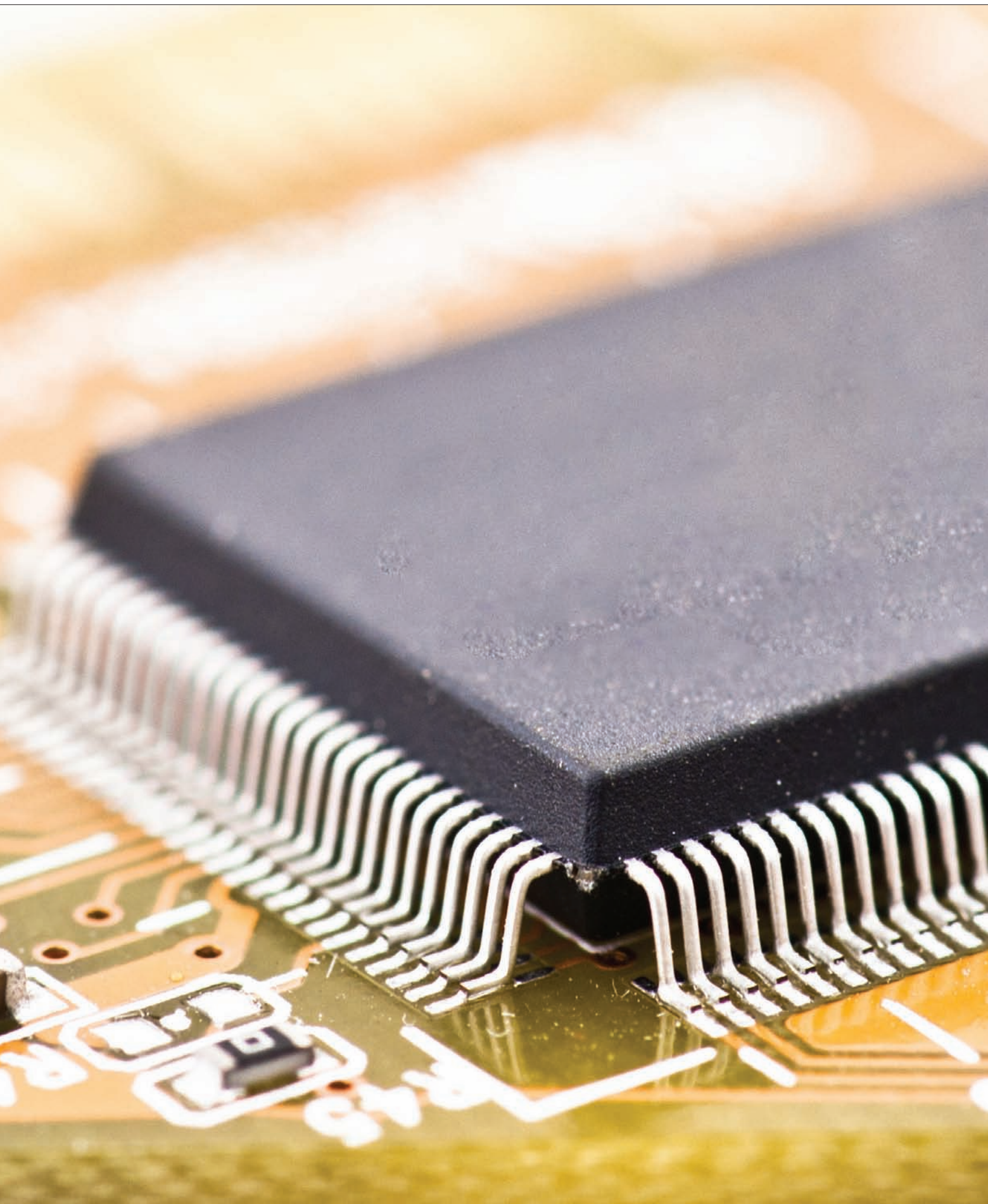
flow. The IC product design flow (top row) needs to be synchronized with an ESD development and implementation flow (middle row). The latter needs to be supported by an ESD check flow (bottom row).

The following sections describe the main IC development phases and give examples of different ESD checks relevant for these phases.

PRODUCT DEFINITION PHASE

The ESD performance specifications usually follow commonly accepted standards. However, depending on the field of application, they can be modified by marketing teams and IC customers. Product design specifications and required ESD performance dictate specifications of ESD components and ESD cells. Based





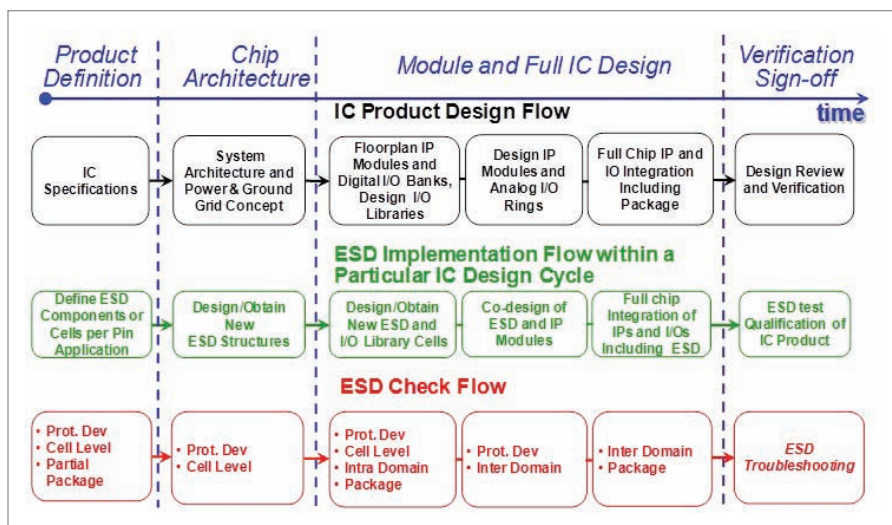


Figure 1: A simple ESD verification flow mapped to sample IC design flow.

on these functional requirements, suitable ESD cells are defined per each pin application node (signal, power, and ground). Typically the ESD cells are made accessible to the designer in a dedicated ESD library.

In a situation when a mature semiconductor technology is used with already developed ESD libraries, only placement and product specific modifications of the existing ESD components and ESD cells need to be verified. For a new IC product that uses a new semiconductor process, an ESD library may not be available and no specific cell level ESD checks can be executed. However, performance specifications

of the needed ESD library could still be defined, together with the IC customer, based on the available ESD technology development data and ESD EDA data from other products/technologies.

Based on the available design data in this design phase, the following ESD checks can be performed:

- Protected device checks to verify that the available ESD library cells can provide the required safe operating conditions for the protected components at each pin, for the given design functional requirements.
- Cell-level checks on the existing ESD cells.

- Package-level checks to determine, for example, expected peak charged device model (CDM) currents, as well as package and die specifications to meet CDM performance specifications.

Due to the nature of these data, a simple check of the ESD compliance can be done based on the ESD characteristics of the ESD cells in a design database. The following is an ESD EDA check example performed during product definition.

An early analysis of the integrity of I/O cell, bus placement and the overall ESD robustness is one of the essential factors of a successful chip design. An ESD floorplanning checker for the chip could enforce the ESD design rules to be verified while planning I/O cell and power bus placement. In particular, the checker could verify the existence of an ESD cell/device between pads, estimate parasitic resistance between pad and ESD cell/device, and give a rough estimate of the chip ESD robustness by predicting pad voltage (Figure 2).

CHIP ARCHITECTURE PHASE

At this design stage, the functional/behavioral level of chip architecture is defined and the required ESD components and library cells are



At this design stage, the functional/behavioral level of chip architecture is defined and the required ESD components and library cells are identified.

Specific tool functionality is needed for the cases where the ESD protection cells are placed in the analog pad ring, which is not available to the team performing the ESD checks at module level.

identified. No circuit or layout level IC description is available in this phase. Similar to the previous section, cell level checks and protected device checks can be performed. The available design data are similar to those described in the previous section.

MODULE AND FULL IC DESIGN PHASE CHECKS

This is the main design activity phase, involving complex interaction between all product teams. It can be divided into three sub-stages.

The first stage is the floorplanning of the chip architecture modules and the standard digital I/O and power banks. The ESD checks that could be done at this design stage are limited to top-level verification of the ESD network within the digital I/O banks and ESD connectivity between the different modules, the related I/O banks in the different power domains and the package level ESD connections. These checks include:

- Protected device checks for the digital modules.
- Cell-level checks for the new ESD library cells.
- Intra-power domain checks for the digital intellectual property (IP).
- Floor plan/top-level ESD checks for the power and ground domain bus crossing.
- Basic package level checks.

The second stage is the design of IP modules and analog I/O pad rings. At this design stage, the analog (and RF) modules and the related I/O banks

are physically designed. In many cases, the analog IP module team is different from the I/O and power/ground cell design team, which is often responsible for integrating the ESD library cells. The module team may not have detailed information about the ESD components used at cell level and special attention is needed when checking the overall ESD implementation. A certain level of co-design between the analog modules and the dedicated ESD protection cells may be needed as well. Based on the available design data, the following ESD checks could be performed:

- Cell-level checks for the analog pin ESD library cells (can be newly developed, e.g. for custom analog form factors or in-module/off-pad ring placement).
- Intra-power domain checks for analog pad rings.
- Intra-power domain checks for each analog module.

- Inter-power domain checks (if there are several power domains in one analog module).
- Protected device checks for the individual modules.
- Special ESD rule checks on specific analog/RF blocks/IP's – e.g., differing ESD target levels.

Specific tool functionality is needed for the cases where the ESD protection cells are placed in the analog pad ring, which is not available to the team performing the ESD checks at module level. Such tool functionality can be extended to allow verification of module ESD robustness against cross-power domain or cross-IP stress events. This is especially useful when the counter pins are not available physically but some information about the involved ESD network (ESD cells, connectivity) is present in the design database. This can be considered a “virtual chip integration” where only a

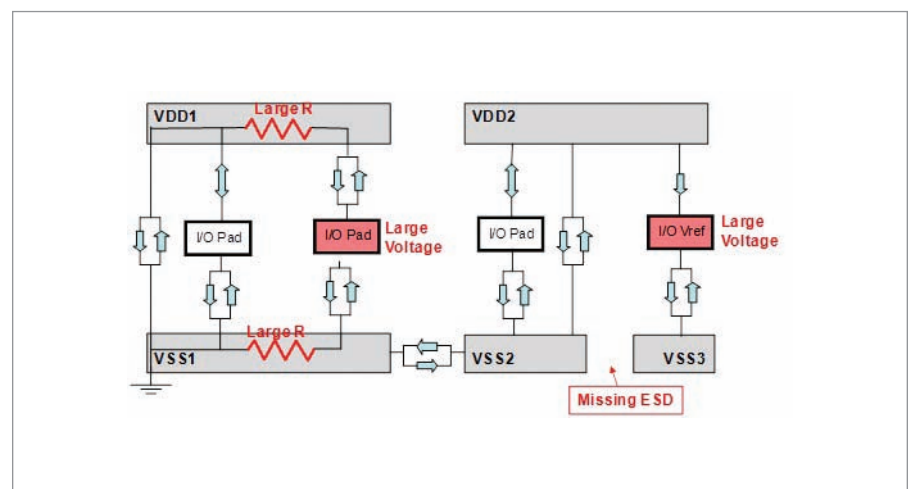


Figure 2: A sample I/O assembly checked with an ESD floor plan checker. Tool output flags missing ESD protection devices and large resistances in the ESD current path.

Final design audits and ESD performance assessments are executed using the verification results from the previous phases.

particular module design is physically available to the team running the check. This situation also applies to the verification of a given module involving evaluation of ESD performance of third party IP (“black box”).

The third stage is full-chip IP and I/O integration, including package. This is the final level of ESD checks applied to the whole IC. The main purpose is to verify the integration of the individual IP ESD circuits at top IC level, to check for the new cross-IP integration ESD violations and parasitic devices, and to verify that the protected components at each individual IP module are still operating in their ESD safe operating area (SOA) for stress combinations including other IP.

Based on the available design data, the following ESD checks could be executed:

- Inter-power domain checks.
- Package-level checks.
- Protected device checks for the full IC.

For certain classes of designs (e.g., some digital designs), it might be possible to implement certain hierarchy of checks so that at the full chip level the individual design blocks are considered as “black boxes” and only the integration of the blocks is verified.

The following is an example of ESD checks of the module and full IC design phase aimed at identifying potential ESD weaknesses of I/O assemblies (rings or arrays). An I/O assembly could be checked at this stage with an ESD verification tool covering both

the layout checks and the electrical checks. The layout checks could ensure that the predefined ESD rules are strictly followed. In particular, the checker could flag input buffer gates and output buffer drains without adequate ESD protection, parasitic bipolars, violations of minimum ESD metal width, etc. The electrical checks of I/O assembly at this stage can vary in complexity: they can use simplified I/O netlists only or include detailed models of ESD protection elements and parasitics. The verification of primary ESD current path existence and checking of alternative current paths for each pin-to-pin combination is the main objective of the check at this stage [2]. The checker could flag the situation where no ESD current path exists or where an unintended parallel path with weak devices becomes preferred during an ESD event. Basic checks can be done using an extracted netlist from the schematic for all pin-to-pin combinations. This can then be followed by a more detailed analysis for selected pins using the netlist extracted from the layout.

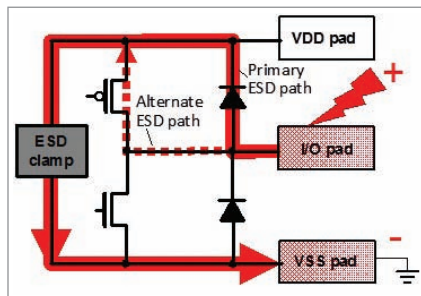


Figure 3: Check of an ESD path in an I/O ring. An appropriate check of these two current paths would involve high-speed static and dynamic simulations on the large netlist of interconnect and ESD relevant components.



Figure 3 shows part of an I/O ring with primary and alternate current paths for a given pin stress combination. An appropriate check of these two current paths would involve high speed static and dynamic simulations on the large netlist of interconnect and ESD relevant components.

DESIGN QUALIFICATION PHASE

In this phase, final design audits and ESD performance assessments are executed using the verification results from the previous phases. This is often done based on a custom, company-defined standard practice methodology, summarized in an “ESD check list” or other document. The goal is to confirm that all required ESD verification activities have been performed.

EDA tool functionality at this design stage is mostly related to reporting and documenting the results of the checks executed earlier and storing the results in a suitable database for further analysis. Such analysis is usually needed for product ESD troubleshooting during IC qualification.

This is often done based on a custom, company-defined standard practice methodology, summarized in an “ESD check list” or other document.

In practical design cases involving complex IC products and ESD solutions, there could be situations in which some ESD violations may still be reported when an IC is sent for manufacturing due to limitations of the ESD verification tools or due to non-ESD-related product development priorities. However, under all circumstances, the result of the formal ESD EDA check runs could allow for easy product ESD troubleshooting. The ESD EDA checker output could help with relating possible ESD test failures with identified ESD design marginalities.

The ESD checks of the final IC verification phase are most extensive. They are similar to the checks which have been performed during earlier design phases. However, ESD EDA tools could be capable of operating on much larger netlists, including full chip resistance, capacitance, and package information. The following are a few

ESD EDA check examples performed during this phase.

A final ESD IC check could include verification of all designated ESD current paths using an EDA tool. To achieve better accuracy for a given pad stress combination, more than one ESD path could be found and analyzed since ESD current flow may not be limited to the shortest path identified earlier. A report from such a tool will include calculated node voltages and currents and can be used for the ESD signoff before the tape-out. Figure 4 shows an example of the final chip-level checker output, where three distinctive ESD paths for a chosen pair of pads (IO_D2 and IO_ANA) were found. Voltages and currents along ESD paths have been found by running DC simulations where an HBM 1.33A current has been forced between the two pads. Simulated voltage potentials and currents at each path node are shown in Figure 4. Bus parasitics have been included in

simulations. For example, the voltage difference between nodes V2 (7.76V) and V3 (5.35V) is coming from both the diode D1 voltage drop (2.39V) and VSSIO bus resistance voltage drop (0.01V). Voltage stresses across most sensitive devices are being monitored to ensure that while the total voltage drop between stressed pads may be high (16.48V), devices are not being stressed in excess of their failure limits. In particular, voltage between VDD and VSS in this example does not exceed the 0.68V, and the IC core can be considered ESD robust.

After completion of the initial IC integration, critical cross-domain boundaries between different supply voltage networks on a chip could be identified. The high voltage drop across these boundaries during an ESD stress makes them more prone to ESD damage than the devices placed within the same power domain. The increasing number of different supply

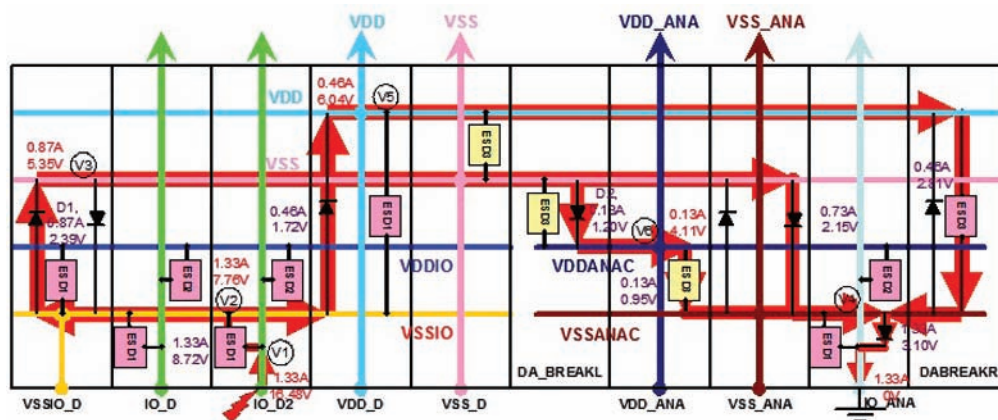


Figure 4: Example of the final chip-level checker output. Simulated voltage potentials and currents at each path node are shown. Bus parasitics are included in simulations.

Final design audits and ESD performance assessments are executed using the verification results from the previous phases.

voltage domains in today's generation of chips necessitates an automated check to find devices that would be impacted during an ESD event. Depending on the acceptable voltage stress level for the specific devices at the domain interface, ESD design weaknesses could be identified by an

EDA tool after checking thousands of possible interface connections. In addition, protection measures already implemented at power domain boundaries (diodes connected to an interface gate oxide, etc.) have to be taken into account as well when analyzing ESD robustness of devices

at power domain boundaries. Figure 5 gives an example of a cross-domain level shifter, where a gate connected to node 1 could be overstressed during an ESD event.

CONCLUSIONS

In this article the, essential requirements of an effective ESD EDA verification flow were described. These requirements

are aligned within the IC design community ESD verification needs. The proposed verification flow offers a systematic approach to check ESD robustness across all IC blocks at different phases of design flow. This approach allows for the avoidance of many ESD design flaws, reducing the overall design cycle time. The ESD EDA tools would improve the ESD predictive capabilities by generating extended netlists (including ESD device, resistance, capacitance and package) and retiring an approach of crude "back of the envelope" extractions, manual/visual checks and resource-intensive SPICE simulations. Another important benefit of these tools is the possibility to use them for systematic ESD design optimization. The ESD EDA check requirements outlined in this article could be the basis for additional effort by the EDA vendors to adapt their tools and to make a comprehensive ESD verification flow feasible. ■

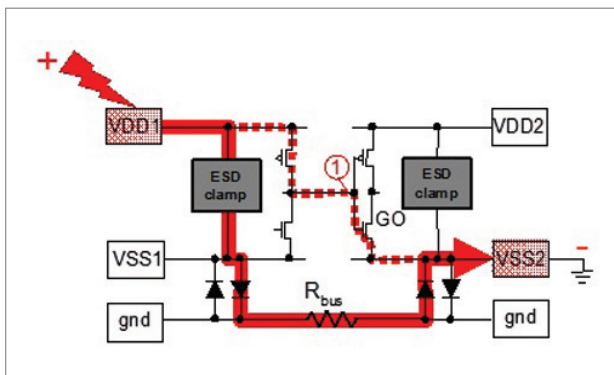


Figure 5: Power domain boundary-crossing check. Due to increased R_{bus} , the primary ESD current path (thick line) becomes less attractive, resulting in stressed gates at node 1.

More details on the proposed ESD EDA verification flow can be found in the ESDA Technical Report ESD TR18.0-01-11 [1], which is available for as a free download at <http://www.esda.org/standards.html>. At the time of the writing, the ESDA EDA Working Group consisted of the following members: Michael Khazhinsky (Silicon Labs), Fabrice Blanc (ARM), Gianluca Boselli (Texas Instruments), Shuqing (Victor) Cao (Global Foundries), Norman Chang (Ansys), Dan Clement (On Semiconductor), Rosario Consiglio (Impulse Semiconductor), Maxim Ershov (Silicon Frontline), Melanie Etherton (Freescale Semiconductor), Eleonora Gevinti (ST), Harald Gossner (Intel), Matthew Hogan (Mentor Graphics), Larry Horwitz (Synopsys), Kelvin Hsueh (ESD Consultant), Mujahid Muhammad (IBM), Louis Thiam (Cadence), Nitesh Trivedi (Infineon), and Vesselin Vassilev (Novorell).

REFERENCES

1. M. Khazhinsky, et al., "ESD Electronic Design Automation Checks," *ESDA Technical Report* ESD TR18.0-01-11, pp. 1-75, 2011.
2. N. Trivedi, et al., "Two Approaches for Design Verification for ESD," *IEW*, pp. 408-418, 2007.

Founded in 1982, the ESD Association is a professional voluntary association dedicated to advancing the theory and practice of electrostatic discharge (ESD) avoidance. From fewer than 100 members, the Association has grown to more than 2,000 members throughout the world. From an initial emphasis on the effects of ESD on electronic components, the Association has broadened its horizons to include

areas such as textiles, plastics, web processing, cleanrooms and graphic arts. To meet the needs of a continually changing environment, the Association is chartered to expand ESD awareness

through standards development, educational programs, local chapters, publications, tutorials, certification and symposia.

(the author)

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is currently an ESD staff engineer/designer at Silicon Labs' Broadcast Products Division in Austin, Texas. Prior to joining Silicon Labs, he worked at Motorola and Freescale Semiconductors where he was in charge of the TCAD development for the new and emerging CMOS and NVM process technologies, as well as the development of ESD, latch-up and I/O physical architecture design solutions with a focus on SOI and ESD EDA. Michael earned the M.S. degrees in Electrical Engineering and Physics from Moscow State Institute of Electronic Engineering and the Ph.D. degree in Physics from Western Michigan University. Michael is a Senior Member of IEEE and the ESD Association. Michael served as a member of the IRPS, IPFA and EOS/ESD Symposium Technical Program Committees, as well as a Workshop Chair and Technical Program Chair of EOS/ESD Symposium. He currently serves on the Management Committee and as the Vice General Chair of the 2011 EOS/ESD Symposium. Michael co-authored over 30 external papers and gave a number of invited talks on ESD, process/device TCAD, and photonic crystals. He was a co-recipient of six EOS/ESD Symposium and SOI Symposium "Best Paper" and "Best Presentation" awards. Michael currently holds fifteen patents on ESD design, with additional patents pending.



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EU News

continued from page 17

New List of Standards 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 June 2012 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/1208_07.

CPSC News

LED Clip-On Desk Lamps Recalled

LG Sourcing, Inc. of North Wilkesboro, NC is recalling about 33,000 LED clip-on desk lamps made in China.

The recalled LED desk lamps were sold at Lowe's stores nationwide from May 2011 to December 2011 for about \$20.

Additional details about this recall are available at incompliancemag.com/news/1208_08.

burn and electric shock to consumers. Bel Air says that it has received seven separate reports of incidents related to the recalled lanterns, including two reports of lanterns catching fire. However, no reports of injuries have been received.

Recalls have been issued for LED clip-on desk lamps and outdoor, wall-mount lanterns. The desk lamps, sold at Lowe's stores, pose a risk of electrical shock. The outdoor lanterns, also sold at Lowe's, can short circuit.

LG Sourcing has reported to the U.S. Consumer Product Safety Commission (CPSC) that the power cord for the lamp can detach where it meets the clamp, exposing energized wires and posing a risk of electric shock to consumers. The company says that it has received five reports of cords detaching, including one report of electric shock and one report of a child having been burned on her hands and leg.

Outdoor, Wall-mount Lanterns Recalled

Bel Air Lighting, Inc. of Valencia, CA has recalled about 100,000 outdoor, wall-mount lanterns manufactured in Guangdong, China.

According to the company, an electrical short circuit can occur in the lanterns' internal wiring, posing a risk of fire,

The outdoor lanterns were sold at Lowe's stores and in lighting showrooms nationwide, and through Lowes.com, from June 2006 through May 2012 for about \$48.

More information about this recall is available at incompliancemag.com/news/1208_09.

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IEEE

UL Standards Update

Underwriters Laboratories has announced the availability of these standards and revisions. For additional information, please visit their website at www.ul.com.

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UL 844: Standard for Luminaires for Use in Hazardous (Classified) Locations
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UL 746E: Standard for Polymeric Materials - Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used In Printed-Wiring Boards

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UL 98: Enclosed and Dead-Front Switches

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UL 608: Standard for Burglary Resistant Vault Doors and Modular Panels

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Revision dated June 29, 2012

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UL 1981: Standard for Central-Station Automation Systems

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UL 60065: Standard for Audio, Video and Similar Electronic Apparatus - Safety Requirements

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From Our "You Can't Make This Stuff Up" File

A New York man has filed a federal lawsuit against iPhone maker Apple for what he claims is false advertising related to Siri, the iPhone's virtual assistant.

Frank M. Fazio claims that Apple's television advertisements which show how Siri works misrepresent the function's actual capabilities. According to the suit, when Fazio asked for directions to a certain place or to locate a store, "Siri either did not understand what Plaintiff (Fazio) was asking, or, after a very long wait time, responded with the wrong answer."

For its part, Apple has filed a motion to dismiss the lawsuit, claiming that Siri is beta technology and represents a work in progress. The company also noted that Fazio could have returned the phone under Apple's 30-day return policy, but failed to do so.

The complete text of the lawsuit is available at the Law Blog of the *Wall Street Journal* at incompliancemag.com/news/1208_10.

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is the Compliance Engineering Manager at Extron Electronics in Anaheim, CA and has responsibility for Extron global regulatory compliance affairs. He has extensive background in compliance which includes product safety, EMC and environmental.



DENNIS HANDLON

is currently a product manager at Agilent Technologies, Inc. signal analysis division. He specializes in electromagnetic interference measurements using the new EMI measurement receiver. Dennis has been involved with the EMC community as an IEEE member since 1990. For Dennis's full bio, please see page 97.



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 27.



ROB KADO

is the EMC Manager and Senior Technical Specialist for Chrysler Group LLC; his responsibilities include Component/Vehicle Validation, Research and Development, Specifications, and Operations. Rob is a member of several SAE/ISO EE/EMC Groups. For Rob's full bio, please see page 74.



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W. MICHAEL KING

is a systems design advisor who has been active in the development of over 1,000 system-product designs in a 50 year career. He serves an international client base as an independent design advisor. For Michael's full bio, please see page 33.



BRIAN LAWRENCE

began his career in electromagnetics at Plessey Research Labs, designing "Stealth" materials for the British armed services. In 1973 he moved to the USA and established a new manufacturing plant for Plessey to provide these materials to the US Navy. For Brian's full bio, please see page 21.



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GEOFFREY PECKHAM

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DALE SANDERS

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See What We're Doing to Simplify EMC Testing!





ITS 6006 EMC IMMUNITY TEST SYSTEM – INGENIOUSLY INTEGRATED TESTING TO 6 GHZ

There has never been a specially designed compact system for radiated immunity EMC testing like this: The ITS 6006 ingeniously integrates a large number of functions, reducing setup time, cable losses, errors and costs. This versatile unit is as flexible as it is safe, and its 2.8" color display makes it especially easy to use. It features an impressive variety of immunity tests to address a wide range of IEC standards. With the ITS 6006, Teseq once again demonstrates its leading expertise in the field of immunity testing.

ITS 6006 at a glance:

- Signal generator with AM/PM/external modulation
- Integrated 4-channel RF switch network
- Amplifier interlock control
- Remote control via USB, RS 232 or LAN
- Extensive EUT monitoring
- Power meter integration

PM 6006 Power meter at a glance:

- RMS power meter, 1 MHz to 6 GHz
- Linear from -45 dBm to 20 dBm
- Connection to PC/USB or directly to an ITS 6006