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THE INTERNATIONAL JOURNAL OF ELECTROMAGNETIC COMPATIBILITY

EMC LIVE 2014 TECHNICAL PROGRAM

ROUNDTABLE:
ELEPHANTS IN THE TEST ROOM

2014 EMC TEST & DESIGN GUIDE

BACK COVER

FEATURED TOPICS

DIRECTORIES

WHO SAYS YOU CAN'T HAVE IT ALL?

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Preamplifiers
20 MHz - 40 GHz
8 Models

Log Periodics
80 MHz - 7 GHz
13 Models

Low Loss Cables
DC - 40 GHz
4 Models

DRG Horns
170 MHz - 40 GHz
6 Models

H-Field Rods
100 Hz - 30 MHz
4 Models

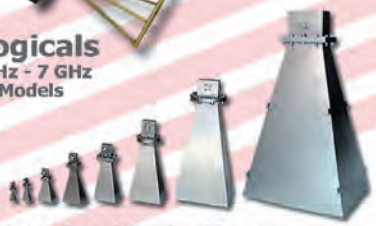
All in one small package

Biconicals
20 MHz - 330 MHz
5 Models

Probes
20 Hz - 1 GHz
16 Models

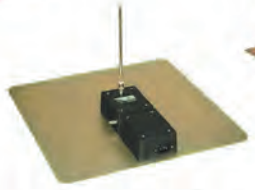
BiLogicals
25 MHz - 7 GHz
8 Models

Loops
20 Hz - 30 MHz
7 Models



Standard Gain Horns
1 GHz - 40 GHz
9 Models

Tripods and Accessories



Monopoles
100 Hz - 60 MHz
5 Models

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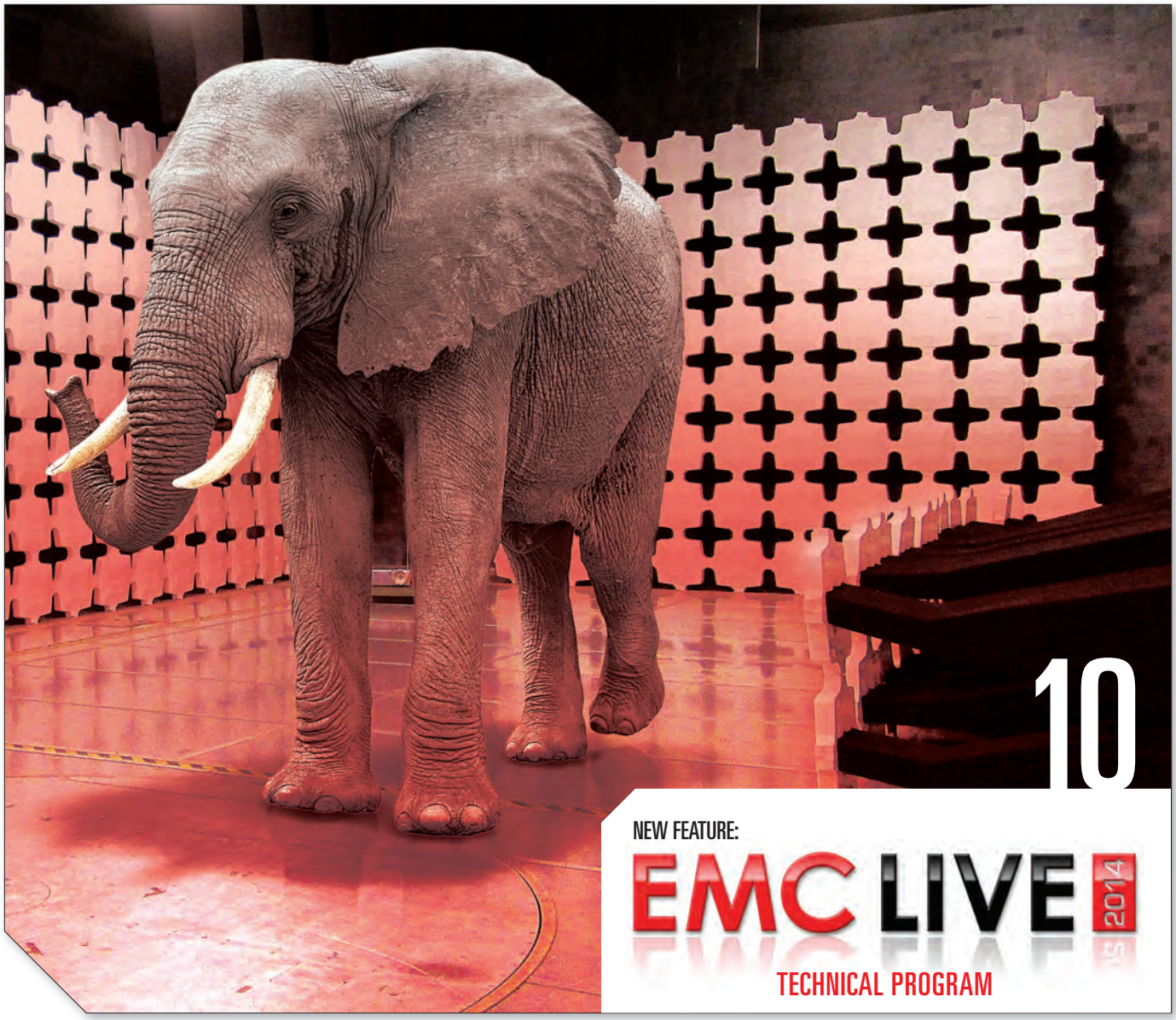
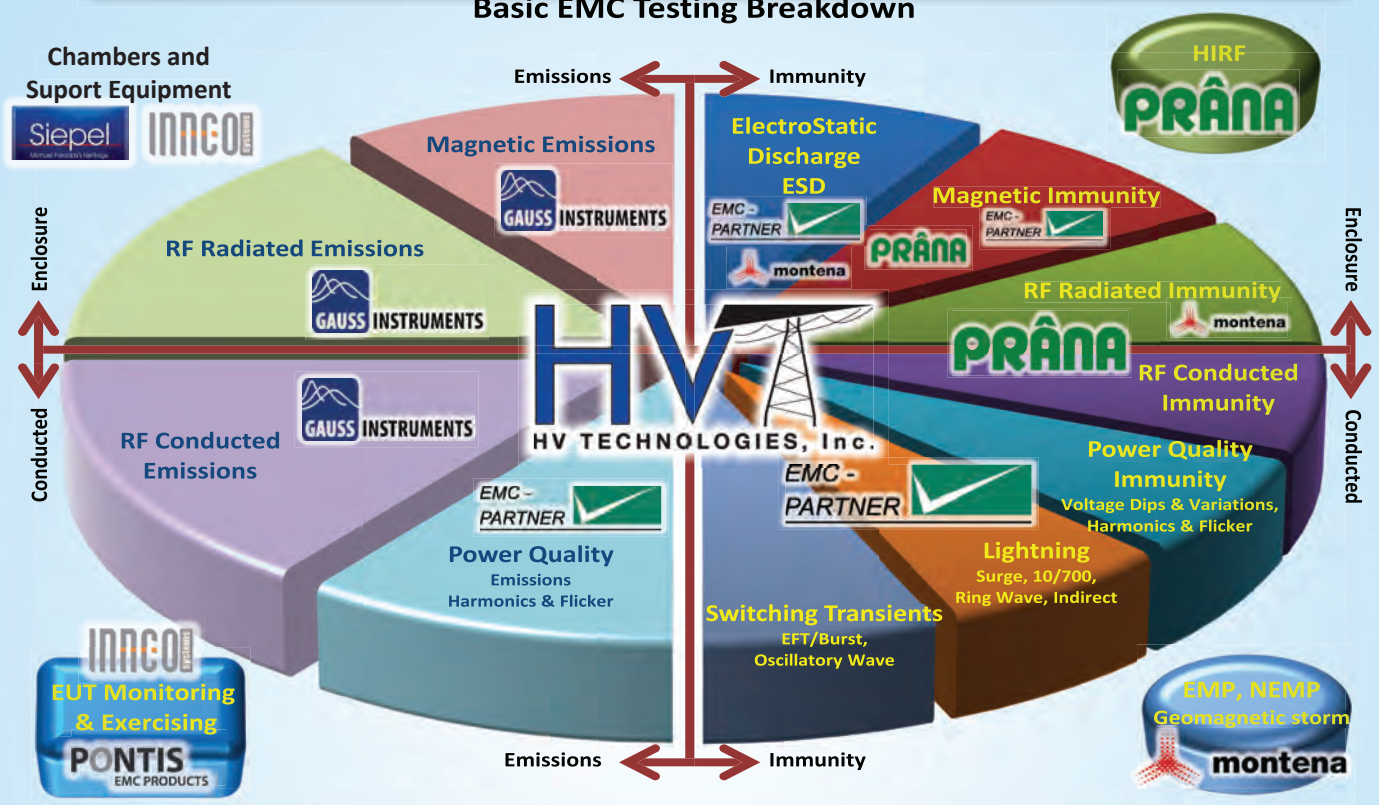


Have Some EMC Pie

ONE SOURCE FOR THE HIGHEST QUALITY

Basic EMC Testing Breakdown



Transient and Impulse Generators
ESD, EFT, Surge, 10/700, Ring Wave, DOW, Common Mode, Harmonics and Flicker, DO-160
Indirect lighting, MIL-STD: CS106, CS115, CS116; Requirements up to 144kV, 100kA

Power Amplifiers
Solid State, Class A, 100% Mismatch tolerance into any VSWR
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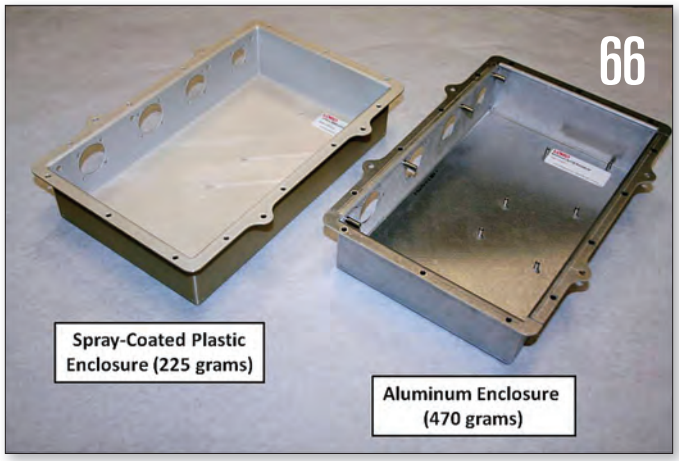
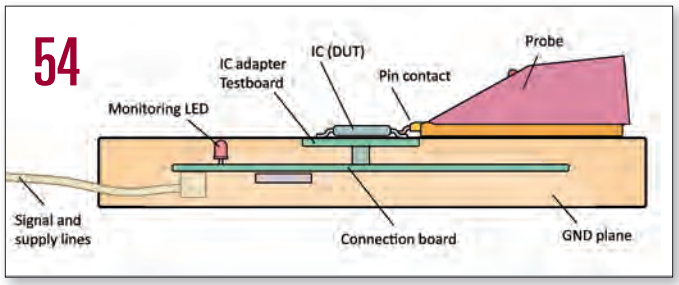
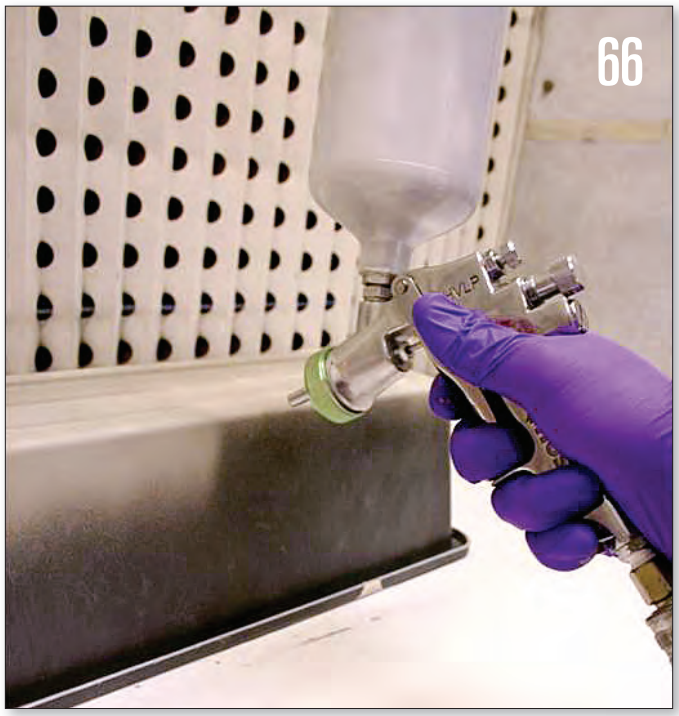
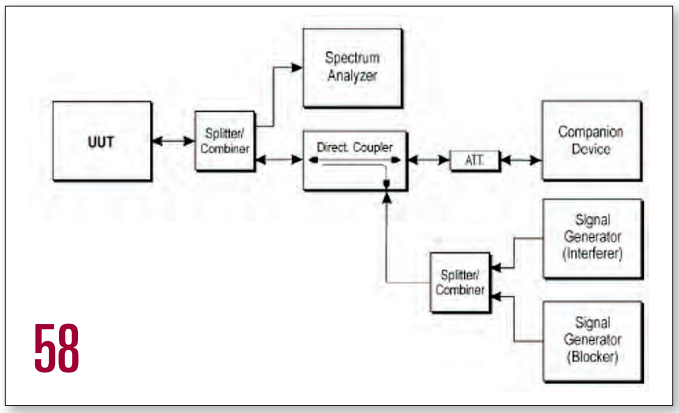


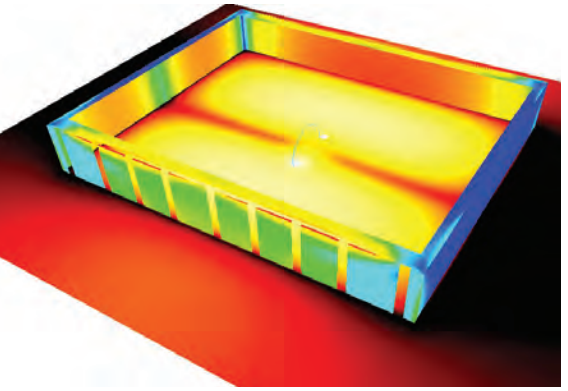






Make the Connection

Find the simple way through complex EM systems with CST STUDIO SUITE



Emissions from a server housing

Components don't exist in electromagnetic isolation. They influence their neighbors' performance. They are affected by the enclosure or structure around them. They are susceptible to outside influences. With System Assembly and Modeling, CST STUDIO SUITE helps optimize component and system performance.

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Observations in EMC Education

WHILE ATTENDING THE RECENT IEEE International Symposium on EMC held in Raleigh, North Carolina this August, several observations converged that struck me regarding educating engineers on EMC theory and product design.

• During the EMC Basics Workshop, presenter and EMC consultant, Lee Hill, asked the audience how many were first time attendees to the symposium. Nearly one third of the hands went up. That is a significant change from past years. I also made note of the higher than average attendance at the symposium this year.

• During Henry Ott's keynote presentation, he observed that many companies no longer have dedicated EMC compliance engineers and that in his consulting practice, product designers seemed to make the same simple design errors, time and again. This reflects my own consulting experience.

• The sales of Patrick André's and my new book, EMI Troubleshooting Cookbook for Product Designers, had unprecedented sales, even though the focus of the book was not directed towards EMC engineers, but rather product designers.

• In interviewing Dr. Todd Hubing, Michelin chair at Clemson University's Automotive Engineering Laboratory, he mentioned there were only a couple universities that had comprehensive EMC engineering programs – Clemson University and Missouri University of Science & Technology, while a small handful offered, at best, just a semester, or so, of EMC-related instruction.

Despite the fact all electronic products must be evaluated and tested for EMI compliance, many companies continue cutting back on staffing for product compliance. There appears to be a growing thirst among product designers (and even EMC engineers) for information on achieving product compliance without having to go through the "design-fail-redesign" cycle.

Events like the IEEE Symposium on EMC and the embedded "Global University", taught throughout the week by top international experts, is a major help for designers, but not enough engineers are aware of this opportunity. There are similar symposia worldwide, but I suspect the issue of a lack of training exists there, as well.

There are many good books on EMC theory, but only a very small handful oriented towards product designers. I believe it would be very difficult for product designers to pick out the specific design requirements for EMI compliance directly from a theoretical point of view. There are also several consultants that teach regular EMI design seminars, and while most of these courses fill to capacity, there's still a huge population of product designers whose first experience with EMC design is by failing at the test facility. Frankly, I'm at a loss as to how to educate a wider audience of designers. (*Editor's Note: One way we at Interference Technology are approaching this problem is by hosting our brand new, free online EMC Live event Oct. 14-16, 2014. Ken will present a live webinar on troubleshooting EMI problems during the event on Tuesday, Oct. 14 at 11 a.m. EST.)* That's one reason Patrick André and I decided to focus our troubleshooting book on the product designers.

Here's a good example from my own personal experience. I had decided to retire from my career as an EMC engineer in 2008, as I would have reached age 55 and been with the company for 20 years, allowing a partial retirement package. I approached my manager in 2006 requesting permission to hire my replacement, which he agreed was the right thing to do. After requesting résumés, I ended up telephone interviewing a dozen likely candidates and inviting three in for personal interviews.

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SUBSCRIPTIONS

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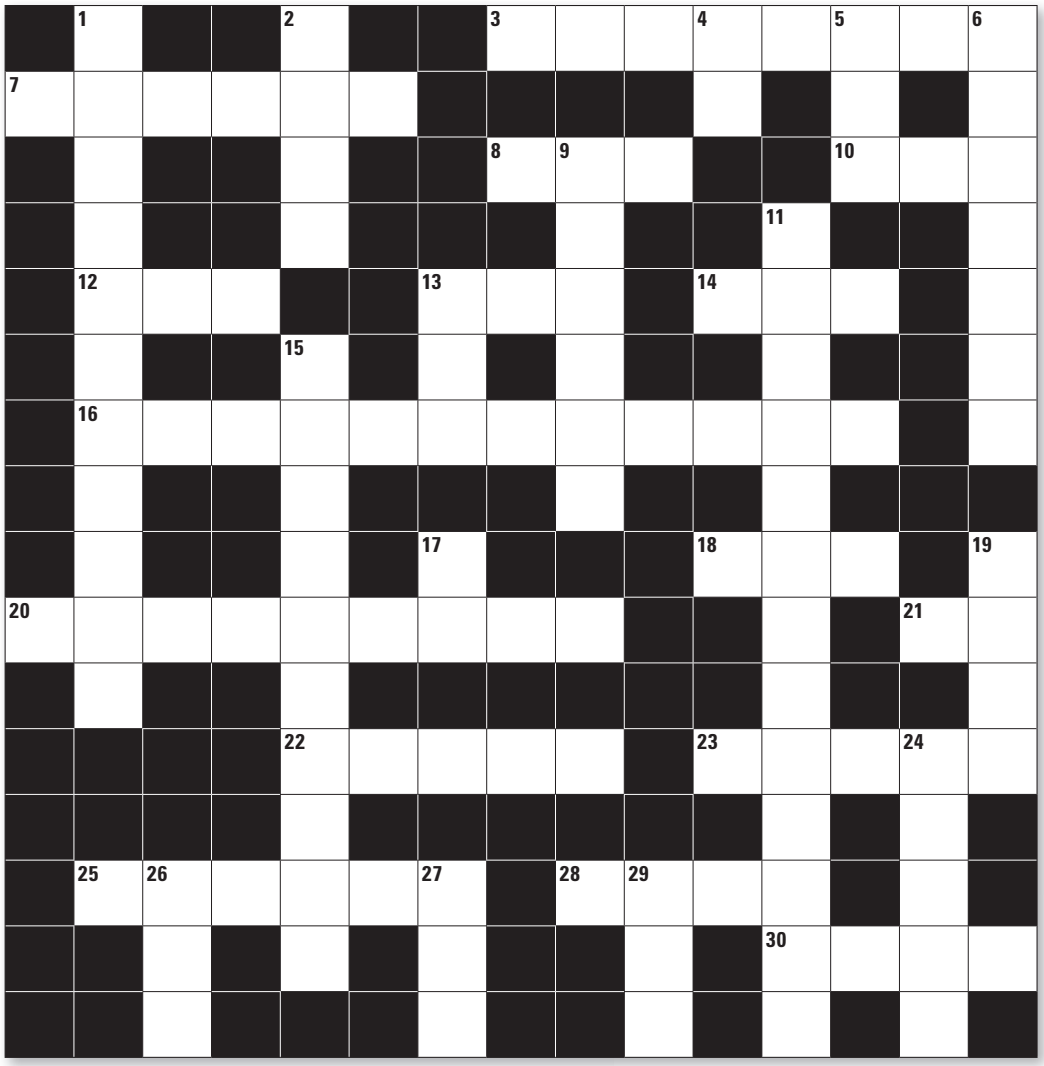

ACROSS

3) and 6) down. If the walls have ears in this judge's room, don't expect a reply
7) and 8) across. EHT can cause this to light up the dark
8) See 7) across
10) A heck of a lot of power, apparently
12) The theme of this crossword
13) Germany's own version of 12) across
14) A few billion of these involved in 7) across
16) With 15 down the bible of EMC since 1970
18) Abbreviated unit of measurement for a French natural philosopher
20) This antenna sounds like it has plane section curves with a focus
21) 1 million Coulombs per second
22) and 23) across. Samuel Plimsoll was way ahead of the game on these constraints
23) See 22) across
25) With 28 across, checking the horizon for the tallest emitter?
28) See 25 across
30) Military purchasers will buy these items if they suit, but expect them to be in the stock room

DOWN

1) Sounds like this piece of lumber only turns up now and then
2) When measuring, dBms. Watts, Amps, and Volts are all one of these
4) This is the mark for Europe
5) German scientist George involved in the resistance?
6) See 3) across
9) Electric guitar control used in compliance testing?
11) This doesn't look good in the test report
13) Energy per unit charge produced by a dynamo
15) See 16 across
17) Never direct and undecided on polarity
19) A horse should never go hungry in this field set up
24) Times are a changing to disseminate
27) and 29) down. This container contains fields, not food
29) See 27 down

By Tom Mullineaux

ANSWERS ON PAGE 70

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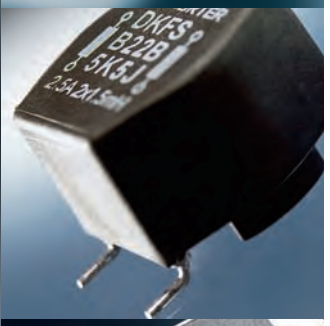

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EMC LIVE 2014

EMC LIVE is a brand new, free, three-day online event hosted by Interference Technology. This live event features practical EMC-related information and topics, including roundtables, webinars and videos, and there's no cost to attend!

KEYNOTE SPEECH:

Keynote: Saying Goodbye to Wires, and Hello to a More Efficient Approach to Powering Up

DATE: TUESDAY, OCTOBER 14 **TIME:** 10:00 A.M. – 10:30 A.M. (EST)

OVERVIEW: With trillions of dollars having been invested in electricity, it's no secret that it's a key mechanism for carrying out most of our operations and day-to-day activities. However, wires and batteries (the traditional tools for enabling electricity transfer) are cumbersome, and as the number of devices continues to increase, managing wires and identifying outlets will only become more difficult. Kaynam Hedayat of WiTricity will explain how wireless electricity addresses these challenges by providing a seamless, easy way to charge. He will speak of how the founders of WiTricity explored a system of two electromagnetic resonators coupled through their magnetic fields. The team was able to identify the strongly coupled regime in this system and showed that strong coupling could be achieved over distances that greatly exceeded the size of the resonant objects themselves – proving that in this strongly coupled regime, efficient wireless power transfer could be enabled. Specifically, Hedayat will offer:

- **An in-depth explanation of resonant energy transfer**
- **An overview of how wireless charging can be applied across vertical markets including consumer electronics, automotive, healthcare, and defense**
- **Insight into when we can expect to live wirelessly – and what needs to happen to realize that future**

ABOUT KAYNAM HEDAYAT

Kaynam Hedayat is the vice president of product management and marketing at WiTricity where he is responsible for defining and driving the marketing, product strategy, and direction of the company for the entire WiTricity product line.

Hedayat joined the company in February of 2013 from EXFO where he served as CTO and Senior Director of Product Management and Marketing of the Service Assurance Business Unit where he was responsible for defining and driving the strategic and technology direction of the firm. Prior to EXFO, he was CTO and VP of product management at Brix Networks Corporation, held consulting and engineering positions of increasing responsibility at PictureTel, Xerox Imaging Systems, Stonehand, Inc., and Digital Equipment Corporation.

A 20+ year industry veteran, Hedayat is the lead author and co-author of several standards and is co-holder of several patents. Additionally, Hedayat is co-author of the book, "Multimedia Systems, Standards, and Networks." Hedayat has a Masters of Engineering degree from Cornell University, and a Bachelor of Science degree in Electrical and Computer Engineering from Northeastern University.

ABOUT WITRICITY

WiTricity Corporation was founded in 2007 to commercialize a new technology for wireless electricity invented and patented two years earlier by a team of physicists from MIT, led by Professor Marin Soljai. Professor Soljai and team proved the magnetic fields of two properly designed devices with closely matched resonant frequencies can couple into a single continuous magnetic field, enabling the transfer of power from one device to the other at high efficiency and over a distance range that is useful for real-world applications.

Dubbed "highly resonant wireless power transfer" – or "WiTricity" for short – the team demonstrated WiTricity technology by illuminating a 60 watt light bulb from a power source over 2 meters away. More important than simply proving they could illuminate a light bulb, the experiment validated their theoretical models of how electric power is wirelessly transferred as a function of the geometry, distance, and electrical properties of the devices used.

ROUNDTABLES:

Roundtable: Analog RFI Immunity Challenges

DATE: TUESDAY, OCTOBER 14 **TIME:** 1:30 P.M. – 2:00 P.M. (EST)

OVERVIEW: RF interference with analog op amps has become a significant problem with the advent of the ubiquitous mobile phone and other RF services into the GHz range. Even op amps with a gain-bandwidth product of only one MHz can respond to RF signals at 2 GHz and above. Why this happens, even with voice frequency op amps, and some approaches to fixing the problem will be discussed.

Analog designers, IC designers, EMC engineers and technicians will find the presentation useful. You can expect to be able to troubleshoot and fix RF interference to op amp and similar circuits quickly and easily.

MODERATOR: DOUG SMITH

Doug Smith is an EMC Engineer and owner of DC Smith Consultants. He runs a High Frequency Measurements Web page with monthly Technical Tidbit articles and a HF News email newsletter. He specializes in design and troubleshooting tips and techniques and has published over 200 technical and white papers.

Roundtable: HEMP and IEMI Threats

DATE: WEDNESDAY, OCTOBER 15 **TIME:** 1:30 P.M. – 2:00 P.M. (EST)

OVERVIEW: This webinar will discuss HEMP and IEMI threats today. The following questions will be asked:

1a) What are the characteristics (and differences) between the HEMP and IEMI threats?

1b) How do these electromagnetic transients relate to more commonly known EM transients such as ESD, lightning and radar?

2) What parts of the critical infrastructures do you consider the most critical for HEMP and IEMI protection?

3) How do you design protection from HEMP and IEMI?

4) What is the role of existing lightning protection for protection from HEMP and IEMI?

5) What is the role of standards in your approach to HEMP and IEMI hardening?

6) What costs do you think are reasonable in protecting facilities from HEMP and/or IEMI?

MODERATOR: BILL RADASKY

Dr. William A. Radasky received his Ph.D. in Electrical Engineering from the University of California at Santa Barbara in 1981. He has worked on high power electromagnetic applications for more than 44 years and has published more than 400 reports, papers and articles dealing with electromagnetic environments, effects and protection during his career. In recent years, he has worked extensively in performing assessments for critical infrastructures to the threats of HEMP, IEMI and severe geomagnetic storms.

Roundtable: Elephants in the Test Room

DATE: THURSDAY, OCTOBER 16 **TIME:** 1:30 P.M. – 2:00 P.M. (EST)

OVERVIEW: Tom Mullineaux will discuss test room controversies, expanding on his popular 'Elephants in the Test Room' blog series at emc-zone.com. The following will be some of his discussions. For more detailed discussions, visit www.emclive2014.com.

ELEPHANT DISCUSSION #1 – Poor EMC Measurement Consistency
ELEPHANT DISCUSSION #2 – Underperforming EMC Chambers
ELEPHANT DISCUSSION #3 – Automotive Tests that Put the Car Audio System Performance First

MODERATOR: TOM MULLINEAUX

An author and RF Engineer, Tom Mullineaux has been in the EMC industry for 20 years, both as a supplier to the industry, and as a hands on program manager, achieving EMC compliance for new products.

Mullineaux received his degree in electrical and electronic engineering from Portsmouth University, England, and is a prolific writer of EMC related articles, with all articles having a strong slant towards the engineering basics behind the tests. He has given many IEEE society presentations, most looking at the physics behind today's commercial, automotive and MIL-STD tests.

WEBINARS

TUESDAY, OCT. 14

ROHDE & SCHWARZ PRESENTS:

"Troubleshooting Today's EMI Problems" Testing Tips for EMI Debug, Pre-Compliance and Compliance Measurements

DATE: TUESDAY, OCTOBER 14 **TIME:** 11:00 A.M. – 11:45 A.M. (EST)

OVERVIEW: Electromagnetic compatibility issues often surface at the last moment in the design cycle, potentially delaying product introductions. Very often, simple pre-compliance measurements and techniques can identify issues early when the cost of implementation is substantially lower and design improvements may be made with less impact on schedules. This seminar covers EMC measurements and troubleshooting techniques at different stages of the design cycle. Practical tools and techniques that can be used for pre-compliance measurements as well as troubleshooting EMC problems in a more formal setting.

WHO SHOULD ATTEND: All design engineers and technicians involved in the development of electronic devices and systems of any kind, where compliance to EMI standards is required. Analog, RF, Mechanical and Digital hardware design engineers will benefit from this course.

SPEAKER: KEN WYATT

Kenneth Wyatt, Sr. EMC Engr, Wyatt Technical Services, holds degrees in biology and electronic engineering and has worked as a product development engineer for 10 years at various aerospace firms on projects ranging from DC-DC power converters to RF and microwave systems for shipboard and space systems. For over 20 years, he has worked as an EMC engineer and has been an independent EMC consultant since 2008.

KEYSIGHT TECHNOLOGIES PRESENTS:

"EMC: Back to Basics"

DATE: TUESDAY, OCTOBER 14 **TIME:** 12:15 P.M. – 1:00 P.M (EST)

OVERVIEW: EMC testing is mandatory in order to sell locally and globally. It is important for everyone involved in any aspect of product design to understand the basics of EMC. We will begin with a brief overview of the EMC market, standards, and test equipment. We will also take a look at the theory of operation of a modern EMI receiver and other EMC equipment. Finally, we will look at key receiver specifications and then walk through the steps to making an emissions measurement.

WHO SHOULD ATTEND: Engineers, technicians and students new to EMC measurements or those needing a refresher on the basics.

SPEAKER: MATTHEW CARTER

Matthew Carter is a product support engineer working in Keysight Technologies' Microwave and Communication Division. He received a B.S. in Electrical Engineering from Portland State University. He is currently focused on electromagnetic compatibility (EMC) and vector signal analysis.

EMSCAN PRESENTS:

"EMC/EMI Testing in Less Than One Second Using Very-Near-Field Techniques"

DATE: TUESDAY, OCTOBER 14 **TIME:** 2:30 P.M. – 3:15 P.M. (EST)

OVERVIEW: Very-near-field measurements of radiated emissions are fast and easy to make and avoid the delays and set-up needed for far-field measurements in a chamber.

A distributed array of sensors for measuring the very-near-field can sit on your desktop and will allow EM and RF testing in less than one second.

Using this technique a designer can get an "emissions map" of a PCB or product in "real-time" and identify EMI and EMC problems early in the design cycle thus saving time and cost. This technique can also visualize the source of emissions that caused systems to fail compliance test and provide the insight required to fix the problem quickly. An 8 GHz scanning limit means it can be used for very high frequency boards where EMI and signal integrity (SI) problems often converge. Advanced applications like high resolution scanning, passive intermodulation testing, multi-frequency support, self-interference detection and absorber performance can also be undertaken by this near-field technique.

SPEAKER: RUSKA PATTON

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

ASTRODYNE PRESENTS:

"Critical Design Issues in Protecting Against EMP and HEMP"

DATE: TUESDAY, OCTOBER 14 **TIME:** 3:45 P.M. – 4:30 P.M. (EST)

OVERVIEW: An overview of Electromagnetic Pulse (EMP) and High Altitude Electromagnetic Pulse (HEMP) threats and how a properly designed EMP/HEMP filter can protect mission critical equipment and facilities from the very fast transient overvoltage's. Issues critical to the design and testing of these filters will be examined.

WHO SHOULD ATTEND: All design and facility engineers interesting in protecting military, government and commercial infrastructure from these threats.

SPEAKER: ANAND AWASTHI

Anand Awasthi is the product manager at Astrodyne Corporation for EMI Filter products. He holds a bachelor's degree in electrical engineering and a master's degree in sales and marketing management. Anand joined LCR Electronics (now part of Astrodyne Corporation) as a sales engineer in 2002. Prior to his current position, he worked in India as area sales manager with Tyco Electronics, Motherson Automotive Group, and Finolex Cables. He has 12 years of experience in EMI filters and a combined 21 years of experience in technical sales and marketing in various capacities.

WEDNESDAY, OCT. 15

CST PRESENTS:

"Simulation of PCB Emissions"

DATE: WEDNESDAY, OCTOBER 15 **TIME:** 11:00 A.M. – 11:45 A.M. (EST)

OVERVIEW: Simulation can answer fundamental design questions early in the design process long before a prototype is available, and helps identify possible and unforeseen coupling paths that are inaccessible by measurements. This webinar will present simulation workflows tailored for EMC, coupling 3D and circuit methods. The comparability of simulation and measurement will also be discussed, using results from a realistic PCB.

WHO SHOULD ATTEND: All design engineers interested in simulation methods.

SPEAKER: ANDREAS BARCHANSKI

Andreas Barchanski is the EMC Market Development Manager at CST. He holds an M.Sc. degree in physics and a Ph.D. in numerical electromagnetics from the Technical University Darmstadt. He joined CST as an application engineer in 2007. Besides EMC, his main interest lies in the simulation of various electronic systems ranging from high speed digital to power electronics.

ROHDE & SCHWARZ PRESENTS:

"MIL-STD 461: Current Status & Future Considerations"

DATE: WEDNESDAY, OCTOBER 15 **TIME:** 12:15 P.M. – 1:00 P.M. (EST)

OVERVIEW: MIL-STD-461 is the United States Military Standard that describes how to test equipment for electromagnetic compatibility, which is often used by civilian organizations as well. MIL-STD-461F is presently in the revision process with a draft MIL-STD-461G to be released shortly. Major changes will be discussed in this presentation, not only in terms of what the changes are but also the reasons and rationale behind them.

WHO SHOULD ATTEND: Test & Design engineers, Test lab engineers and technicians, and those involved with EMC testing.

SPEAKER: KEN JAVOR

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

TUV RHEINLAND PRESENTS:

"Compliance Testing for Wireless Devices"

DATE: WEDNESDAY, OCTOBER 15 **TIME:** 2:30 P.M. – 3:15 P.M (EST)

OVERVIEW: This webinar will discuss both radio and EMC testing requirements for wireless devices, hand-held computers, wearable devices, medical devices, local-area networks, personal-area networks and radio frequency/barcode reading devices.

YOU WILL LEARN: EMC Aspects for Implantable Devices; Testing for Wireless Medical Devices; FDA Perspective on EMC of Medical Devices; Risk Mitigation and Management; Wireless Performance Testing Methods.

SPEAKER: RANDY MASLINE

Masline is the senior EMC/Wireless Engineer at TUV Rheinland. He started his career in the US Marine Corps as a radio communication specialist in 1981 and acquired his degree after being honorably discharged in 1984. He then went back to military communications at Harris RF in Rochester NY, working in the test engineering department performing Mil-STD testing for shipboard radios. He joined Eastman Kodak Company in the design engineering department and soon joined a 4-man team starting a "Design for EMC" lab. There, he spent the next 10 years assisting design engineers with proper EMC design techniques. In 2006, he joined TUV Rheinland, and is responsible for testing devices to meet EMC compliance for FCC, Industry Canada, European (CE) standards. He is an ANSI certified TCB/FCB Reviewer and Certifier for multiple scopes of intentional radiators.

ETS LINDGREN PRESENTS:

"HEMP/ IEMI Threats: Specifics on How to Protect Critical Infrastructure Systems with Specialized Shielding"

DATE: WEDNESDAY, OCTOBER 15 **TIME:** 3:45 P.M. – 4:30 P.M. (EST)

OVERVIEW: This webinar will focus on how high altitude electromagnetic pulse (HEMP) and intentional electromagnetic interference (IEMI) pose a serious threat to the operation of critical infrastructure systems – utilities, transportation, communication, etc. – which are dependent on susceptible electronic circuitry. Damage can be mitigated or eliminated with specialized shielding and point-of-entry systems incorporated in facility and equipment design. Specific examples will be provided including a recent EMP shield installation for the control center for a large public utility company. The challenge to accommodate numerous entry points for MEP and HVAC requirements while maintaining shield integrity and pulse protection will be discussed.

SPEAKER: MICHAEL CARUSO

Caruso is director of government & specialty business development for ETS-Lindgren. He is a recognized leader in the RF Shielded Enclosure/Anechoic Chamber Industry with 30-years' experience in account management, project management, technical applications, business development, marketing and sales planning. Caruso chairs ETS-Lindgren's HEMP/EMP Product Team and has been involved in a sales, design, engineering and project management capacity for hundreds of projects involving high performance RF Shielding, both large and small over the years totaling over $75MM. Caruso also led the EMC Power Electronics testing program for the Boeing 787-8 while at Ingenium Testing Laboratory.

THURSDAY, OCT. 16

HV TECH PRESENTS:

"Power and I/O Line Testing Standards Updates for MIL/Aero, CE, Energy Meter Industries"

DATE: THURSDAY, OCTOBER 16 **TIME:** 11:00 A.M. – 11:45 A.M. (EST)

OVERVIEW: This webinar covers some of the recent updates to current standards, new actions and some of what is to come with regards to Power and IO line testing. Understand and know the effects from these changes on your equipment (EUT/DUT) and what effect it will have on existing lab test equipment.

- Updated: IEC 61000-4-4 Ed3 for Electrical Fast Transient (EFT) or Burst was published in 2013 and is now starting to be rolled into requirements - what effect does this have on the test and test equipment?
- Updated: IEC 61000-4-5 Ed3 was published this year and required changes to how the surge is verified through the CDN.
- NEW!: IEC 61000-4-19 is a brand new standard for differential mode coupling find out why this test is needed for want products and how to perform testing.
- Future MIL-STD-461G is being worked on; find out about the proposed new tests: CS117 & RS106 for Indirect lighting and ESD testing.

WHO SHOULD ATTEND: All CE EMC test personnel: managers, technicians and test engineers, manufacturer personnel responsible for selecting test labs, energy meter product quality/EMC test personnel; and MIL and Avionics EMC personnel. Everyone involved with EMC testing should be aware of these changes.

SPEAKER: JASON SMITH

Jason Smith graduated with a B.S. from the University of Delaware in 1997 majoring in Engineering Technology. He has over 17 years' experience in the EMC industry. First testing and managing an independent EMC test lab later became an Applications Engineering Manager for a prominent EMC and RF test equipment manufacture. He has been a member of the USNC (US National Committee) to SC77B and SC77C, a participating member of WG10 (IEC 61000-4-3, -6) and the SAE AE2 Lightning committee.

Smith joined HV Technologies Inc. in January 2012; his current position is the EMC sales and marketing manager.

EMC LIVE PRESENTS:

"Latest Developments in EMI Shielding Technology*"

DATE: THURSDAY, OCTOBER 16 TIME: 12:15 P.M. - 1:00 P.M. (EST)

OVERVIEW: This webinar discusses what's new in EMI shielding technology. Excellent shielding techniques are needed as electromagnetic interference is an often-occurring disruption in the communication of an electrical device caused by foreign electromagnetic waves. This webinar will use examples to show how a good shielding technique can improve a product.

WHO SHOULD ATTEND: All electronic, mechanical, and design engineers who are looking to improve their practical knowledge in the field of electromagnetic interference and compatibility.

* Subject to change

SPEAKER: TBD

Speaker information to come soon. Check www.emclive2014.com for updates. EMC Live is a brand new, online three day event hosted by Interference Technology. Featuring practical information and topics, this event will include roundtables, webinars and videos on everything EMC-related, and there's no cost to attend.

ROHDE & SCHWARZ PRESENTS:

"How to Significantly Reduce EMI Test Time" Time Domain Scans vs. Stepped Frequency Scans in EMI Test Receivers

DATE: THURSDAY, OCTOBER 16 TIME: 2:30 P.M. – 3:15 P.M. (EST)

OVERVIEW: Throughout product development, radiated emissions are repeatedly measured to ensure compliance to EMI standards. The use of Time Domain Scan greatly reduces measurement time without compromising accuracy, and thus can significantly save development costs. Get answers to how Time Domain Scan works and it's advantages. We will compare the speed and measurement accuracy of a conventional Frequency Stepped Scan versus an advanced FFT-based Time Domain Scan, and give tips on making optimal use of this advanced methodology.

WHO SHOULD ATTEND: All design engineers and technicians involved in the development of electronic devices and systems of any kind, where compliance to EMI standards is required.

SPEAKER: BILL WANGARD

Bill Wangard is the EMI Receiver and Radio monitoring Product Manager at Rohde & Schwarz. He has 20+ years of RF and Receiver experience at Motorola and Rohde & Schwarz. Wangard has authored numerous patents at Motorola.

ACS PRESENTS:

"2.4 GHz Wireless Devices to Europe – Big Changes to EN 300 328 Next Year"

DATE: THURSDAY, OCTOBER 16 TIME: 3:45 P.M. – 4:30 P.M. (EST)

OVERVIEW: This webinar will be an informative discussion between Advanced Compliance Solutions, Inc. VP of Technology, Sam Wismer, and Director of Wireless Certifications, Kirby Munroe.
The session will focus on the drastically changing requirements for wireless devices in Europe that are operating in the 2.4GHz frequency band. Devices including Wi-Fi, Zigbee, Bluetooth, etc. are required to meet EN 300 328, a harmonized product standard under the R&TTE Directive which will experience significant changes in its testing requirements as it transitions from v1.7.1 to v1.8.1 at the end of this year. Starting with an overview of the standard and then detailing the new technical requirements for the new edition, the webinar will be valuable to those interested in the implications the changes will have on manufacturers and test labs alike.

WHO SHOULD ATTEND: Wireless design engineers, compliance test engineers and product regulatory compliance leaders that work with 2.4 GHz devices such as Wi-Fi, Bluetooth and Zigbee, and any support industries.

SPEAKER: SAM WISMER

Wismer is the vice president of Technology at ACS. With 12 years of industry experience before joining ACS in 2001 as its first employee, he plays an integral role in ACS's mission to remove barriers to compliance and ensure customers meet their objectives. In 1994, while earning his degree in Electronics Engineering at DeVry University, he started working for a small test lab where he gained an in-depth introduction to the EMC and compliance testing industry. He joined LXE, which designs wireless computers and data collection solutions. Wismer's responsibilities grew from testing for EMC and wireless compliance to securing necessary certifications for products in countries around the world. As Senior Regulatory Engineer, Wismer led a staff of professionals dedicated to expediting the approval process and reducing the time to market.

The Need to Develop a Standardized Program for the Education and Training of Electromagnetic Compatibility

ANTHONY A DIBIASE
EMC/Product Safety Consultant
Spec-Hardened Systems

Engineers at the university level, nationally, is impacting the United State's competitiveness in the global economy. EMC Engineering studies at the university undergraduate and graduate level are required in order to aid product manufacturers in producing their products at lower cost and also allowing them to meet their time-to-market objectives. The issuing of new regulatory directive and standards by an increasing number of counties requires well trained EMC Engineers that can efficiently and cost effectively respond to all these new regulatory compliance requirements.

THERE IS AN EVOLUTION in the study of electromagnetic field effects on electrical and electronic products and systems. It is progressing from an engineering art to an engineering science. This is in part due to the fact that the electromagnetic field source environment is increasing in complexity along with a greater intensity. The complexity and sophistication of newer technology products has added to an increased need for more consideration of electromagnetic compatibility (EMC) factors. These factors have increased the requirement for technical universities to implement programs in EMC Engineering degree studies into their engineering curriculum. EMC Engineers are needed to work in electrical and electronic design formulations to insure that they meet their functional and regulatory compliance requirements

INTRODUCTION

The lack of a systematic universal program for the formal education of EMC

UNIVERSITIES ELECTRICAL ENGINEERING CURRICULUMS AND THEIR RELATIONSHIP TO EMC ENGINEERING

Knowledge in the field of the laws-of-physics, including electromagnetic field theory, is required in the understanding of the principles related to EMC Engineering. The lack of an adequate EMC design development education on the university level is contributing to erosion of the United State's (US) technical and export capabilities. At the present time this field of study is not a standard requirement in the engineering programs of most universities. A comprehensive knowledge in the disciplines of electrical, mechanical, chemical, and computer science are required as a prerequisite base for performing design and certification tasks related to EMC.

The study of requirements for an EMC engineering program produces the fact that they have a very good fit with the existing electrical engineering program, since the required curriculum prerequisite courses

are already exist within the electrical engineering program. Engineers whose responsibilities include the design and development of electrical and electronic products and systems must deal with issues related to EMC for these products and systems, for they must be designed to meet their regulatory compliance requirements. These engineers must posses the education and work experience background to effectively perform this task.

PRESENTLY AVAILABLE EMC EDUCATIONAL RESOURCES

Listed below are some of the EMC educational resources that are available to EMC Engineers that can aid them in their continuing education efforts.

(1) EMC webinars presenting information on various EMC topics
(2) EMC seminars which have presentation on EMC subjects
(3) Symposiums where various EMC subjects are discussed
(4) University sponsored EMC programs which provide instructions on various EMC topics
(5) EMC experience obtained by working in EMC job related positions
(6) Individual EMC studies through reading EMC material in technical articles published in periodical magazines (i.e. ITEM)
(7) Attending universities sponsored courses in EMC studies, for example;
(a) Clemson University (Vehicle Electronics Laboratory – CVEC). The Clemson University automotive engineering program awards degrees for a curriculum that includes EMC studies
(b) The University of California at Las Angeles (UCLA) – Has a program that awards certificates in EMC studies.
(c) George Washington University Center for Professional Development – The university has presented educational seminars on EMC related subjects.
(d) University of Wisconsin at Milwaukee Collage of Engineering – Has sponsored seminars on the topic of EMC.
(e) University of Missouri College of Science and Technology at Rolla – The university has recently opened a new EMC research center in partnership with a major corporation involving an aviation research project.
(f) University of Michigan – The university is involved in cosponsoring seminars that are related to EMC automotive systems.
(g) Grand Valley State University – Provides EMC studies for EMC Engineers through their EMC Center.
(h) Oklahoma State University – Presents short courses covering EMC topics including EMC testing considerations

These EMC continuing education resources can be utilized to allow EMC Engineers to expand their knowledge base, but they do not substitute for a formal EMC education coupled with work experience.

CAREER OPPORTUNITIES FOR EMC ENGINEERS

There are many career opportunities for EMC Engineers available, some of these are listed below.

(1) Working with EMC requirements in the design and development of electrical and electronics products and systems.
(2) EMC test engineering that involves EMC testing of products and systems in their development, pre-compliance, and compliance stages.
(3) Quality Assurance and Reliability engineers that are responsible for assuring that EMC requirements of products and systems are maintained though to their end-of-life stage.
(4) Regulatory Compliance managers that are responsible for managing a EMC regulatory compliance program, and to insure that the manufacture's products meet their cost and time-to-market objectives.
(5) Sales Engineers that sale EMC test equipment are required to have basic knowledge in EMC theory and practical EMC practices.
(6) EMC consultants with advanced knowledge in specialized areas of EMC applications.
(7) Research EMC Engineers working in the field of studying on the effects of electromagetic fields on electrical and electronic products and humans.
(8) EMC Software engineers responsible for the development EMC simulation programs.

A formal EMC education at the university level is an excellent basis for becoming an effective and competent EMC engineer.

CONCLUSION

While there are various sources of EMC educational programs available to engineers, the requirement for a comprehensive standardized formal educational program at the university level is urgently needed, and will increase in the years to come. EMC engineering will continue to evolve an EMC education based on a trial-and-error approach method to an engineering science. This is due to the fact that EMC principles are derived from the basic laws of physics and their complexity. Therefore, the need for the understanding of the theoretical and the practical application of EMC principles becomes essential. It needs to become a standardized integral part of the electrical engineering curriculum.

AUTHOR BIO

Anthony A. DiBiase is the president of Spec-Hardened Systems, which is an EMC and Product Safety consulting firm. He has 25 years of experience consulting in the field of EMC, Product Safety, and Environmental/Health Safety. He was employed for a period of 30 years at the Eastman Kodak Company. His responsibilities in this company included Reliability, Quality Assurance Engineering, and radiation and nuclear effects hardening of spacecraft system designs. He also was employed working in the field of radiation and nuclear effects hardening at the General Electric Company and the Bell Aerospace Corporation. He is a graduate of the Rochester Institute of Technology and holds a BSEE degree. He has presented many seminars and training programs on the topics of EMC and product safety.

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EMC TEST LAB DIRECTORY

WHEREVER YOU ARE IN THE WORLD you now have access to local testing facilities. We have created an easy-to-use directory of global labs and their services grouped alphabetically by country, state and city, so that our readers can identify labs closest to them. We have strived to make this directory as accurate as possible; however, we realize that every lab or service may not be listed. If you own or work for an EMC test lab and we have missed you or omitted one of your services, please let us know. Our goal is to have the most concise, informative and up-to-date information. E-mail any additions, revisions and suggestions to bstas@item-media.net.

CITY	COMPANY NAME / WEBSITE	PHONE #	BELLCORE/TELCORDIA	CB/CAB/TCB	EMISSIONS	EMP/LIGHTNING EFFECTS	ESD	EURO CERTIFICATIONS	FCC PART 15 & 18	FCC PART 68	IMMUNITY	LIGHTNING STRIKE	MIL-STD 188/125	MIL-STD 461/462	NVLAP/A2LA APPROVED	PRODUCT SAFETY	RADHAZ TESTING	RS03 > 200 V/METER	REPAIR/CALIBRATION	RTCA DO-160	SHIELDING EFFECTIVENESS	TEMPEST
USA																						
ALABAMA																						
Huntsville	EMC Compliance	(256) 650-5261	■		•		■		■		■		■	•	■		■		■	•	■	
Huntsville	NASA Marshall Space Flight Center www.msfc.nasa.gov	(256) 544-0694	■		•	•	•		■		•	■	■	•	■		■		■	•	■	
Huntsville	Redstone Technical Test Center (Army) http://www.atec.army.mil/DTC/who_rttc_is.htm	(256) 876-3556	■		•	•	•		•	•	•	■	■	•	■		•	•	■	•	•	
Huntsville	Wyle Laboratories www.wyle.com	(256) 837-4411	■	•	•		•	•	•	•	•	■	■	•	•	•	•		■	•	•	
ARIZONA																						
Chandler	DNB Engineering, Inc. www.dnbenginc.com	(855) 936-2837	■		•	•	•		■		•		•	•	•		■	•	■	•	•	
Ft. Huachuca	EPG Blacktail Canyon Test Facility www.epg.army.mil/Facilities.aspx	(520) 533-5819	■		■		■		■		■		■	•	■		■	•	■	•	•	•
Gilbert	Orbital Sciences www.orbital.com	(480) 355-7574	■		•		■		■		•	■	■	•	■		■	•	■		•	
Phoenix	Compliance Testing, LLC, aka Flom Test Lab www.compliancetesting.com	(480) 926-3100	■	•	•		•	•	•		•	■	■		•	•	■	•	■		•	
Phoenix	Sypris Test & Measurement www.sypris.com	(602) 395-5911	■		■		■		■		■	■	■		■		■		■		■	
Scottsdale	General Dynamics C4 Systems	(480) 441-5321	■		■		■		■		■	■	■	•	•		■		■		•	•
Tempe	Lab-Tech, Inc. www.advancedtechnologieslab.com	(480) 317-0700	■		■		•		■		■	■	■		■		■		■		■	
Tempe	National Technical Systems www.nts.com	(480) 966-5517	•	•	•	•	•	•	•	•	•	•	•	•	■		■	•	■	•	•	
Tempe	TUV Rheinland of North America, Inc. www.tuv.com	(480) 966-1700	■		■		■		■		■	■	■		■	•	■		■		■	
Tucson	RMS EMI Laboratory	(520) 665-5990	■		■		■		■		■	■	•	•	■		■		■		■	

u•nique [yōō-nēk′]
adjective
being the only one of its kind; unlike anything else:

[*predic*] *(unique to) belonging or connected to (one particular person, group, place or thing)*

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CALIFORNIA																						
Agoura	Compatible Electronics, Inc. www.celectronics.com	(818) 597-0600	■	•	•		•	•	•		•			■	•		■		■	•	■	
Anaheim	EMC TEMPEST Engineering http://emctempest.com	(714) 778-1726	■		•		•					•		■			■	•	■	•	•	
Brea	CKC Laboratories, Inc. www.ckc.com	(714) 993-6112	■	•	•		•		•		•				•	•	■		■		•	
Brea	Compatible Electronics, Inc. www.celectronics.com	(714) 579-0500	•	•	•		•	•	•	•	•			■	•		■		■	•	■	
Calabasas	National Technical Systems (NTS) www.nts.com	(800) 270-2516	•	•	•	•	•	•	•	•	•	•	•	■	•	•	■	•	■	•	•	•
Carlsbad	NEMKO www.nemko.com	(760) 444-3500	•	•	•	•	•	•	•	•	•	•	•	■	•	•	■	•	■	•	•	
Carlsbad	TUV Rheinland of North America, Inc. www.tuv.com	(760) 929-1781	■		■		■	■		■		■		■	•		■		■		■	
China Lake	NAWCWD EMI Lab	(760) 939-4669	■		•	•	■	■		■		■	•	■			■		■		■	
Chino	Robinson's Enterprise www.robinsonsenterprises.com/services.html	(909) 591-3648	■		■		■	•	■	■		■	•	■			■		■		■	
Costa Mesa	Independent Testing Laboratories, Inc. www.itltesting.net	(714) 662-1011	■		•		■	•	■	•		■	•	■			■		■	•	■	
E. Rancho Dominguez	Liberty Bel EMC/EMI Services	(310) 537-4235	■	•		•	■		■		•	•		■			■	•	■	•	■	
El Dorado Hills	Sanesi Associates	(916) 496-1760	■	•	•		•	•	•		•			■			■		■		•	
El Segundo	Wyle Laboratories www.wyle.com	(310) 322-1763	■		■		■	•	■	■		■		■			■		■		■	
Escondido	RF Exposure Lab, LLC www.rfexposurelab.com	(760) 737-3131	■		■		■	■	■	■		■		•		•	■		■		■	
Fremont	CKC Laboratories, Inc. www.ckc.com	(510) 249-1170	■	•	•		•		•		•		•	•			■	•	■	•	•	
Fremont	Underwriters Laboratories, Inc. www.ul.com	(510) 771-1000	•	•	•		•	•	•	•	•			•	•		■		■		■	
Fremont	National Technical Systems (NTS) www.nts.com	(510) 578-3500	•	•	•	•	•	•	•	•	•			•	•		■		■	•	■	
Fremont	Elma Electronics, Inc. www.elma.com	(510) 656-3400	■		■		■	■		■		■		■			■		■		•	
Fremont	EMCE Engineering, Inc.	(510) 490-4307	•	•	•		•	•	•	•	•			•		•	■	•	■		■	
Fullerton	DNB Engineering, Inc. www.dnbenginc.com	(800) 282-1462	■		•	•	•	■	■	■	•	•	•	•	■		■	•	■	•	•	
Fullerton	National Technical Systems (NTS) www.nts.com	(714) 879-6110	■		•	•	•	■	■	■	•	•	•	•	■		■	•	■	•	•	
Gardena	Parker EMC Engineering	(910) 823-2345	■		•		■	•	•	■		•	•	■		•	■	•	■	•	•	
Garden Grove	Semtronics www.semtronics.com	(714) 799-9810	■		■		•	■	■	■		■		■		■	■	•	■		■	
Gilroy	Scientific Hardware Systems www.scientifichardware.com	(408) 848-8868	■		■		■	•	■	■		■		■		■	■		■		■	
Irvine	7Layers, Inc. www.7layers.com	(949) 716-6512	■		•		■	■	■	■		■		■		■	■		■		■	
Irvine	Mitsubishi Digital Electronics America www.mitsubishi-tv.com	(949) 465-6206	■		•		■	■	■	■		■		■		■	■		■		■	
Irvine	Northwest EMC www.nwemc.com	(888) 364-2378	■	•	•		•		•		•			■		■	■		■		■	

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Lake Forest	Compatible Electronics, Inc. www.celectronics.com	(949) 587-0400		•	•		•	•	•		•			•	•	•				•		
Lake Forest	Intertek www.intertek.com	(800) 976-5352		•	•	•	•	•	•		•				•	•						
Los Angeles	Field Management Services www.fms-corp.com	(323) 937-1562																			•	
Los Gatos	Pulver Laboratories, Inc. www.pulverlabs.com	(408) 399-7000			•	•	•	•	•		•	•				•					•	
Mariposa	CKC Laboratories, Inc. www.ckc.com	(209) 966-5240		•	•		•		•		•				•						•	
Menlo Park	Intertek www.intertek.com	(800) 976-5352	•	•	•	•	•	•	•		•			•	•	•						
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Milpitas	SIEMIC Testing and Certification Services www.siemic.com	(408) 526 1188		•	•	•	•	•	•	•	•	•			•	•	•	•			•	
Mountain View	Electro Magnetic Test, Inc. www.emtlabs.com	(650) 965-4000		•	•		•	•	•	•	•	•			•	•						
Mountain View	EMT Labs www.emtlabs.com	(650) 965-4000			•		•	•	•	•	•				•	•						
Mountain View	EMC Compliance Management Group www.ce-mag.com	(650) 988-0900	•	•	•		•	•	•		•			•	•	•				•	•	
Newark	National Technical Systems (NTS) www.nts.com	(510) 578-3500	•	•	•	•	•	•	•	•	•			•	•					•		
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Oakland	ITW Richmond Technology	(510) 655-1263					•															
Orange	G & M Compliance, Inc. www.gmcompliance.com	(714) 628-1020	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•
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San Diego	Lambda Electronics www.lambda.com	(619) 575-4400			•				•		•											

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San Jose	Arc Technical Resources, Inc. www.arctechnical.com	(408) 263-6486					•	•	•	•	•	•	•	•				•		•	•	
San Jose	ATLAS Compliance & Engineering Inc. www.atlasce.com	(866) 573-9742			•		•	•		•	•				•	•					•	
San Jose	Safety Engineering Laboratory www.seldirect.com	(408) 544-1890					•									•						
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Santa Clara	TÜV Rheinland of North America, Inc. www.tuv.com	(925) 249-9123		•	•		•	•	•		•				•	•	•					

CITY	COMPANY NAME / WEBSITE	PHONE #	BELLCORE/TELCORDIA	CB/CAB/TCB	EMISSIONS	EMP/LIGHTNING EFFECTS	ESD	EURO CERTIFICATIONS	FCC PART 15 & 18	FCC PART 68	IMMUNITY	LIGHTNING STRIKE	MIL-STD 188/125	MIL-STD 461/462	NVLAP/A2LA APPROVED	PRODUCT SAFETY	RADHAZ TESTING	RS03 > 200 V/METER	REPAIR/CALIBRATION	RTCA DO-160	SHIELDING EFFECTIVENESS	TEMPEST
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Sunol	ITC Engineering Services, Inc. www.itcemc.com	(925) 862-2944	■		■		■	■	■	■	■		■	■	■	■	■	•	■		■	
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A801M202	800MHz～2GHz	10W～2kW
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  - PDN Design, analysis, simulation, modeling and measurement techniques
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- Chip-level SI and PI
  - On-chip and off-chip high-speed signaling techniques;
  - 3-D IC, TSV, and Multi-Chip Modules
- Tools and methodologies
  - Jitter/Noise/Crosstalk/BER;
  - De-embedding methodologies
  - TD and FD measurement techniques
  - Embedded test
- Simulation and modeling techniques
  - High-frequency and electromagnetic simulation techniques
  - Simulation and measurement correlation
  - Advanced simulation tools/algorithms
  - Device modeling and characterization
- System co-design
  - SI/PI for chip/package/board/connector / cable co-design
  - SI/PI co-analysis
  - System-level SI/PI/EMI co-design

Theme Topic II
EMC for Emerging Technologies (TC11, SCs)

- Wireless EMC
- Radio-Frequency Interference
- Smart Grid EMC
- Nano-Materials and Silicon Photonics
- Unmanned Aircraft Systems EMC
- Power Electronics EMC

Theme Topic III
Space EMC

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- Personnel & Laboratory Accreditation
- EMC Education
- Legal Issues

EMC Measurements (TC2)
- Test Instrumentation & Facilities
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- EM Signal Environment
- Atmospheric & Man-Made Noise

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- Shielding, Gasketing & Filtering
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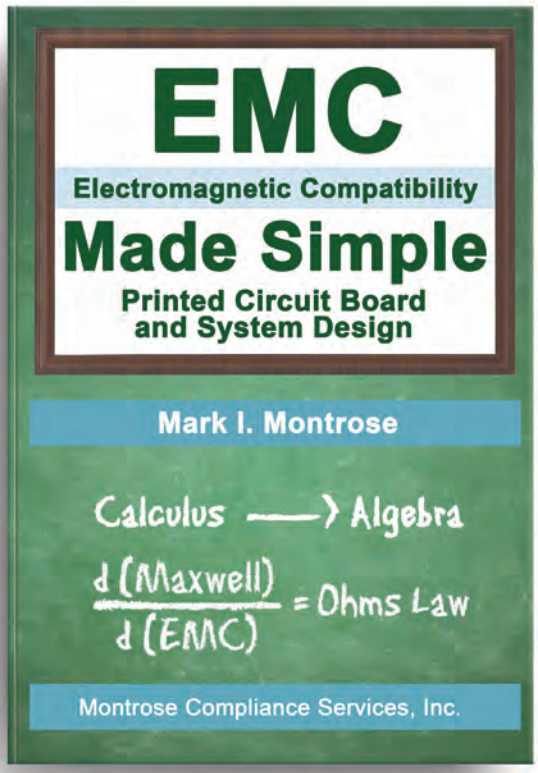

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MAINE																						
Portland	Enerdoor www.enerdoor.com	(207) 210-6511	■		•		•	•	■		•		■		■		■		■		■	
MARYLAND																						
Baltimore	MET Laboratories, Inc. www.metlabs.com	(410) 354-3300	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•
Beltsville	Antenna Research Associates www.ara-inc.com	(301) 937-8888	■		■		■		■		■		■		■		■		•		■	
Columbia	Advanced Programs Inc., Cyber Assurance Services Lab www.advprograms.com	(410) 312-5859	■		•	•	•		■		•		■	•	■		■	•		•	•	•
Columbia	DRS Advanced Programs www.advprograms.com	(410) 312-5800	■		■		■		■		■		■	•	■		■			•	■	•
Columbia	PCTest Engineering Lab www.pctestlab.com	(410) 290-6652	■	•	•	•	•	•	•	•	•		■		■	•	■				■	•
Damascus	F-Squared Laboratories, Inc. http://f2labs.com	(301) 253-4500	■		•	•	•	•	•	•	•		■	•	■		■			•	■	
Elkridge	ATEC Industries, Ltd. www.atecindustries.com	(443) 459-5080	■		■	•	•		■		•	•	•	•	■		■				•	
			■		■		■		■		■		■		■		■		■		■	
Frederick	**The American Association for Lab Accreditation; www.a2la.org**	**(301) 644-3217**	■		■		■		■		■		■	•	■		■		■		■	
Gaithersburg	Washington Laboratories, Ltd. www.wll.com	(301) 216-1500	■		•	•		•	•		•	•	•	•	•	•	•	•		•	•	
Hunt Valley	Trace Laboratories–East http://tracelabs.com	(410) 584-9099	•		■		•		■		■		■		■		■				■	•
Patuxent River	Naval Air Warfare Ctr., Aircraft Div. www.navair.navy.mil/nawcad	(301) 342-1663	■		•	•	•		■		■	•	■	•	■		•	•		•	•	
Rockville	P.J. Mondin, P.E. Consultants	(301) 460-5864	■		■		■		•		■		■	•	■		■				•	•
Rockville	Spectrum Research & Testing Laboratory, Inc.	(301) 670-2818	■		■		•	•	•	•	■		■		•	•	■				■	•
Westminster	Electrical Test Instruments, Inc. www.electricaltestinstruments.com	(410) 857-1880	■		■		■		■		■		■		■		■		•		■	•
MASSACHUSETTS																						
Billerica	Quest Engineering Solutions www.qes.com	(978) 667-7000	■		■		■		■		■		■		■		■		■		•	
Billerica	Sypris Test & Measurement www.sypris.com	(978) 663-2137	■		■		■		■		■		■		■		■		•	•	■	
Boxborough	Intertek www.intertek.com	(800) 976-5352	■	•	•	•	•	•	•	•	•		■	•	•	•	■	•		•	•	
Boxborough	National Technical Systems www.nts.com	(978) 266-1001	•	•	•	•	•	•	•	•	•	•	•	•	•		■	•		•	•	
Boxborough	TUV Rheinland of North America, Inc. www.tuv.com	(978) 266-9500	■		■		■		■		■		■		■	•	■				■	
Foxboro	N.E. Product Safety Society, Inc. www.nepss.net	(508) 543-6599	■		■		■		■		■		■		■	•	■				■	
Gloucester	Euroconsult, Inc. euroconsult-inc.com	(978) 282-8890	■		•		■	•	■		•		■		■	•	■				■	

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Lexington	Design Automation, Inc.	(781) 862-8998	■		•	•	•		•	•	•	•	■		■	•	■		■		■	
Marlboro	Compliance Management Group www.cmgcorp.net	(978) 431-1985	•		•		•	•	•		•		■		•	•	■		■		•	
Littleton	Curtis-Straus LLC, subsidiary of Bureau Veritas www.curtis-straus.com	(978) 486-8880	•	•	•		•	•	•	•	•		■	•	•	•	■		■	•	•	
Mansfield	Motorola Test Lab Services Group motorola.com/testservices/index.html	(508) 851-8484	■		■		■		•		■		■		•	•	■		■		■	
Marlboro	Compliance Management Group www.cmgcorp.net	(508) 460-1400	•		•		•	•	•		•		■		•	•	■		■		•	
Marlboro	The Compliance Management Group www.cmgcorp.net	(508) 281-5985	■	•	•		•	•	•		•		■		•	•	■		■		■	
Milford	Test Site Services, Inc. www.testsiteservices.com	(508) 962-1662	•	•	•		•	•	•	•	•	•	■	•	•	•	■	•	■	•	•	
Newton	EMC Test Design, LLC www.emctd.com	(508) 292-1833	■		■		■		■		■		■		■		■		■		■	
Peabody	TUV SUD America Inc. www.tuvamerica.com	(800) TUV-0123	•		•	•	•	•	•		•	•	■	•	•	•	■	•	■	•	•	
Pittsfield	Lightning Technologies, Inc. www.nts.com/locations/pittsfield	(413) 499-2135	■		■	•	•		■		■	•	■		•	■	■		■	•	■	
Wilmington	Thermo Fisher Scientific www.thermofisher.com	(978) 275-0800	•		■	•	•		•	•	•	•	■	•	■	■	■		•	•	■	
Parker Chomerics			■		■		■		■		■		■		■	■	■		■		■	
Woburn	Chomerics, Div. of Parker Hannifin Corp. www.chomerics.com	(781) 935-4850	■		•	•	•	•	•		•	•	•	•	•	•	•	•	■	•	•	
Woburn	NELCO www.nelcoworldwide.com	(781) 933-1940	■		■		■		■		■		■		■		■		■		•	
MICHIGAN																						
Auburn Hills	TÜV SÜD America, Inc. www.tuvamerica.com	(248) 393-6984	■		■		■	•	■		■		■		■		■		■		■	
Belleville	Willow Run Test Labs, LLC www.wrtest.com	(734) 252-9785	■		•		•		•		■		■		■		■		■		•	
Burton	Trialon Corporation www.trialon.com	(810) 341-7931	■		•		•		■		■		■		•		■		■		■	
Detroit	National Technical Systems www.nts.com	(313) 835-0044	■		■		■		■		■		■		•		■	•	■		■	
Detroit	TUV Rheinland of North America, Inc. www.tuv.com	(734) 207-9852	■		■		■		■		■		■		■	•	■		■		■	
Grand Rapids	Intertek www.intertek.com	(800) 976-5352	■		•	•	•	•	•		•	•	■		•	•	■	•	■	•	■	
Holland	TÜV SÜD America, Inc. www.tuvamerica.com	(616) 546-3902	■		■		■		■		■		■		■		■	•	■		■	
Milford	Jacobs Technology, Inc. www.jacobstechnology.com	(248) 676-1101	■		•		•	•	■		•		■	•	•		■		■		■	
Novi	Sypris Test & Measurement www.sypris.com	(248) 305-5200	■		■		■		■		■		■		■		■	•	■		■	
Novi	Underwriters Laboratories, Inc. www.ul.com	(248) 427-5300	■		•		•	•	■		•		■	•	•	•	■		■	•	•	

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Plymouth	TÜV SÜD America, Inc. www.tuvamerica.com	(734) 455-4841	•		•	•	•	•	•		•			•	•	•		•			•	
Saginaw	Delphi Steering EMC Lab www.emisoft.co.uk	(989) 797-0318			•		•				•											
Sister Lakes	AHD EMC Lab www.ahde.com	(269) 313-2433			•		•	•	•		•			•	•							•
Warren	Detroit Testing Laboratory, Inc. www.dtl-inc.com	(586) 754-9000					•	•							•							
MINNESOTA																						
Brooklyn Park	Northwest EMC, Inc. www.nwemc.com	(888) 364-2378		•	•		•		•		•				•							
Glencoe	International Certification Services, Inc. www.ics-intl.com	(320) 864-4444	•		•		•	•	•		•			•	•	•				•	•	
Maple Grove	TUV Rheinland of North America, Inc. www.tuv.com	(763) 315-5012		•			•	•	•	•					•	•						
Millville	TÜV SÜD America, Inc. www.tuvamerica.com	(651) 604-3490		•	•			•														
Minneapolis	Alpha EMC, Inc. www.alphaemc.com	(763) 561-4410				•	•	•	•			•					•	•		•	•	
Minneapolis	Environ Laboratories, LLC www.environlab.com	(800) 826-3710	•		•	•	•				•	•	•	•	•		•	•		•	•	
Minneapolis	Honeywell	(612) 951-5773																•				
New Brighton	TÜV SÜD America, Inc. www.tuvamerica.com	(651) 631-2487		•	•		•	•	•		•	•		•	•	•				•		
New Hope	Conductive Containers, Inc. corstat.com	(763) 537-2090					•	•														
Oakdale	Intertek www.intertek.com	(800) 976-5352		•	•	•	•	•	•		•				•	•						
Rochester	IBM www.ibm.com	(507) 253-6201			•		•				•				•							
St. Paul	3M www.3m.com	(651) 778-4577		•	•		•	•	•		•				•							•
Taylor Falls	TÜV SÜD America, Inc. www.tuvamerica.com	(651) 638-0297	•		•	•	•	•	•		•	•		•	•	•		•	•	•	•	•
MISSOURI																						
St. Louis	Boeing-St. Louis EMC Lab www.boeing.com	(314) 233-7798												•	•			•				•
NEBRASKA																						
Lincoln	NCEE Labs www.nceelabs.com	(402) 323-6233			•		•	•	•		•			•	•	•				•		
NEW HAMPSHIRE																						
Goffstown	**Retlif Testing Laboratories www.retlif.com**	**(603) 497-4600**		•	•	•	•	•	•	•	•	•		•	•	•	•	•		•	•	•
Hudson	Core Compliance Testing Services www.corecompliancetesting.com	(603) 889-5545			•		•		•		•	•			•							
Sando wn	Compliance Worldwide, Inc. www.cw-inc.com	(603) 887-3903			•		•		•	•	•	•			•							
NEW JERSEY																						
Annandale	NU Laboratories, Inc. www.nulabs.com	(908) 713-9300					•							•	•							•
Bridgeport	Analab, LLC www.analab1.com	(800) analab-X			•					•						•		•				

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Bridgewater	Lichtig EMC Consulting www.lichtigemc.com	(908) 541-0213	•		•		•		•		•		•		•		•		•		•	
Camden	L-3 Communication Systems-East www.l-3com.com/cs-east	(856) 338-3000																				
Clifton	NJ-MET www.njmetmtl.com	(973) 546-5393	•							•												•
Edison	Metex Corporation www.metexcorp.com	(732) 287-0800																		•		
	TESEQ Advanced Test Solutions for EMC																					
Edison	**TESEQ, Inc.** **www.teseq.com**	**(732) 417-0501**			•					•												
Fairfield	SGS U.S. Testing Co., Inc. www.sgsgroup.us.com	(800) 777-8378	•		•			•						•	•							
Farmingdale	EMC Technologists A Div. of I2R Corp. www.emctech.com	(732) 919-1100	•		•		•	•	•	•			•									
Hillsborough	Advanced Compliance Laboratory, Inc. http://ac-lab.com	(908) 927-9288			•			•	•	•				•	•							

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Murray Hill	Alcatel-Lucent Global Product Compliance Laboratory (GPCL) www.gpcl.com	(908) 582-5444	•		•		•	•	•	•	•			•	•	•					•	
Lakehurst	Naval Air Warfare Ctr., Aircraft Div. www.navair.navy.mil/nawcad	(732) 323-2085												•	•			•				
Lakewood	BAE Systems www.baesystems.com	(732) 364-0049			•	•	•			•		•	•			•	•		•			
Lincroft	**Don HEIRMAN Consultants www.donheirman.com**	**(732) 741-7723**			•				•													•
Piscataway	Telcordia Technologies, Inc. www.telcordia.com	(800) 521-2673	•	•	•		•		•		•	•		•	•							
Rutherford	SGS International Certification Services, Inc.; www.sgs.com	(800) 747-9047						•														
Sayreville	Sypris Test & Measurement www.sypris.com	(732) 721-6116																•				
Thorofare	NDI Engineering Company www.ndieng.com	(856) 848-0033																		•		
Tinton Falls	National Technical Systems (NTS) www.nts.com	(732) 936-0800	•	•	•	•		•	•	•	•	•	•	•	•	•		•		•	•	•
Wayne	Sypris Test & Measurement www.sypris.com	(973) 628-1363			•		•	•	•		•			•					•			
NEW MEXICO																						
Albuquerque	Advanced Testing Services, Inc. www.advanced-testing.com	(505) 292-2032										•				•				•		
White Sands	USA WSMR, Survivability Directorate www.wsmr.army.mil	(575) 678-6107			•	•	•			•	•		•			•	•			•		
NEW YORK																						
Bohemia	Dayton T. Brown, Inc. www.daytontbrown.com	(800) TEST-456	•		•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•
College Point	Aero Nav Laboratories, Inc. www.aeronavlabs.com	(718) 939-4422	•			•		•		•	•		•	•			•		•	•	•	•
Deer Park	MCG Surge Protection, Inc. www.mcgsurge.com	(800) 851-1508									•											
Deer Park	Universal Shielding Corp. www.universalshielding.com	(631) 667-7900																		•		
Johnson City	BAE Systems Controls, Inc. www.baesystems.com	(607) 770-3771			•	•					•		•	•			•		•			
Johnstown	Electro-Metrics Corp. www.electro-metrics.com	(518) 762-2600																•				
Liverpool	Diversified Technologies www.dttlab.com	(315) 457-0245			•		•	•	•		•			•		•					•	
Liverpool	Source1 Solutions www.source1compliance.com	(315) 730-5667			•		•	•	•		•			•		•					•	
Medford	American Environments Co. www.aeco.com	(631) 736-5883	•		•	•	•	•	•		•	•		•		•				•	•	
Medina	TREK, Inc. www.trekinc.com	(585) 798-3140					•															
Melville	Underwriters Laboratories, LLC. www.ul.com	(631) 546-4346	•	•	•		•	•	•	•	•				•	•					•	
Northport	Mohr, R.J., Assoc., Inc. www.rjm.li	(631) 754-1142				•	•	•	•	•		•		•						•	•	

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Owego	Lockheed Martin Federal Systems www.lockheedmartin.com	(607) 751-2938	■		•	•	•		•		•		■		•		■	•	■		•	•
Palmyra	Source1 Solutions www.source1compliance.com	(315) 730-5667	■		•		■	•	■		•		■	•	■	•	■		■		•	
Poughkeepsie	IBM Corp. Poughkeepsie EMC Lab www.ibm.com	(607) 752-2225	■	•	■		■		•		■		■		■		■		■		■	
Rochester	Chomerics, Div. of Parker Hannifin www.chomerics.com	(781) 939-4158	■		•	•	•	•	•	•	•	•	■		•	•	■		■		•	
Rochester	Spec-Hardened Systems	(585) 225-2857	■		■	•	•	•	•	•	■	•	■	•	■	•	■		■		•	
Webster	TUV Rheinland Of North America www.tuv.com	(315) 569-7524	■	•	•		•	•	•		•	■	■		•	•	•		■		■	
	RETLIF TESTING LABORATORIES		■		■		■		■		■		■		■		■		■		■	
Ronkonkoma	**Retlif Testing Laboratories www.retlif.com**	**(631) 737-1500**	■	•	•	•	•	•	•	•	•	•	■	•	•	•	•	•	■	•	•	
NORTH CAROLINA																						
Cary	CertifiGroup www.certifigroup.com	(800) 422-1651	■	•	■		•	■		■			■		•	•	■		■		■	

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Cary	MET Laboratories, Inc. www.metlabs.com	(919) 481-9319	•	•	•		•	•	•	•	•	•		•	•	•		•		•	•	
Concord	F-Squared Laboratories, Inc. http://f2labs.com	(704) 918-4609		•	•	•	•	•	•	•	•	•			•	•					•	
Fayetteville	Partnership for Defense Innovation R&D Lab; www.ncpdi.org	(910) 307-3000			•				•					•						•		
Greensboro	Electrical South, LP www.schneiderelectricrepair.com	(800) 950-9550																•				
Greenville	Lawrence Behr Associates (LBA) www.lbagroup.com	(252) 757-0279			•											•	•				•	
New Bern	iNARTE, Inc. www.narte.org	(252) 672-0111								•												
Raleigh	MicroCraft Corporation	(919) 872-2272			•	•	•				•	•	•		•						•	
Res. Triangle Pk.	Educated Design & Dev., Inc. (ED&D) www.productsafet.com	(919) 469-9434		•										•	•			•				•
Res. Triangle Pk.	IBM RTP EMC Test Labs www.ibm.com	(919) 543-0837			•				•		•											
Res. Triangle Pk.	Underwriters Laboratories, LLC. www.ul.com	(919) 549-0957	•	•	•		•	•	•	•	•				•	•					•	
Youngsville	TÜV Rheinland Of North America Inc. www.tuv.com	(919) 554-3668		•	•		•	•	•		•				•	•	•					
OHIO																						
Brooklyn Heights	Sypris Test & Measurement www.sypris.com	(216) 741-7040																•				
Middlefield	F-Squared Laboratories, Inc. http://f2labs.com	(877) 405-1580		•	•	•	•	•	•	•	•				•	•					•	
Chesterland	EU Compliance Services, Inc. www.eucs.com	(440) 918-1425			•		•	•	•		•					•	•					
Cleveland	CSA International www.csa-international.org	(216) 524-4990						•								•						
Cleveland	NASA GRC EMI Lab facilities.grc.nasa.gov/emi/index.html	(216) 433-2533											•								•	
Cleveland	Smith Electronics	(440) 526-4386			•		•	•	•		•											
Fairborn	Sypris Test & Measurement www.sypris.com	(937) 427-3444																•				
Mason	L-3 Cincinnati Electronics www.cinele.com	(513) 573-6100			•		•				•		•				•		•			
Mentor	EU Compliance Services, Inc. www.eucs.com	(440) 918-1425			•		•	•			•					•					•	
Springboro	Pioneer Automotive Technologies	(937) 746-6600			•		•		•		•		•	•								
OKLAHOMA																						
Tulsa	Integrated Sciences, Inc.	(918) 493-3399					•															
OREGON																						
Beaverton	Tektronix www.tek.com	(407) 551-2738	•											•						•		
Hillsboro	Cascade TEK www.cascadetek.com	(503) 648-1818	•											•						•		
Hillsboro	ElectroMagnetic Investigations, LLC	(503) 466-1160			•		•	•	•		•		•	•							•	

CITY	COMPANY NAME / WEBSITE	PHONE #	BELLCORE/TELCORDIA	CB/CAB/TCB	EMISSIONS	EMP/LIGHTNING EFFECTS	ESD	EURO CERTIFICATIONS	FCC PART 15 & 18	FCC PART 68	IMMUNITY	LIGHTNING STRIKE	MIL-STD 188/125	MIL-STD 461/462	NVLAP/A2LA APPROVED	PRODUCT SAFETY	RADHAZ TESTING	RS03 > 200 V/METER	REPAIR/CALIBRATION	RTCA DO-160	SHIELDING EFFECTIVENESS	TEMPEST
NORTHWEST EMC																						
Hillsboro	**Northwest EMC, Inc. www.nwemc.com**	**(888) 364-2378**		•	•		•		•		•				•					•	•	
Portland	TÜV SÜD America, Inc. www.tuvamerica.com	(503) 598-7580		•		•		•								•						
Tillamook	ElectroMagnetic Investigations, LLC	(503) 466-1160			•																	
PENNSYLVANIA																						
Annville	CHAR Services, Division of AMS Corporation www.amschar.com	(717) 867-2788			•	•	•				•			•								
Boalsburg	Seven Mountains Scientific, Inc. www.7ms.com	(814) 466-6559								•				•							•	
Chambersburg	Cuming Lehman Chambers http://cuminglehman.com	(717) 263-4101			•						•			•						•		
Glenside	Electro-Tech Systems, Inc. www.electrotechsystems.com	(215) 887-2196	•				•														•	
Harleysville	**Retlif Testing Laboratories www.retlif.com**	**(215) 256-4133**		•	•	•	•	•	•	•	•	•		•	•	•	•	•		•	•	

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Hatfield	Laboratory Testing Inc. www.labtesting.com	(215) 997-9080	■		■		■		■		■		■	•		■		•		■		
New Castle	Keystone Compliance LLC www.keystonecompliance.com	(724) 657-9940	•		•	•	•	•	•		•	•	•	•	•	•	•	•		•	•	
Pottstown	BEC Inc. www.bec-ccl.com	(610) 970-6880	■		•		•		•		•			•		■					•	
State College	Videon Central, Inc. www.videon-central.com	(814) 235-1111	■		•		•	•	•							■				•		
West Conshohocken	Alion Science & Technology www.alionscience.com	(610) 825-1960	■		•	•	•				•	•		•			•	•		•	•	
Willow Grove	Nelson Design Services www.nelson-design.com	(215) 784-9600	■			•	■		■		■		■			■					•	
TENNESSEE																						
Knoxville	Global Testing Labs LLC www.globaltestinglabs.com	(865) 525-0137	■		•		■		•		•		■	•		■		■		■		
Knoxville	Southern Testing Services, Inc.	(865) 966-5330	■		■		■		■		■		■	•		■		■		■		
Knoxville	AMS Corporation www.ams-corp.com	(865) 691-1756	■		•		•		■		•		■	•		■		■		■		
TEXAS																						
Austin	Austin EMC www.austinemc.com	(512) 219-6650	■		•		•		■		•		■	•		■		•		■		
Austin	BAE Systems IDS Test Services www.baesystems.com	(512) 929-2410	■		■		■		■		■	•		■		■	•	■		■		
Austin	MET Laboratories, Inc. www.metlabs.com	(512) 287-2500	•	•	•		•	•	•	•	•	•		•	•	•		•		•	•	
Austin	TUV Rheinland of North America, Inc. www.tuv.com	(512) 927-0070	■		■		■		■		■		■	■		•	■	■		■		
Cedar Park	TDK RF Solutions, Inc. www.tdkrfsolutions.com	(512) 258-9478	■		•		•	•	•	•	•		■	•		■		■		■		
Euless	Ronald G. Jones, P.E.	(817) 267-1476	■		■	•	■		■		■	•	■	■		■		■		■		
Houston	DNV Certification	(281) 721-6600	■		■		■	•	■		■		■	■		■		■		■		
Lewisville	Nemko USA www.nemko.com	(972) 436-9600	■	•	•		•	•	•	•	•		■	•	•	•	•	■		•	•	
Plano	National Technical Systems www.nts.com	(972) 509-2566	•	•	•	•	•	•	•	•	•	•	■	•	•	■	•	■		•	•	
Plano	Intertek www.intertek.com	(800) 976-5352	■		•	•	•	•	•		•		■	■	•	■		■		■		
Richardson	Sypris Test & Measurement www.sypris.com	(972) 231-4443	■		■		■		■		■		■	■		■		•		■		
Round Rock	Professional Testing (EMI), Inc. www.ptitest.com	(512) 244-3371	■		•		•		•		•	•	■	•	•	■		•	•	•		
San Antonio	Southwest Research Institute www.swri.org	(210) 684-5111	•		•	•	•	•	•	•	•	•	•	•	•	■	•	■	•	•		
UTAH																						
Coalville	DNB Engineering, Inc. www.dnbenginc.com	(435) 336-4433	•		•		•	•	•	•	•		■	■	•	■		■		■		
Ogden	Little Mountain Test Facility (LMTF)	(801) 315-2320	■		•	•	•		■		•		•	•		■	•	■	•	•		
Salt Lake City	Communication Certification Laboratory www.cclab.com	(801) 972-6146	■		•		•	•	•	•	•		■	•	•	■		■		■		
Salt Lake City	L3 Communication Systems–West www2.l-3com.com/csw/	(801) 594-2560	■		•		■	•	•		■		■	•		■		■	•	■		

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VERMONT																						
Essex Junction	Huber & Suhner www.hubersuhner.com	(802) 878-0555	■		■		■		■		•	■		■		■		■		■		
Middlebury	Green Mountain Electromagnetics, Inc. www.gmelectro.com	(802) 388-3390	■		■		■	•	•	•		■	•	■		■		■		■		
VIRGINIA																						
Dulles	Orbital Sciences Corp. www.orbital.com	(480) 355-7574	■		•		■		■		•	■	•	■		■	•	■		■		
Falls Church	Raytheon Prototype Services www.raytheon.com	(703) 849-1562	■		•		■		■		•	■	•	■		■		■		■		
Fredericksburg	E-LABS INC. www.e-labsinc.com	(540) 834-0372	■		•		■	•	■		•	■	•	■	•	■		■	•	■		
Fredericksburg	Vitatech Engineering, LLC http://vitatech.net	(540) 286-1984	•		•		■	•	•	•	•	■	•	■		■		■		■		
Herndon	Rhein Tech Laboratories, Inc. www.rheintech.com	(703) 689-0368	■		•		■	•	•	•		■	•	■	•	■		■	•	■		
McLean	American TCB	(703) 847-4700	■		•	•	■	•	•	•	•	■		■		■		■		■		
Reston	TEMPEST, Inc. (VA) www.tempest-inc.com	(703) 709-9543	■		•		■	•	•	•	•	■	•	■		■		■		■		

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Richmond	Technology International, Inc. www.techintl.com	(804) 794-4144	■	•	■		■	•	■		■		■		■	•	■		■		■	•
WASHINGTON																						
Bothell	CKC Laboratories, Inc	(425) 402-1717	■	•	■	•	■		■		■	•	■	•	■		■	•	■	•	■	
Sultan	Northwest EMC, Inc. www.nwemc.com	(888) 364-2378	■		■		■		■		■		■		■	•	■		■		■	
WISCONSIN																						
Butler	Emission Control, Ltd. www.emissioncontrol.com	(262) 790-0092	■		■		■		■		■		■		■		■		■		■	
Cedarburg	L.S. Research www.lsr.com	(262) 375-4400	■	•	■		■		■		■		■		■		■		■		■	
Genoa City	**D.L.S. Electronic Systems, Inc. www.dlsemc.com**	**(847) 537-6400**	■	•	■		■		■		■		■		■		■		■		■	
Neenah	International Compliance Laboratories www.icl-us.com	(920) 720-5555	■		■		■		■		■		■		■		■		■		■	
CANADA																						
ALBERTA																						
Airdrie	Electronics Test Centre - Airdrie www.etc-mpb.com	(403) 912-0037	■		■		■	•	■		■		■	•	■		■		■	•	■	
Calgary	EMSCAN Corporation www.emscan.com	(403) 291-0313	■		■		■		■		■		■		■		■		■		■	
Medley	Aerospace Engrg. Test Establishment (DND) www.armedforces-int.com	(780) 840-8000	■		■		■		■		■		■		■		■		■	•	■	
BRITISH COLUMBIA																						
Abbotsford	Protocol EMC www.protocol-emc.com	(604) 218-1762	■		■	•	■	•	■		■	•	■	•	■	•	■		■		■	
Kelowna	Celltech Labs, Inc. www.celltechlabs.com	(250) 765-7650	■	•	■		■	•	■	•	■		■		■		■		■		■	•
Pitt Meadows	QAI Laboratories www.qai.org	(604) 460-4453	■		■		■	•	■		■		■		■		■		■		■	
Richmond	LabTest Certification, Inc. www.labtestcert.com	(604) 247-0444	■		■	•	■	•	■	•	■		■	•	■	•	■		■	•	■	
ONTARIO																						
Kanata	Electronics Test Centre www.etc-mpb.com	(613) 599-6800	•		■	•	■	•	■	•	■	•		•	■	•	■	•		•	■	
Merrickville	EMC Consulting, Inc. www.emcconsultinginc.com	(613) 269-4247	■		■	•	■	•	■		■	•	■	•			■		■		■	
Nepean	APREL Laboratories www.aprel.com	(613) 820-2730	•		■	•		•	■	•	■	•		•	■	•	■		■	•	■	
Nepean	Multilek Inc. www.multilek.ca	(613) 226-2365			■		■				■			•					■			
Oakville	Ultratech Group of Labs www.ultratech-labs.com	(905) 829-1570	■	•		•	■	•	■	•		•	■	•	■	•	■	•		•	■	
Ottawa	ASR Technologies www.asrtechnologiesinc.com	(613) 737-2026				•	■	•	■			•	■	•							■	
Ottawa	Nemko www.nemko.com	(613) 737-9680	•	•	■	•	■	•	■	•	■	•	■	•	■	•	■	•	■	•	■	
Ottawa	Power & Controls Engineering Ltd. www.pcel.ca	(613) 829-0820	■		■		■					■	•		■		■				■	•
Ottawa	Raymond EMC Enclosures Limited http://raymondemc.ca	(800) EMC-1495	■		■		■		■			■			■		■		■		■	

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Scarborough	Vican Electronics http://vican.ca	(416) 412-2111	•		•		•	•	•	•	•			•					•		•	•
Toronto	CSA International www.csa-international.org	(866) 797-4272		•	•			•	•		•				•	•						
Toronto	Global EMC Inc. www.globalemclabs.com	(905) 883-8189	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Toronto	TUV Rheinland of North America, Inc. www.tuv.com	(416) 733-7781														•						
QUEBEC																						
Lavale	Les Enterprises EMC Monde Inc. www.globalemclabs.com	(450) 687 4976	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Montreal	Centre de Recherche Industrielle du Quebec www.criq.qc.ca	(514) 383-1550			•			•	•		•					•						
Quebec	Comlab, Inc. www.comlab.com	(418) 682-3380					•	•	•		•											
Quebec	FISO Technologies www.fiso.com	(418) 688-8065				•					•			•		•	•				•	
ASIA																						
CHINA																						
Beijing	SIEMIC Beijing (China) Laboratories www.siemic.com.cn	+86 1068049809		•	•	•	•	•	•	•	•				•	•						
Beijing	TÜV Rheinland (China) Ltd. www.tuv.com	+86 1065666660			•		•	•	•		•					•						
Guangzhou	TÜV Rheinland (GuangDong) Ltd. www.tuv.com	+86 2028391888		•	•		•	•	•		•					•						
Hong Kong	TÜV Rheinland Hong Kong Ltd. www.tuv.com	+85 221921000		•	•		•	•	•		•					•						
Nanjing	SIEMIC (Nanjing) China Laboratories www.siemic.com.cn	+86 2586730128		•	•		•		•	•	•	•			•	•					•	
Shanghai	CETECOM Shanghi www.cetecom.com	+86 2168795890		•	•		•	•	•		•				•	•						
Shanghai	SIEMIC Shanghai (China) Laboratories	+86 2164812901		•	•	•	•	•	•	•	•	•			•	•						
Shanghai	TÜV Rheinland (Shanghai) Co., Ltd. www.tuv.com	+86 2161081188		•	•		•	•	•		•					•						
Shenzhen	SIEMIC (Shenzhen) China Laboratories www.siemic.com	408-526-1188		•	•	•	•	•	•	•	•	•			•	•						
Taipei	TÜV Rheinland Taiwan Ltd. www.tuv.com	+88 6221727000		•	•		•	•	•		•					•						
JAPAN																						
Tokyo	CETECOM Japan www.cetecom.com	+81 036 663 8990		•	•		•	•	•		•				•	•						
Tokyo	**e-Ohtama, Ltd. www.tuv-ohtama.co.jp**	**+81 044 980 2050**			•						•					•					•	
Yokohama	TUV Rheinland Japan Ltd. www.tuv.com	+81 454 701850		•	•		•	•	•	•	•					•						
KOREA																						
Gyeonggi-do	CETECOM MOVON Ltd. www.cetecom.com	+82 031 321 2988		•	•		•	•	•		•				•	•						
TAIWAN																						
Taipei	SIEMIC Certification Servces www.siemic.com	408-526-1188		•				•														

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Taipei City	CETECOM Taiwan www.cetecom.com	+886 2 2564 3338	■		■		■	•	■		■		■		■	•	■		■		■	
EUROPE			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
BELGIUM																						
Erpe-Mere	Blue Guide EMC Lab www.bgemc.com	+32 (0) 53 60 16 01	■		•		■	•	■		■		■		■	•	■		•		■	
GERMANY																						
Dortmund	EMC Test NRW GmbH www.emc-test.de	+49 231 974 2750	■		•		■	•	■		■		■		■		■		■		■	
Egling	MOOSER Consulting GmbH www.mooser-consulting.de	+49 817 692250	■		•	•	■		■		■		■	•	■		■		■		•	•
Erlangen	Siemens AG www.siemens.com	+49 91 317 32977	■		•		■		■		■		■		■		■		■		■	
Essen	CETECOM GmbH (Germany) www.cetecom.com	+49 205 495 190	■	•	•		■	•	■		■		■		■	•	■		■		•	
Karlsruhe	Siemens AG www.siemens.com	+49 721 595 2039	■		•	•	■	•	■		■		■	•	■	•	■		■		■	
Ludwigsburg	Mooser EMC Technik GmbH www.mooser-consulting.de	+49 714 164 8260	■		•		■	•	■		■		■	•	■		■	•	■		■	
Moggast	EMCCons Dr. Rasek GmbH & Co www.emcc.de	+49 919 49016	•	•	•	•	■	•	■	•	■	•	■	•	■	•	■	•	■		■	
Nürnberg	TUV Rheinland www.tuv.com	+49 911 655 5995	■	•	•		■	•	■		■		■		■	•	■		■		■	
Ratingen	7Layers www.7layers.com	+49 210 27490	■		•		■	•	■		■		■		■		■		■		•	
Wismar	CEcert GmbH www.cecert.com	+49 3841 2242 906	■		•		■		■		■		■		■		■		■		■	
Saarbruecken	CETECOM ICT Services GmbH www.cetecom.com	+49 681 598 8438	■	•	•		■	•	■		■		■	•	■	•	■	•	■	•	■	
Siegen	EMC Testhaus Dr. Schreiber GmbH www.emc-testhaus.de	+49 271 382702	■		•	•	■	•	■		■	•	■	•	■	•	■		•	•	•	
Straubing	TÜV SÜD SENTON GmbH www.tuev-sued.de	+49 942 155220	■		•		■	•	■		■		■	•	■		■		■	•	■	
Unterleinleiter	EMCCons Dr. Rasek GmbH & Co www.emcc.de	+49 919 49016	•	•	•	•	■	•	■	•	■	•	■	•	■	•	■	•	■	•	■	
Verden	Block Elektronik GmbH http://www.block.eu/en_US/home	+49 4231 678–0	■		•		■		■		■		■		■		■		■		■	
HUNGARY																						
Budapest	TÜV Rheinland InterCert Kft. www.tuv.com	+36 30 349 8828	■	•	•	•	■	•	■		■		■		■	•	■		■		■	
THE NETHERLANDS																						
Dordrecht	Holland Shielding Systems BV www.hollandshielding.com	+31 78 613 1366	■		■	•	■		■		■	•	■	•	■		■		■		■	•
Eindhoven	EMCMCC www.emcmcc.nl	+31 653 81 1267	■		•	•	■		■		■		■	•	■	•	■	•	■		■	
Eindhoven	Philips Innovation Services www.innovationservices.philips.com	+31 402 74 6762	■	•	•		■	•	■		■		■		■	•	■		■		■	
Woerden	DARE!! Measurements www.dare.nl	+31 348 430 979	■	•	•		■	•	■		■		■	•	■	•	■	•	■		■	
POLAND																						
Poznan	ILiM - Laboratory of Electronic Devices www.ilim.poznan.pl/LA	+48 618 504 989	■	•	•		■	•	■		■		■		■	•	■		■		■	

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SERBIA																						
Belgrade	Idvorsky Laboratories www.idvorsky.com	+ 38 111 677 6329	■		•		•		■		•		■		■		■		■		■	
SPAIN																						
Barcelona	GCEM-UPC www.upc.edu/web/gcem	+34 93 401 1021	■		•		•	•	•		•		■		■		■		■		■	
SWITZERLAND																						
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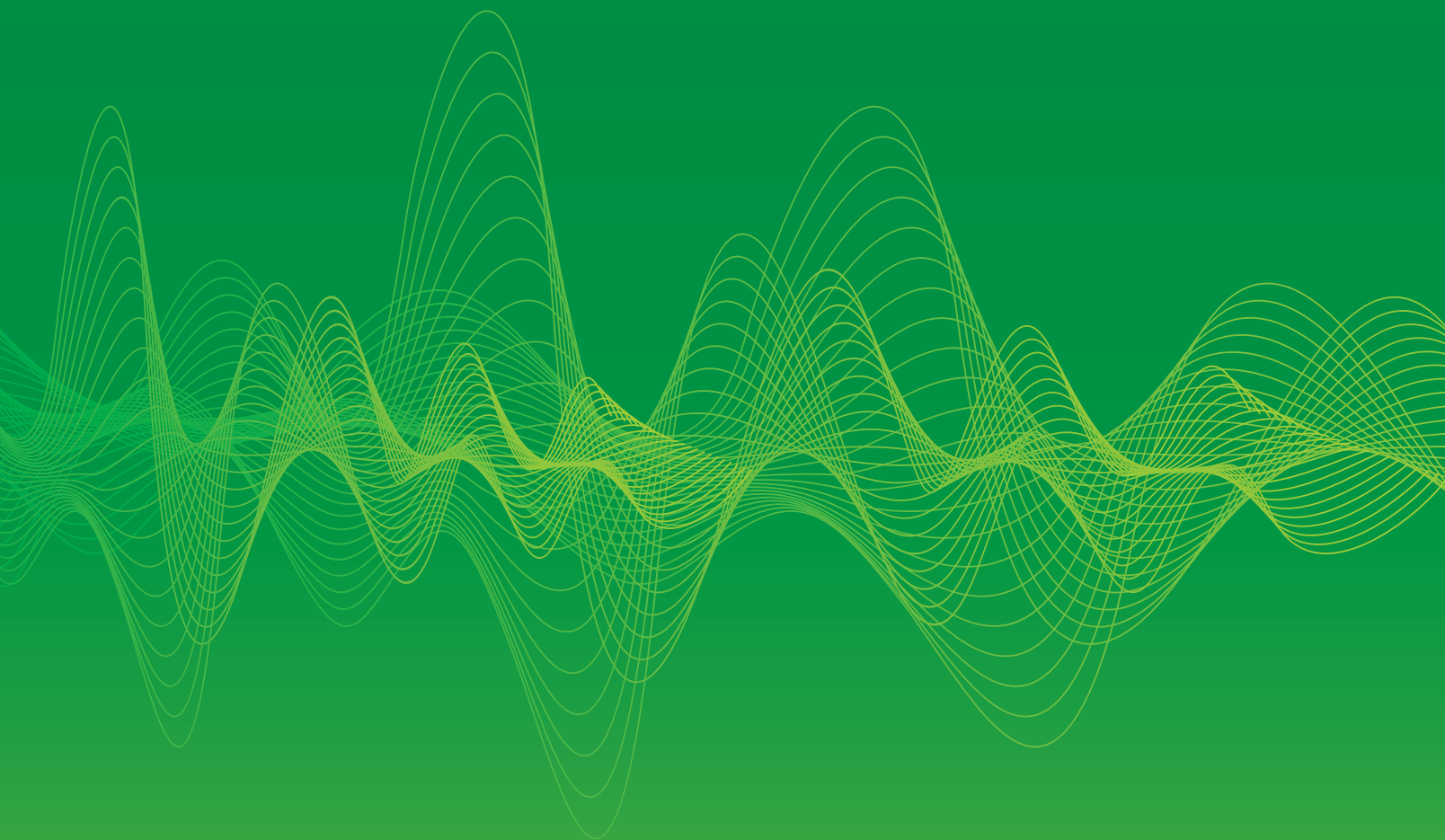

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EMP Protecting Housing and Solar Rooftops

DON WHITE
Consultant
EMP Solutions

THIS ARTICLE presents some methods of EMP (electromagnetic pulse) protection for facilities. The EMC (electromagnetic compatibility) community provides most of the products and know how for structure shielding, bonding and grounding, plus cabling and connector surge suppression along with filtering. They also provide the service for on-site compliance testing of an EMP protected installation.

OVERVIEW

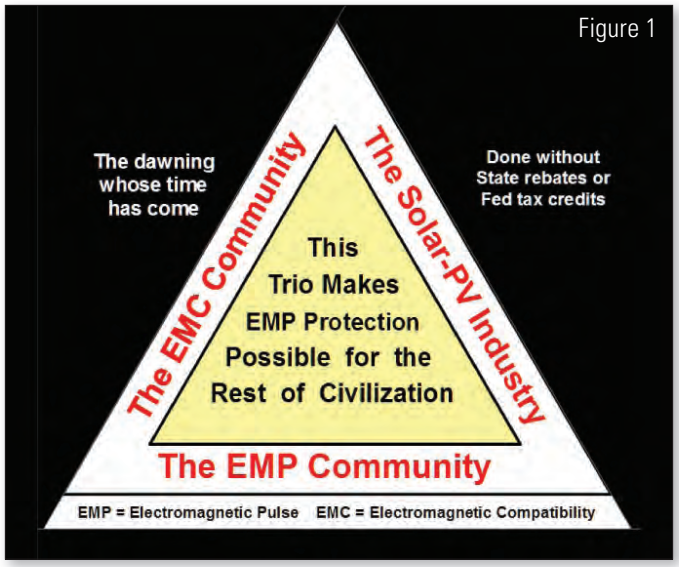
This article provides the least expensive EMP protection process for the massive residential USA population since retrofit protection of existing homes is expensive. This is partly because the government, at all levels, is perceived to have abdicated their fiduciary protection responsibility. EMP survivalists and preppers have independently moved forward to cover some of the protection gap. However, there results a post-EMP era of bare bones survival lifestyle is sacrificed after an EMP event. This article shows how a post-EMP era can economically protect and retain most of ones' lost lifestyle.

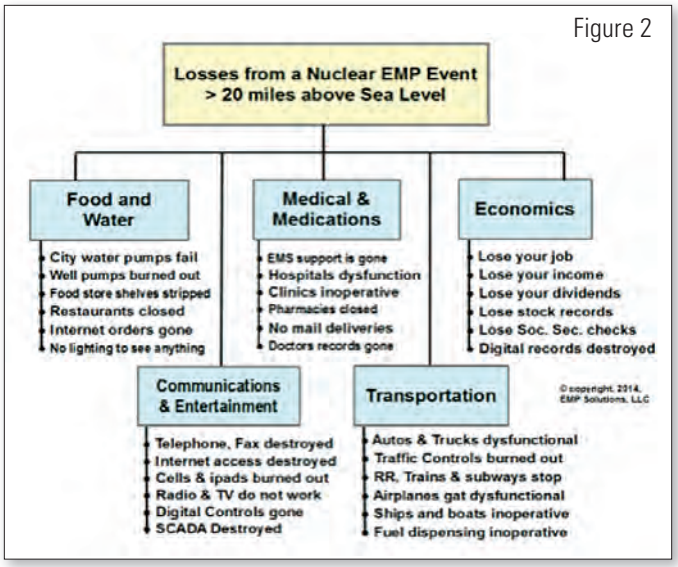
To be optimized along with cost and lifestyle are security, attainability and some ways and means. The small backyard cottage shed becomes the backbone of residential escape. Deed restrictions may make the "backyard" world not attainable, in some cases. Instead, the advantages of "Circle-the-Wagons" concept applies with communities providing the core of security attainability. Real estate developers help make it happen and counties make pragmatic administration and financing possible.

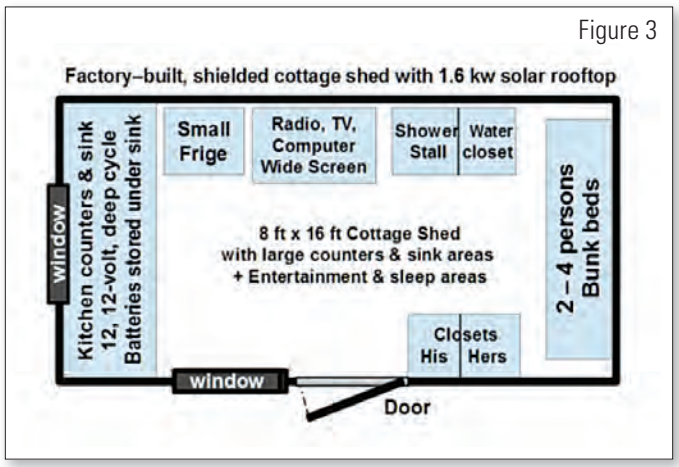
Since EMP protected solar rooftops, plus batteries, is the heart of available electricity, the Solar rooftop folks have joined the EMP and EMC community to make an EMP-EMC solar joint venture (Figure 1). This article outlines how the venture is accomplished as a county mission objective for most of the 3,141 counties in the US.

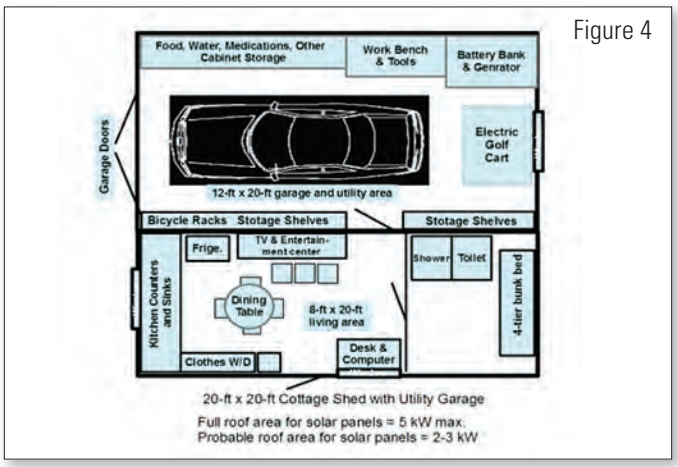
SOME LESSONS LEARNED ABOUT EMP PROTECTION AND SURVIVAL

Following an EMP incident (Figure 2) comes immediate local replenishment shortage (store shelves quickly raided and stripped). Survivalists and preppers have warned about the need to become inconspicuous. They must have a survival location out in the country since it is perceived that fellow man will steal and kill for water and food. This suggests people's escape should be in groups that provide their own security. This "Circle-the-Wagons" concept reduces individual family protection costs and significantly increases the available survival group knowledge base to generate viable communi-









ties in size from tens to eventually thousands.

Peripheral electronic security walls take on creative means and residents can enjoy their vegetable gardens. In many cases, these real-estate developments are housed on farmers' properties that already enjoy the right settings. They all contain ponds so that most part-time residents can enjoy waterfront, if one is available. County community, cottage-shed developments also provides an excellent weekly escape for many.

Because vehicles are mostly inoperative following an EMP event, bicycles with container carts and protected electric golf carts are the preferred modes of transport out to the country cottage-shed locations.

Unless you already have an operational EMP Protection G roup, then form one of your own. Use the county as a default-level of operation. For example, generate a group of five: from the county Economic Development office or County administrator, Chamber of Commerce, an engineer or architect, a member from the pragmatic EMP survivalist group, plus a secretary. They create, generate and use educational and training materials and programs, establish plans and timelines and help make things happen. In short, this is bottom-up management. They also swap their findings, plans and actions with neighboring counties and their state on a timely basis.

COTTAGE SHED CONSTRUCTION

A cottage shed is defined as a small detached shed, configured into a liveable home with its own solar rooftop. With backup batteries, cottage sheds have 24/7 electricity for nighttime and overcast skies. Generators have limited value as they require fuel which is likely not to be available for long periods of time following an EMP incident.

Cottage shed sizes range from 8 ft. x 12 ft. (2.4 m x 3.7 m) in Figure 3 to double-wide sizes of 16 ft x 30 ft (5.2 x 9.1 m). Thus, the area of the cottage may range from 96 sq. ft. (8.9 m2) to 480 sq. ft. (45 m2). They are made from manufactured homes, shipping container homes, Amish homes and other sources. The Amish homes are particularly viable as they cost about $28/sq. ft. before EMP protection. Solar rooftops will cost about $2/watt today to about $1/watt in 2016.

A somewhat expanded version of Figure 3 to accommodate an automobile and a golf cart, plus more storage space is shown in Figure 4. The 400 sq. ft. foot-print will support up to 4 kW of solar rooftop power. This is enough for heaver loads like outside wall-mounted air conditioners, washer and dryers and hot-water heater. Special EMP protection considerations are discussed below.

Shown in Figure 5 are samples of cottage sheds before solar

Figure 5

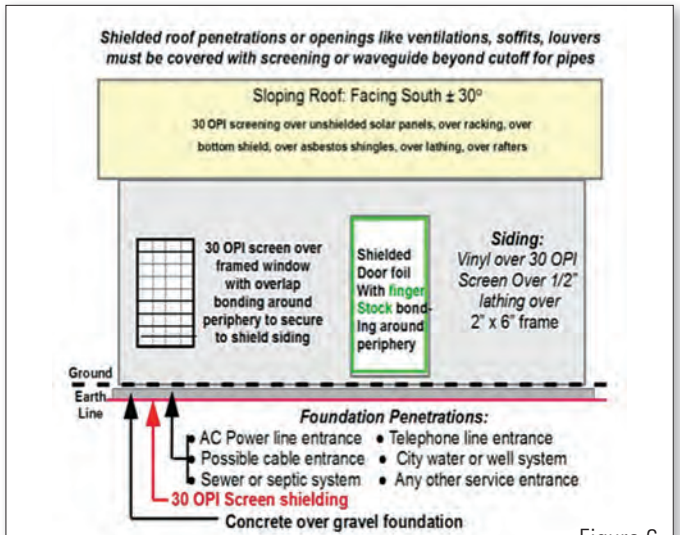


Figure 6

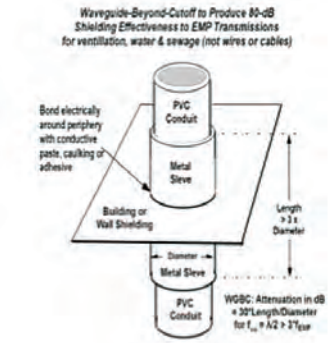


Figure 7

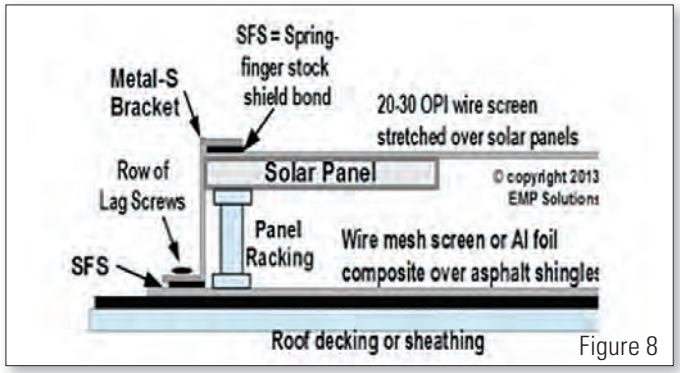


Figure 8

rooftops and EMP protection are added. They are mostly stick-built with modified concrete foundations, siding, rafters, etc. Note the A-frame designed to maximize solar rooftop power output in more northern latitudes so that roofslope more nearly equals site latitude.

[solar output = k*cos(latitude-slope), discussed later].

EMP PROTECTING COTTAGE SHEDS

To save time and money, the shed is ***not*** built first and then EMP protection added. This sequence results from the choice of materials, how shield portions are bonded; special treatment of roofs, vents, siding windows and doors and foundations. For example, the popular to be, 30 OPI (openings per inch) shielded metal screen is laid down and overlapped under the concrete footing rebars. With proper bonding to the structure siding, the foundation is thus shielded with no discontinuity among seams. The power-line and telephone bottom entrances and water line and sewage lines are specially treated.

The above construction of the later-to-be-added solar rooftop is in fact only partly added at the end of construction. The reason is that the solar panels and micro-inverters are encased in their own screening mechanism and require that a bottom shield be added before the solar rooftop is installed. A rough first sketch of is process is illustrated in Figure 6.

The shielding of the four sides may be either a 3-5 mil (0.003" = 0.076 mm) aluminum foil template or 30 OPI screen which is available in wide rolls. Cuts or adjustments are made for windows and a door.

The foundation and rooftop become the challenge since they have several penetrations as shown in Figure 7. Surge suppressors are required at points of cable entry. Waveguide beyond cutoffs are used for vent pipes and water and sewage handling as shown in Figure 7.

ADDING A SOLAR-PV ROOFTOP

Adding a solar rooftop is a simple and well-known procedure. It typically consists of a number of 3 ft x 5 ft, first solar-cell generation, silicone solar-PV panels, connected in a series/parallel combination. Their DC output is converted to AC via an inverter located near the main power distribution panel. Sometimes, micro-inverters are used, one at each panel output and the AC outputs are combined in parallel.

A second solar cell generation, thin film, Cadmium Telluride, CdTe, is gaining popularity for solar and now represents about 25% of the installations in the US. Although efficiency is about 17% vs. 20% for solar, it is less expensive per watt output.

For EMP protection, it is logical that each panel have a 30 OPI shield screen built in for quality control and cost reduction. Such is not yet commercially available and may remain so until about 2016. Meanwhile, EMP protection is made available by first laying down a screen over the asphalt shingles and then applying the panel racking.

Finally, a top screen to cover solar panels, interconnecting wiring and microinverters, is used. This procedure may be abandoned by 2016 when built-in solar panel shielding becomes commercially available. Figure 8 shows the temporary shield over the rooftop approach.

ABOUT SOLAR POWER OUTPUT

The rated power output corresponds to the solar panel exactly pointing to (perpendicular to) the unobscured sun at high noon=a condition that rarely exists in parts of the US. Several factors contribute to a lower power output:

- Building site latitude
- Building roof not facing South ± 30° in Northern
- Hemisphere
- Building roof slope
- Season dependency
- Time of day

Table 1 relates the above variables. Table 2 provides a list of the latitudes corresponding to some of the key USA cities.

Consider the following example in metro Washington DC of a 20 ft. x 20 ft cottage shed including car protection as previously shown in Figure 4. The flat roof structure will accommodate 18, 3ft x 5ft panels in a 3 x 6 array, The rating of the solar panel manufacturer is 225 watts per panel. The maximum available power is 225 watts/panel x 18 panels = 4 kW.

From table 2, the latitude of Washington is 38 degrees. For a flat roof, that produces a relative efficiency of cos(38-0)=79% for the March and September equinoxes at high noon, the kWh (kilowatt hours) per day is roughly equal to 3x the power at noon; therefore the solar system on a clear day is producing 4 kW x 0.79 x 3 =9.5 kWh/day. The accompanying battery system provides the energy source at night and cloudy days.

Knowing the power consumption of all the appliances and approximate use times allows the assignment of loads plus allowing some of the energy for battery charging.

TABLE 1: BRIGHTNESS CORRECTIONS FOR VARIABLES

Site Latitude - Roof Slope in degrees	Spring & Fall Equinoxes			Winter Solstice Noon	Summer Solstice Noon
	Noon 12 p.m.	10 a.m. & 2 p.m.	8 a.m. & 4 p.m.		
0	100%	87%	50%	92%	92%
10	98%	85%	49%	90%	93%
20	94%	81%	45%	86%	98%
30	87%	74%	39%	79%	95%
40	77%	64%	31%	69%	84%
50	64%	53%	21%	57%	72%
60	50%	39%	9%	43%	57%

Note: Based on the cosine of resulting solar angle.

TABLE 2: USA CITY LOCATION LATITUDES

City and State	Latit. degr	City and State	Latit. degr	City and State	Latit. degr
Atlanta, GA	33	Houston, TX	29	Pittsburgh, PA	40
Austin, TX	30	Indianapolis, IN	39	San Francisco, CA	37
Baltimore, MD	39	Jacksonville, FL	30	Seattle, WA	48
Boston, MA	42	Miami, FL	25	St. Louis, MO	38
Chicago, IL	41	Minneapolis, MN	44	Sacramento, CA	38
Cleveland, OH	41	Mojave Dsrt, CA	35	San Antonio, TX	29
Dallas, TX	32	Los Angeles, CA	34	San Bernardino, CA	34
Denver, CO	39	Newark, NJ	40	San Diego, CA	32
Detroit, MI	42	New York, NY	40	San Jose, CA	37
Fairbanks, AK	64	Philadelphia, PA	39	Tampa, FL	27
Hartford, CT	41	Phoenix, AZ	33	Washington, DC	38
Honolulu, HI	21				

COTTAGE SHED SITE EMP PROTECTION TEST COMPLIANCE.

Once an EMP protected installation is declared to be finished, it is time to verify EMP protection compliance by on-site testing. A small van or pickup truck is located as shown in Figure 9. It contains an RF scanning oscillator or sweeper which feeds a power amplifier that drives radiating test antennas pointing at the building to the right. Inside the building is a tracking receiver driven by similar pickup antennas.

The test configuration is first calibrated to form a reference with both transmitter and receiver configurations located on the outside (step 1). Tests are made at the seven test frequencies (1MHz–1 GHz) as shown in Table 3 (obtained from the Fourier Transform of the EMP pulse waveform threat), and the RF attenuator settings recorded. Then, maintaining the same distance between transmitter and receiver, both are moved as shown in step 2 with the receiver configuration moved to the middle of the building and attenuator settings again recorded to get the same received levels. The difference between the attenuator settings in step 1 and step 2 constitutes the building RF shielding effectiveness in dB for the test frequency.

Test setup for determining site shielding performance

The tests are repeated for the other remaining three sides of the building, recording the shielding effectiveness of each side for all seven test frequencies. Then, for each of the seven frequencies, the corresponding four side shielding effectiveness are compared and the smallest value (least shielding) is selected. These results constitute the building EMP shielding

effectiveness. They are compared with table 3 to determine EMP test compliance.

If the building is large (several floors or acres in size), the transmitter may have to be located in a helicopter

While the building EMP and Solar EMP compliance tests can be done simultaneously, in the early stages, it may be best to do each separately. This will facilitate diagnostics-and-fix, if required. The building compliance test must be done first. Test procedural details are well beyond the level of this article.

COMMUNITIES OF EMP PROTECTED COTTAGE SHEDS WITH SOLAR ROOFTOPS

EMP Survivalists recognize and state six items needed for their survival:

- Water (and tools and methods for purification)
- Food, especially freeze-dried, 25-year shelf life
- Prescribed medications and first aid supplies
- Bartering items (since money is worthless)
- An escape place or hut in the country away from starving neighbors and other uninvited intruders

As EMP survivalists learn they can live better in larger EMP protected communities, they will form such communities. There are 62 million homeowners associations members in the U.S. They tend to have a tighter cohesion among their members. As the EMP threat becomes clearer, homeowner associations members may develop a community of cottage-sheds within, perhaps 50 miles or closer to their main residence. This gives rise to a new real estate development prospects. Illustrated in Figure 10 is one example of many.

Illustrated is a group of 44, ¼-acre lots (could be as low as 1/10 acre per lot) surrounding a two-acre pond – both for relaxation/esthetics, as well as a water source for enhanced survival including deep submersed wells. To keep the pond water fresh, there is a spraying fountain and fish. Most lot owners will have a small vegetable garden and a few will have fruit trees.

The above conceptual development is partly protected from outside intrusion by an electronic wall with proximity alarms surrounding the facility. The right side of the Figure 10 contains an owners' common area for entertainment and some vitals storage and replenishment. There is added a beach for those not having a property front on the pond. A water-surrounded, community

TABLE 3: REQUIRED SHIELDING EFFECTIVENESS

Frequency	SE Needed
≤ 100 kHz	80 dB
1 MHz	80 dB
3 MHz	77 dB
10 MHz	65 dB
30 MHz	52 dB
100 MHz	30 dB
300 MHz	10 dB
≥ 1 GHz	0 dB

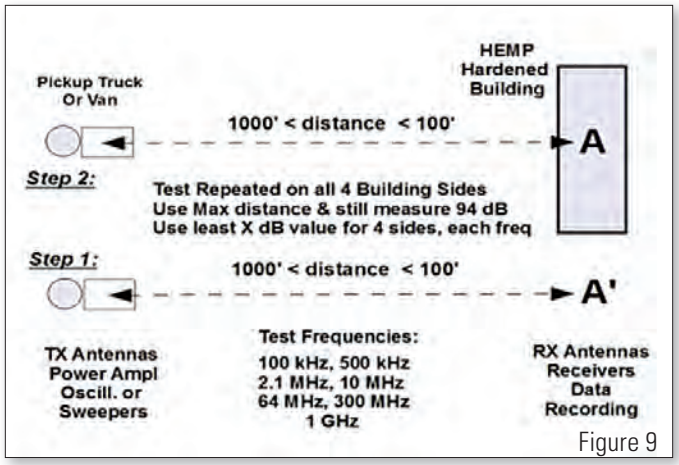


Figure 9

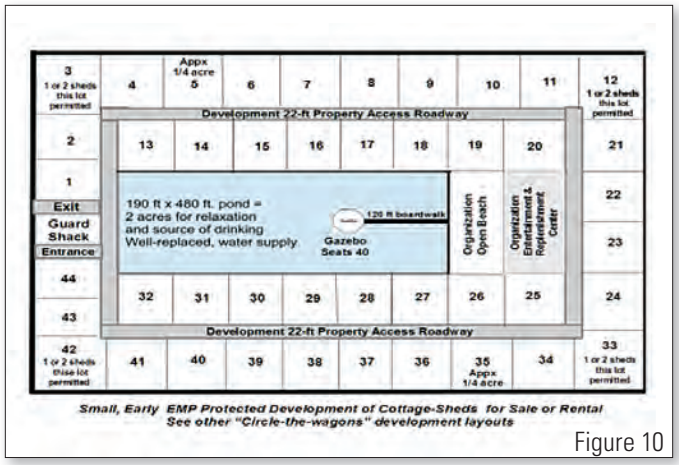


Figure 10

gazebo seats up to 40 with 120-ft. boardwalk access.

Timely spoilable replenishments are a major problem following an EMP disaster, since the site may be several hundreds of miles to the nearest non-EMP sources. Thus, for larger developments, or for one per average-size county, a relatively inexpensive 4,000 ft (1,200 meter) mat-lined, dirt runway is installed. This can accommodate a 70-ton payload, Globemaster III aircraft.

The above concept invites other real estate entrepreneurs or some large corporations to establish their own development with completely EMP protected facilities. These may be sold or rented.

SUMMARY OF ARTICLE AND JOBS GENERATION BENEFITS

The cost for an average size 8 ft. x 20 ft., EMP protected, cottage shed with solar rooftop, community well and septic over the next decade will be about $18,000. This is a fraction of the cost to EMP protect (retrofit) an existing home with solar panels along. If only 20% of the 121 million American households go this route, revenues will approximate: 20% x 121,000,000 x $18,000/unit = $436 billion. This averages $44 billion per year over a decade.

For every $225,000 in cottage-shed related sales (money spent back into an economy) produces one average paying job of $48,000/year. The above $44 billion/year corresponds to 2,000,000 jobs for a 10-year period. This buildup represents about 3.5 million jobs/year at the 10th year. This increases at an accelerated rate as more of the remaining 80% of the American families move toward their week-end country, EMP protected retreat.

In summary here are the benefits:

- Provides for a retention of lifestyle not available to unprepared Americans, in general, and EMP survivalists and preppers, in particular
- Provides a second weekend, escape home for participation by you and others with common interests and shared comradery
- Electricity is "free" both for pre- and post-EMP era
- Expands selected Federal laboratories to create and produce detailed pilot EMP-protected cottage sheds, community lighting, traffic lights, water and sewer public works and other infrastructure
- Revitalize both the earlier mentioned County Economic Development Offices and companion Chambers of Commerce to support activity development and issuance of County and Corporate bonds
- Greatly expands the revenues of participating solar panels, inverters, shielding, surge suppressor and related product providers
- Greatly expands the revenues of participating solar rooftop installers, EMP test houses, maintenance and other service personnel
- Opens up new markets for real estate developers for country-style, cottage shed communities

For more information:

- *EMP – Protect Family, Homes and Community,* 3rd edition. 2013. Don White and Jerry Emanuelson.
- *EMP Protecting Housing and Solar.* 2014. Don White.
- www.emp-safeguard.com
- www.empprotection.org
- www.futurescience.com/emp.html

AUTHOR BIO

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White has written and published 14 technical books over a span of 30 years. His last book was "The EMC, Telecom and Computer Encyclopedia," an 800-page compendium.

At Don White Consultants, he published a bimonthly trade journal called EMC Technology magazine circulated over four continents. He was the technical editor and wrote many of the tutorial articles. White is past president of IEEE Electromagnetic Compatibility Society.

How Much ESD Can an IC Bear? IC Immunity Tests Performed Under the Influence of ESD

SVEN KONIG
EMC Engineer
Langer EMV-Technik GmbH

NOWADAYS, ELECTRONIC devices have to meet the highest standards in terms of ESD immunity. "According to estimates of TÜV NORD, the manufacturing industry incurs costs amounting to millions of euros every year due to electrostatic discharges. ESD effects lead to circuit failures which in turn bring a vehicle, a process or a production line to a halt." An electronic system must be able to function reliably and without failure even under the severest conditions.

But at best an electronic system is only as good as its individual components, which must consequently meet these high demands too. A special point of interest is integrated circuits (ICs), which hardly any of today's electronic systems can do without. But which tests are available in practice to evaluate ICs in terms of their ESD immunity and how are these tests carried out?

Metallic housings and complex EMC measures such as ground layers, filters, etc. are often used to make modules or devices immune to ESD. These methods are very expensive and require a great deal of development work. Conventional EMC measures are usually only used for the prototype or at a very late development stage of the module or device, and even then, only if the compliance test has shown that the device's immunity is inadequate. These measures are taken to ensure the device's functionality. A much better solution, however, would be to subject the components intended for use such as ICs, connectors, etc. to comprehensive EMC analyses and especially to an ESD test right from the beginning even before the electronic development process starts. This would allow the developer or designer to make plans on how and where to use the components on the basis of their robustness and help him save time and cut development costs.

There are usually two different approaches that can be chosen in practice to ensure a module's or device's EMC.

In the first approach, the device is developed up to the initial sample or prototype. At this development stage the device is subject to an EMC compliance test where the EMC requirements are defined for the complete system. Potential weak points such as inadequately dimensioned connectors or sensitive ICs are only discovered in this compliance test and it will not be easy to modify them at this stage. The entire device or the module will be unable to achieve the defined EMC

objectives so that comprehensive redesign work will be necessary, which in turn will entail a loss in development time and additional EMC measures.

In the second approach, which is better, a separate EMC test is carried out for each of the planned components before the development process starts. This helps the developer determine their EMC parameters and assess if they suit the actual EMC demands of the entire system. It is thus possible to select appropriate components for a robust electronic design when the development is being planned.

ICs are particularly important for the EMC immunity of modules and devices. The IC's are becoming smaller and smaller and their clock rates faster and faster. The operating voltages as well as the associated operating points are being constantly reduced for energy efficiency reasons. This often makes ICs the weak points of the entire system and it is thus particularly important for them to satisfy the defined EMC requirements. For this reason EMC tests have to be carried out on ICs to ensure the functionality of the entire system.

The test procedures for ICs must be based on the compliance tests for devices. But conventional compliance tests cannot be used directly for ICs since the disturbances defined in the standard do not become effective on the IC during a compliance test on the module. The standard disturbance that is coupled into the device with a disturbance generator from outside subjects the IC and its line networks to magnetic and electrical fields. Due to this effect, namely magnetic and electrical coupling, the disturbances at the IC differ from the standard disturbances in terms of form, amplitude and mode of action.

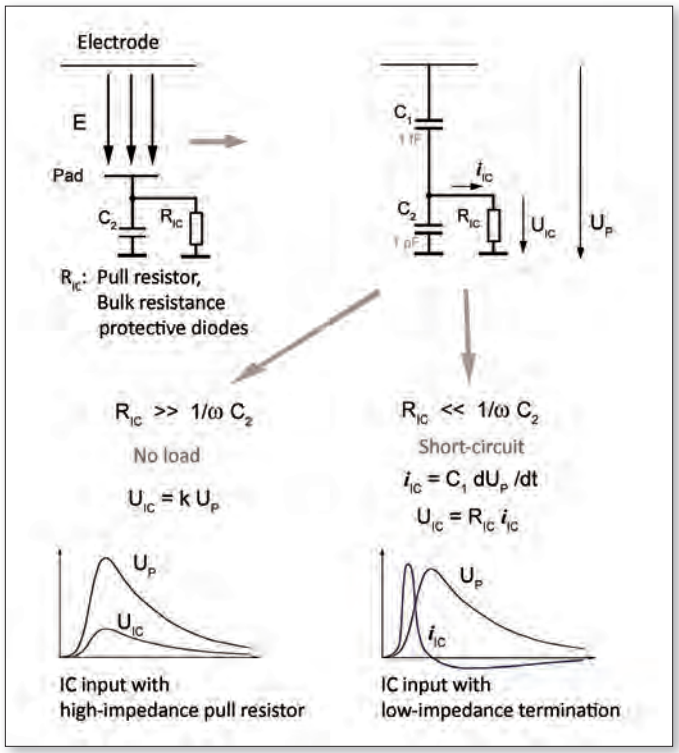

FIGURE 2: Coupling mechanism of the electrical field.

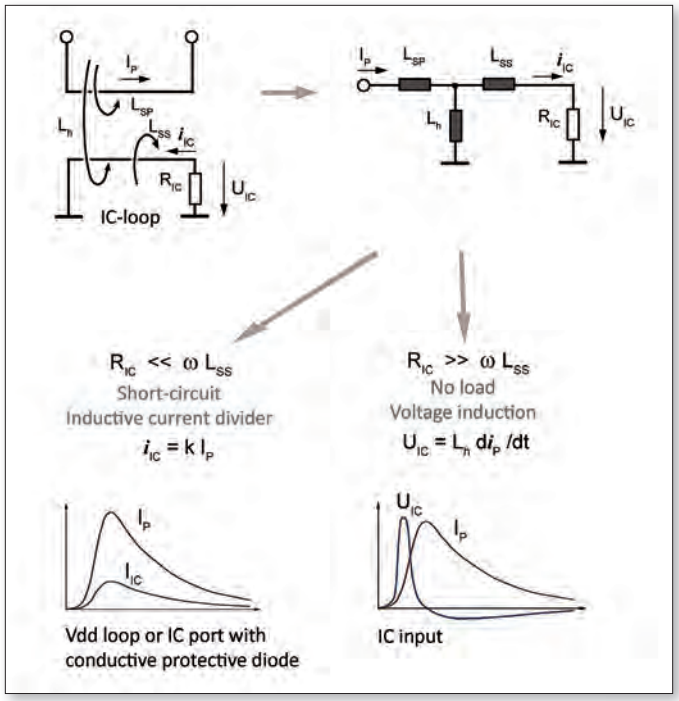

FIGURE 1: Coupling mechanism of the magnetic field.

IC test procedures thus have to be redefined as separate test procedures.

Apart from the desired standard pulse, parasitic fields are similarly generated directly by the generator which may also interfere with the device as a whole or its individual parts. These unwanted electrical and magnetic fields essentially depend on the type and position of the ESD generator. This may lead to a great deal of inaccuracy in device tests. Even the direct ESD tests on individual IC pins carried out by some IC manufacturers are thus inaccurate and cannot be reproduced.

Disturbances therefore have to be defined at the circuit on the basis of magnetic and electrical coupling. In the event of magnetic interference, the disturbance current generates a corresponding magnetic field in the device. A disturbance voltage can be induced in existing loops (e.g. line networks). This disturbance pulse drops on high-impedance IC inputs and interferes with these. Furthermore, the disturbance can also affect other areas within the IC such as PLL, core, etc. The supply system, low-impedance signals as well as lines that are capacitively connected to the ground or Vcc, for example, are critical lines when it comes to interference through magnetic fields.

The magnetic coupling effect can be compared to a transformer (Figure 1). Interference with the IC's low-impedance Vdd loops results in an inductive current divider. The disturbance current generated by the disturbance generator is transferred to the IC's line networks. Interference with IC inputs that are connected at low impedance leads to the differentiation of the disturbance pulse if a magnetic field is applied. The induced voltages have much faster

rise times and are shorter than the actual disturbance generated by the ESD generator. Today's circuits are fast enough to evaluate these differentiated disturbances (< 1 ns) and to be affected by them.

It is mainly lines with high impedance that are sensitive to electrical interference. The voltage difference between the circuit and its environment such as metal parts, ESD generator, etc. generates an electrical field that may affect the signals or the circuit. The resulting voltage pulse may lead to an interference with the IC depending on its sensitivity. Reset, clock, quartz, test pins or high-impedance measurement inputs of A/D converters, for example, are critical pins or lines.

The capacitance between the IC's line networks and its environment is the quantity that is decisive for the coupling mechanism of the electrical field (Figure 2). The disturbance is also differentiated if an IC input that is wired at low impedance is subject to capacitive interference. The disturbance pulse is transmitted directly via the capacitive voltage divider if the lines are connected at high impedance. The effects on the IC are ultimately similar to those caused by magnetic coupling.

Today's manufacturers usually test the resistibility of their ICs. These tests (e.g. HBM; MM; HMM) only ensure the IC's resistibility during production, for example. They have nothing to do with how an IC can be interfered with in its respective field of use. Tests that are based on standard burst and ESD tests are nowadays used to ensure an IC's trouble-free operation. The transient injection method (IEC-62250-3) requires that disturbance pulses from the standard burst generator are applied directly to the IC pins. This generator, however, has no matched line

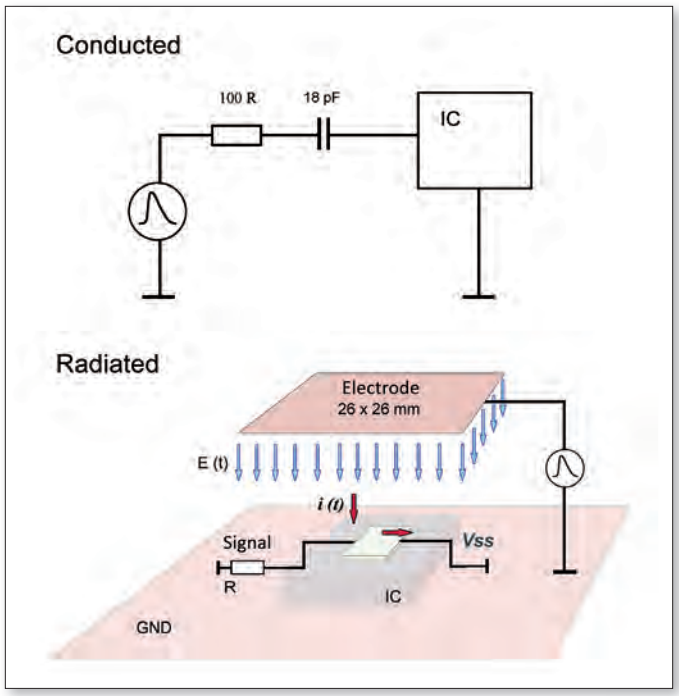

FIGURE 4: Electrical coupling; simulation with a high-impedance source (R >> 50 Ohm).

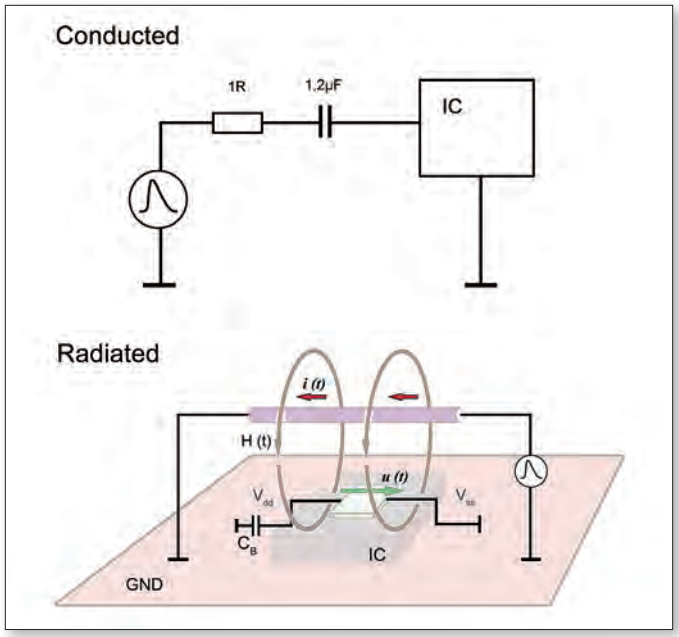

FIGURE 3: Magnetic coupling; simulation with a very low-impedance source (R << 50 Ohm).

termination and the measurement set-up is electrically long resulting in undefined disturbances. Instead of using the disturbance current and/or disturbance voltage directly at the pin, the no-load voltage at the generator is used to evaluate the IC's immunity. The disadvantage of this method is that it allows no conclusions on the IC's sensitivity to electrical or magnetic fields. The powered ESD susceptibility test (also HMM) requires that the ESD pulse is applied directly to the IC pin. This disturbance will not occur in this way at the IC in practice. Furthermore, unwanted electrical and magnetic disturbance fields, are generated at the ESD generator which will also affect the IC under test. This makes the tests hard, if not impossible to reproduce.

Useful test procedures must simulate the physical principles of action in the device. A very low-impedance source (R<<50 Ohm) is required to simulate magnetic coupling into the IC pin. This allows the generation of a disturbance as occurs in IC use through voltage induction in the IC or at the line networks (Figure 3). A disturbance generator with a very high impedance is required to simulate electrical coupling (R>>50 Ohm). In conjunction with a very low coupling capacitance, this allows the simulation of electrical interference (Figure 4).

The IC test system allows the user to perform different test procedures on the circuits without interaction and in a reproducible way.

The IC is mounted on a test board and connected to all necessary and/or wanted signals and a power supply. This test board enables an EMC compliant connection of the device under test and contains all necessary filter elements to ensure that the IC and its environment are

decoupled. The test board is connected to the connection board. The connection board is a unit that is used to control and monitor the device under test (IC). The test board and the connection board are located in the ground plane. The ground plane is the reference ground for the tests. The device under test and the corresponding test systems (probes) can thus be properly connected under RF conditions and the measurement set-up is confined to a small space. The probes are suitable to perform both emission measurements and immunity tests (Figure 5). They are placed on the ground plane and connected to this at low impedance. The probe allows the user to contact any pin flexibly and directly. The complete measurement system is contained in the probe and does not have to be integrated in the layout of the test board.

Different probes can be used to simulate the ESD principles of action mentioned in the first part of this article. A very low-impedance pulse generator is integrated in the current probes to simulate the effects of magnetic interference that affect the IC in practical use under the influence of ESD. The interference mechanisms caused by electrical fields can be simulated with the voltage probes. These have high impedance and a very low coupling capacitance. The test system enables the developer to contact an individual pin and determine the different electrical and magnetic interference levels of a pin through an automatic test procedure if necessary. Apart from conducted IC test methods, a variety of systems for radiated measurements (RF, ESD, Burst) are available.

The IC test system has the following benefits for the users:

- the EMC parameters of individual components can be compared directly
- components can be selected for specific layouts
- the immunity behaviour of components can be predicted

Similarly, the IC manufacturers can benefit from testing their circuits with the IC test system:

- the EMC parameters of existing ICs can be verified
- causes of disturbances can be clarified
- IC optimisation processes can be carried out with the IC test system in an efficient and expedient way

The IC test system is suitable to perform all IC measurements/tests (compliance measurements as well as measurements during development) and to determine all relevant EMC parameters of ICs.

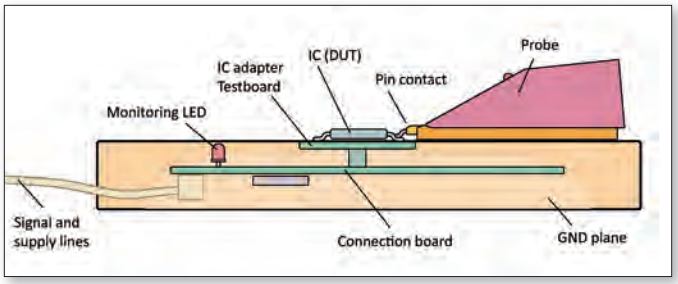

FIGURE 5: Measurement set-up with a probe to simulate the effects of magnetic coupling.

AUTHOR BIO

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New EU Requirements and Test Methods for 2.4 GHz ISM Data Transmission Equipment

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NIMA MOLAEI
LESLIE BAI
EMC Test Engineers
SIEMIC Laboratories

ABSTRACT

NEW EUROPEAN Union Directive requirements have been introduced for 2.4GHz ISM (industrial, scientific and medical) Data Transmission Equipment, which will be in effect starting January 1, 2015. This article presents an overview of the regulatory compliance requirements, and provides a detailed analysis on the differences between the current standard ETSI EN 300 328 V1.7.1 (2006) and the new standard ETSI EN 300 328 V1.8.1 (2012). Also included is an introduction to the new required test methods, as well as some of the unique test setups.

Keywords – EU, European Union, R&TTE, ISM, ETSI, EN 300 328, SIEMIC

INTRODUCTION

To regulate the consumer marketplace and protect the residents in the European Union (EU), regulations, directives, decisions, recommendations and opinions are developed and negotiated among the member states. These legislative requirements cover various product aspects, including safety, health, and environmental protection, as well as protecting the public infrastructure, such as the telecommunications systems and frequency spectrum. In May 1985, the EU "New Approach to Technical Harmonization and Standards" was defined, which represented an innovative way to achieve technical harmonization. It clearly introduced the separation of responsibilities between the European Commission (EC) legislators and the European standards bodies in the legal framework, including the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI).

Basically the EC directives define the essential requirements, and the EU standards bodies have the responsibility to develop the corresponding technical specifications needed to meet the essential requirements of the directives, which are called standards. These approved standards are published in the EC Official Journal (OJ), and become the EU harmonized standards. Compliance with these standards provides a presumption of conformity with the applicable requirements of the harmonized legislation. Thus manufacturers, conformity assessment bodies, and other participating economic operators can use these harmonized standards to demonstrate that products, services, and processes comply with the relevant EU legislation.

The three standards bodies CEN, CENELEC and ETSI are responsible for the preparation of Harmonized Standards under the EC's Radio and Telecommunications Ter-

minal Equipment (R&TTE) Directive (1999/5/EC), which was published in the EC OJ on 7 April 1999. The Directive covers all radio and telecom equipment intended to be connected to public telecommunications and radio networks in the EU.

In June 2012, ETSI updated two standards that were added to the EC OJ in October 2012, which take effect on January 1, 2015, becoming the official harmonized EU standards on this effective date. These two standards are:

- ETSI EN 300 328 V1.8.1- Data transmission equipment operating in the 2.4 GHz ISM band and using wide band modulation techniques;
- ETSI EN 301 893 V1.7.1- 5 GHz high performance RLAN;

These two standards cover a wide range of products, including WLAN, Bluetooth, ZigBee, 2.4 GHz remote control, and Fixed PTP products. Both of the ETSI standards provide a presumption of conformity (or compliance) with Article 3.2 of the R&TTE Directive. However the current versions of these standards will cease to provide a presumption of conformity on 31 December 2014, so the EU Declarations of Conformity (DOC) for the R&TTE Directive based on the standard EN 300 328, V1.7.1 would need to be re-evaluated before the end of 2014 against the new V1.8.1 standard.

In this paper, we will focus on the standard EN 300 328 V1.8.1, which has significant changes compared to the current V1.7.1 version, in both of the technical requirements and the test methods to be used to evaluate compliance.

II. DETAILED ANALYSIS OF EN 300 328: V1.7.1 VS. V1.8.1

As mentioned, there are a lot of updates in the V1.8.1 version of ETSI EN 300 328. The reasons given for this standard update are to improve the usage and quality of data transmission equipment operating in the 2.4 GHz ISM band, and to make the standard more generic, in order to cover all different possible product types.

ETSI EN 300 328 V1.7.1 was added to the Official Journal as a harmonized standard in December 2009. This version added a spectrum sharing requirement, stating that a medium access protocol must be implemented, targeted for equipment designs based on an international standard protocol, such as IEEE (Institute of Electrical and Electronics Engineers) 802.11, IEEE 802.11n, or IEEE 802.15.4.

There wasn't a clear test methodology defined for the spectrum sharing in V1.7.1, which has resulted in a lot of misunderstanding and confusion. Test labs aren't always sure how to evaluate for these compliance requirements, and usually will have to rely on a declaration from the manufacturer to state that the equipment is equipped with a mechanism to utilize the spectrum sharing. But some manufacturers don't want to provide this type of declaration, because they assume the test lab should evaluate and provide the conclusions concerning compliance.

This causes difficulties when equipment is to be tested per this standard, and a good solution isn't known. For Wi-Fi, Bluetooth, and ZigBee devices, which were designed with specific spectrum sharing mechanisms implemented per the IEEE protocol, compliance can be achieved based on the declaration. But for those cases where the equipment is not designed to a standard IEEE protocol, how can the spectrum sharing capability be evaluated?

This situation will be addressed with the adoption of the new V1.8.1 standard version. The Medium Access Protocol will be replaced by adaptivity testing requirements, and the new version has detailed technical requirements on the interference detection threshold and timing. It will also provide step-by-step testing procedures, making the new requirements to be more efficiently followed.

The following options for spectrum sharing mechanism are included in V1.8.1:

- For Frequency Hopping Spread Spectrum (FHSS) systems
  - Adaptive Systems
    - Listen Before Talk (LBT) based Detect and Avoid (DAA)
    - Other forms of DAA (non-LBT)
  - Non-Adaptive Systems
    - Medium Utilization (MU)
- For non-FHSS systems (anything else)
  - Adaptive Systems
    - LBT based DAA
    - Other forms of DAA (non-LBT)
  - Non-Adaptive Systems
    - Medium Utilization (MU)

Additional changes were made on other requires tests, with the purpose of making the standard more generic, in order to cover the different equipment types operating in the 2.4 GHz frequency band. The technical requirements are separated into two major wide band equipment types. The first is FHSS (Frequency Hopping Spread Spectrum) equipment, and the second is Wide Band Modulation equipment other than FHSS.

In Table 1 you will find a brief summary of the major differences in the technical requirement between EN 300 328 V1.7.1 and EN 300 328 V1.8.1. These major changes in version V1.8.1 are:

- *RF Output Power:* New test instrument requirements, and new test procedures are added, plus consideration for MIMO (Multiple Input, Multiple Output), but the limits remains the same.
- *Unwanted Transmitter Emissions:* Adds the requirements for Out Of Band (OOB) domain emissions, and defines a frequency range that extends two bandwidths away from the operating frequency. The corresponding test procedure is also defined. For spurious emission domains, the measurement detector is changed, and requires using high resolution points during while sweeping, in order to obtain accurate test data. Finally, the prescan and final measurements are defined separately.
- *Power Spectral Density:* This has been normalized to the power measurement results obtained, and the new test procedure requires extensive calculation, but the limits remain unchanged.
- *Frequency Range:* The test procedure has changed to use a 99 percent bandwidth measurement, to be performed only at nominal conditions.
- *Adaptivity and Receiver Blocking:* Adaptive and non-adaptive devices operating at more than 10 dBm e.i.r.p, (equivalent isotropically radiated power) are now subject to new timing restrictions. In addition, adaptive equipment will need to be able to detect interference, and cease transmission when interference is detected.

TEST METHODS TO SUPPORT ETSI EN 300 328 V1.8.1

Together with the changes to the technical requirements, the test procedures are also re-defined to provide more appropriate

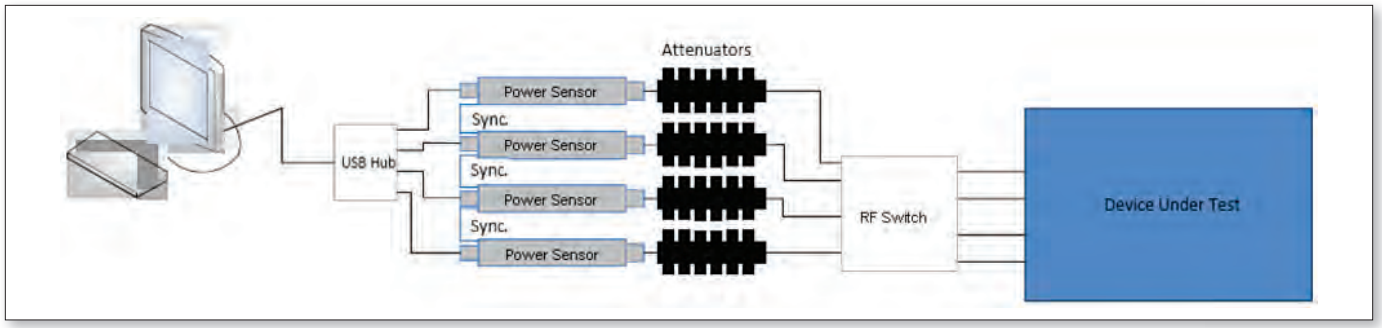

FIGURE 1: Test Setup for RF Output Power Testing

methods to evaluate product compliance. The test procedures are also becoming more generic, so they can be used for different types of equipment.

Environmental Conditions

The conditions for testing are changed from V1.7.1, where the extreme environmental conditions and extreme power source criteria had to follow the requirements as described in clause 5.3, but in V1.8.1, they are declared by the manufacturer, based on the actual operating condition for the equipment.

Unit Under Test (UUT) Operating Conditions

For the operation conditions of the UUT per V1.8.1, it needs to be configured for the normal operation mode, which means the UUT may have an inconsistent duty cycle, and different transmission characteristics, depending on the equipment type and specific operating mode. In the current V1.7.1 version, the UUT should be configured as a continuous transmission test mode (100% duty cycle). The problem is, this kind of mode requires using special tools or software from the manufacturer, which sometimes is difficult to obtain; and the actual real-life RF performance of the equipment may not match what it's expected to be during the normal operation mode used during compliance testing. There is also the potential for "fudging" the results by using the special test mode prepared by manufacturer intentionally with the sole purpose of enabling the UUT to pass testing. The new rule in V1.8.1 effectively addresses this issue, and requires all measurements to be performed in the normal operation mode, thus making the measurements consistent and more accurate.

RF Output Power Measurement

For RF output power measurement, a fast power sensor suitable for 2.4 GHz and capable of 1 MS/s (Mega Samples per second) must be used. The measured sample must represent the power of the signal. The measurement duration is defined for both non-adaptive and adaptive equipment, in order to improve accuracy. While either the radiated or conducted measurement method can be used, they all need to follow similar data acquisition steps to obtain the results.

- For conducted measurement on devices with one transmit chain, sample the transmit signal, and store the raw data.
- For conducted measurements on devices with multiple transmit chains, measurements needs to be made at all transmit ports simultaneously, and the power of the individual samples of all ports needs to be stored and summed.

- For radiated measurements, the UUT must be configured and antenna(s) positioned for maximum e.i.r.p. levels towards the measuring antenna, including smart antenna systems and systems capable of beam forming. The fast power sensor is also required for the measurement; a spectrum analyzer should not be used.

The start and stop times of each burst are stored, and should be used to calculate the RMS (Root Mean Square) power over the burst period. The maximum e.i.r.p. calculation to determine the RF Output Power (P) sums three measured values, the highest Pburst value (A), antenna assembly gain (G) and the additional beam forming gain (Y), as given by the formula:

$$P = A + G + Y$$

The use of fast power sensors and simultaneous measurements for MIMO chains eliminates the possibility of using an alternative method for the power measurement. The special and unique power sensors which can comply with the requirement per V1.8.1 are becoming very hot commodities in the test equipment market. We will now talk about the method for the major test items.

The testing of RF Output Power will be based on the use of fast power sensors, and may require 4 power sensors to work simultaneously for 4x4 MIMO devices. A suggested test setup is shown in Figure 1.

Power Spectral Density

The Power Spectral Density (PSD) can be measured using a high resolution spectrum analyzer. The detector to be used has been defined specifically as an RMS detector, instead of an average detector referenced in version V1.7.1. The sweep points in the measurement frequency range are defined to make sure the necessary accuracy is achieved. If the spectrum analyzer used does not support enough sweep points, the frequency band can be segmented.

Per the procedure defined in V1.8.1, the PSD measurement is not simply sweeping on the spectrum analyzer and marking the highest amplitude. A sweep is made with a Resolution Bandwidth (RBW) of 10 KHz and a Video Bandwidth (VBW) of 30 KHz, utilizing a RMS detector, while capturing more than 8350 sweep points. Next, all the values in the sweep need are summed and normalized to RF Output Power e.i.r.p. units to obtain the normalization factor, which will incorporate all the individual values to produce the normalized amplitude. This measurement is made starting from the first sample in the file (lowest frequency), then adding up the power of the following samples in 1 MHz segments, and recording the results for power and position (i.e. sample #1 to #100), then repeating measurements by shifting the start point of the samples by 1, then repeating the procedure for all individual values until the all values have been covered. The highest resulting 1 MHz segment sample that results will be the maximum PSD value.

Transmitter Spurious Emissions in the Out of Band Domain

This is a new item added in the V1.8.1 version. The purpose is to limit the unwanted transmitter emissions in the Out Of Band (OOB) domain on frequencies immediately outside the required bandwidth, which results from the modulation process, but excludes spurious emissions. This measurement is performed by using the Time Domain Power Measurement function on a spectrum analyzer. The measurement detector is set for RMS, and at least 5000 sweep points are required. The measurement frequency range depends on the UUT's Operating Bandwidth (OBW), from (2400 MHz – 2BW) to (2483.5 MHz + 2BW). With a Resolution Bandwidth (RBW) of 1 MHz and SPAN set to 0 Hz, the Time Domain Power measurement needs to be repeated at each center frequency that is 1MHz from the edge of each defined ISM (Industrial, Scientific and Medical) band frequency range. Similar to the RF output power measurement, the declared antenna assembly gain "G" in dBi must be added to the results for each of the 1 MHz segments. For equipment with multiple transmit chains, the measurements need to be repeated for each of the active transmit chains. The highest value in each 1 MHz segment is the highest transmitter spurious emissions in the OOB domain.

Adaptivity and Receiver Blocking

One of the most important changes in the V1.8.1 is the addition of an Adaptivity and Receiver Blocking testing requirement, which tests how equipment adapts to its environment by identifying other transmissions present in the band, then "adapting" by excluding them its selected frequencies and channels of operation. The adaptivity is part of the requirement for

TABLE 1: DIFFERENCES IN THE TECHNICAL REQUIREMENTS BETWEEN ETSI EN 300 328 VERSIONS V1.7.1 AND V1.8.1

Test Item	EN 300 328 V1.7.1(2006-10)	EN 300 328 V1.8.1(2012-07)
Equipment Types	FHSS and DSSS	FHSS, other Wide Band modulation, adaptive and non-adaptive equipment.
RF output Power	100mW maximum e.i.r.p	100m W mean e.i.r.p (need to consider beam forming gain)
Power Spectral Density (non-FHSS only)	10Bm/MHz maximum e.i.r.p spectral density	10dBm/MHz, mean e.i.r.p. spectral density
Duty Cycle, TX-Sequence, TX-Gap	Not defined	Duty Cycle shall be equal to or less than the maximum value declared. - For FHSS: max TX-sequence time ≤ 5 ms, min TX-Gap time ≥ 5 ms - For non-FHSS: TX-sequence time = Min. TX-Gap time = M (Note: 3.5mS < M < 10mS)
Dwell time, Minimum Frequency Occupation and Hopping Sequence (FHSS only)	Frequency Hopping requirements: Dwell time < 0.4s Hopping channel, Hopping sequence	Dwell time, Minimum Frequency Occupation and hopping sequence Hopping frequency separation: new limits
Medium access protocol	A medium access protocol shall be implemented	Medium Utilization factor only for Non-adaptive equipment with and EIRP > 10mW; Limit: ≤ 10%
Adaptivity	No requirement	Only for adaptive equipment with e.i.r.p > 10 mW
Occupied Bandwidth	No requirement	99% OBW shall fall within the used band. FHSS and Non-AFH equipment (e.i.r.p > 10 dBm): Occupied Channel Bandwidth ≤ 5 MHz Non- FHSS and non-AFH equipment (e.i.r.p > 10 dBm): Occupied Channel Bandwidth < 20 MHz
Transmitter unwanted emission in the Out Of Band domain	No requirement	Specified the limit mask for out of band unwanted emissions.
Transmitter spurious emissions	Defined	Limit unchanged, but the measurement setting of RBW and detector changed.
Receiver spurious emissions	Defined	Limit unchanged, but the measurement setting of RBW and detector changed.
Receiver blocking	No requirement	only for adaptive equipment with EIRP > 10mW

spectrum sharing. It used to be called "Medium Access Protocol Mechanism" and mainly relied on the manufacturer's declaration. WLAN or ZigBee products are designed per standards such as IEEE 802.11 or IEEE Std. 802.15.4, and will have a LBT spectrum sharing mechanism based on the Clear Channel Assessment (CCA) mode that detects RF energy, so they can comply with the spectrum sharing requirement. However, there are detailed technical requirements and test procedures defined in V1.8.1 for the purpose of evaluating devices that do not have this type of standardized spectrum sharing mechanism implemented. The concept of adaptivity is also complicated by the depth of detail necessary in the standard so it will be generic enough to cover different adaptive equipment types that may be introduced.

During the testing, a Wide Band noise signal is injected into the UUT's antenna port, such as an interference signal centered on the hopping frequency or the operating frequency being tested. The interference signal must be a band limited noise signal that has a flat PSD. Usually this kind of signal is to be generated by the Adaptive White Gaussian Noise (AWGN) generation function on a vector signal generator.

The adaptivity and receiver blocking tests are combined and performed together, and a typical test configuration can be seen in Figure 2. The test procedure contains the following basic steps:

Step 1: Connect the UUT and companion devices, then connect the interference signal generator, the blocking signal generator, and the spectrum analyzer. The spectrum analyzer is used to monitor the transmissions of the UUT in response to the interfering and the blocking signals.

Step 2: Configure the UUT for normal transmissions with a sufficient load that allows the demonstration of compliance of the adaptive mechanism on the hopping frequencies tested. Then verify the UUT's Channel Occupancy Time and minimum Idle Period.
Step 3: Add in the interference signal.
Step 4: Verify the spectrum sharing mechanism's reaction to the interference signal.
Step 5: Add in the blocking signal, and verify the UUT's reaction.
Step6: Remove both the interference and blocking signals, then verify the UUT's reaction.

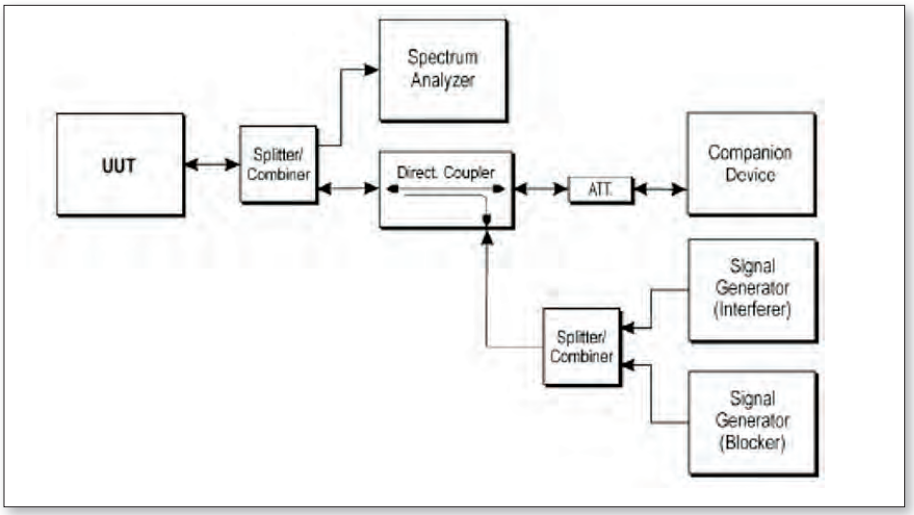

FIGURE 2: Test setup for Adaptivity and Receiver Blocking testing

Note that the UUT is allowed to transmit control signals after the detection of interference signal, as long as the duty cycle of control signal does not exceed the limit given in the standard.

A typical test setup for adaptivity and receiver blocking testing is shown in Figure 2.

UNIQUE TEST SETUP CHANGES IN ETSI EN 300 328 V1.8.1

The EN 300 328 V1.8.1standard specifies the requirements for measurement test instrument functions, performance and settings, which are quite different from the V1.7.1 requirements. Some of the more unique test equipment requirements include:

- Fast power sensors suitable for 2.4GHz, and capable of 1 MS/s for RF Output Power measurements, and it needs to support simultaneous measurements on MIMO devices.
- Higher performance spectrum analyzers with over 30, 000 sweep sample points for Dwell Time, Minimum Frequency Occupation, and Hopping Sequence measurement
- Spectrum analyzers with RMS detectors for most measurements
- Time Domain Power Measurement functions for transmitter spurious emissions in the OOB domain
- Wide band noise sources for interference signals must have less than 1.5 dB ripple for Adaptivity testing

Also note that an Adaptive White Gaussian Noise (AWGN) generator to support noise bandwidths above 160 MHz will be required if the testing is to be performed on an 802.11ac device with 160 MHz bandwidth.

Table 1 compares the changes for twelve key test criteria between the current ETSI EN 300 328 V1.7.1 and the soon to be implemented ETSI EN 300 328 V1.8.1.

FUTURE DEVELOPMENTS FOR ETSI EN 300 328

While manufacturers and testing labs are currently transitioning to the EN 300 328 V1.8.1 standard, ETSI has already published the draft version of EN 300 328 V1.8.2. This version is currently in the European Norm standards approval process, with a resolution meeting scheduled in September, 2014, to be followed by an additional national vote on the modified version, if there are comments. The final version that passes the national vote will be published as EN 300 328 V1.9.1, which is expected to happen sometime in 2015.

Some possible changes in the future version V1.8.2 could include:

- For FHSS, there are proposed changes on some definitions, such as dwell time, as well as some technical requirements and corresponding test methods.
- For non-FHSS and LBT based adaptive system, such as IEEE 802.15.4 and IEEE 802.11, the requirements and test methods for adaptivity testing will be clarified. Formulas for calculating 'Extended CCA time' and 'Channel Occupancy Time' have been removed and replaced by fixed values, or a range of fixed values.
- Changes to the spurious emission tests for the detector type instrument setting, including a clarification that the radiated testing needs to be performed on the UUT, even if RF conducted testing is performed.

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- ETSI EN 300 328 V.8.2: 2014 (Draft version)
- Presentation on EN 300 328 & EN 301 893, R&TTE CA meeting – Amsterdam – May 2014
- Article 288 of the Treaty on the Functioning of the European Union

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EMC Basics: Designing to Prevent EMI in Electronic Devices

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Senior Staff Scientist, Chemical Research
LORD Corporation

ELECTROMAGNETIC interference (EMI) is an unwanted disruption in the communication of an electrical device caused by foreign electromagnetic waves. Such foreign waves or radiation induce electrical currents that interfere with the device's normal operation. Simply stated, EMI is the result of the intrusion between foreign and desired signals.

EMI can intermittently render a device inoperable. While this interruption can be benign, such as disturbing a cell phone conversation, it can have serious consequences for applications in the transportation industry, where, for example, just a brief interruption in the avionics system of an aircraft can be dangerous.

When designing electronic devices, manufacturers must conform to regional and global regulations to prevent electromagnetic interference. Since almost any device that has some electronic component is susceptible to foreign radiation, manufacturers have developed several circuit-grounding and device-shielding methods.

EMI-SHIELDING METHODS

Electrical device manufacturers have traditionally used metallic enclosures to safeguard against EMI. Metal enclosures, made from materials such as aluminum, steel, nickel, and nickel-iron alloys, deliver a relatively thick and exceptionally conductive boundary around the electronic device that reflects and absorbs disruptive signals. Although metallic enclosures do a good job of minimizing EMI, they are heavier than desired for many electronic applications.

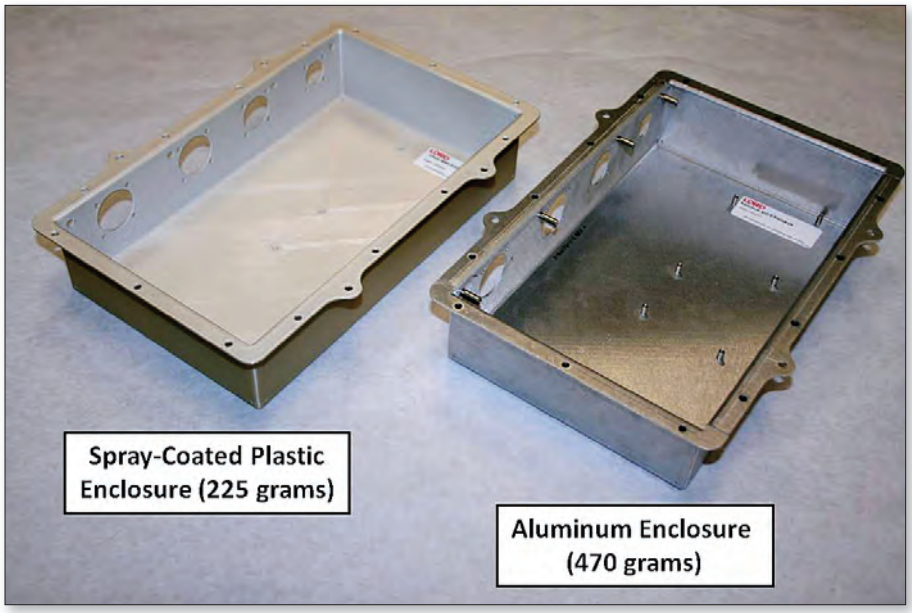
In the quest for lighter weight construction materials, many manufacturers are switching to thermoplastics. Thermoplastic enclosures are easier and quicker to manufacture. With metals, the enclosure's shape must be stamped, a costly and time-consuming process which is not readily adaptable to intricate shapes. Thermoplastics, however, can be easily injection-molded into complex shapes at a high-throughput. This combination of lightweight design and production speed makes plastic enclosures less expensive to manufacture than metallic enclosures.

On the other hand, plastics are inherently electrically insulating, thereby offering negligible EMI protection. To overcome this problem, manufacturers often resort to using an electroless plating process or the plastics are coated with heavily-filled conductive coatings. This transforms the plastic part into an EMI shield.

Electroless plating is an intensive, multi-step, chemical process that ultimately deposits a pure, thin metal coating onto the plastic. While electroless plating

does provide high shielding levels owing to its pure metallic coating, the process is environmentally unfriendly and time-consuming and, in turn, can be labor-intensive and expensive. Specifically, plastics are first swollen by solvent, and then etched with strong acids such as sulphuric and chromic acids. Following etching, the parts are rinsed, a catalyst is applied to the surface, and lastly, the metal, such as copper or nickel, is deposited onto the surface through a reduction reaction. This process, which can entail additional rinsing steps, has come under scrutiny lately because it uses hazardous chemicals that pose harm to the operator and the environment. Due to increasing environmental regulations, shield designers are resorting to alternative coating techniques for plastics.

In addition to safety and environmental issues, electroless plating can suffer from limited adhesion, especially around exposed edges or corners or where stresses in the substrate may



Highly conductive epoxy coatings enable aluminum-like shielding levels at a fraction-of-the-weight of traditional enclosures. This photo shows the weight savings realized by converting from an aluminum enclosure (right) to a thermoplastic enclosure (left) that has been sprayed with the new epoxy coating.

be high. In such situations, the metal coating may flake off, thereby leading to holes through which electromagnetic waves can penetrate. This issue is compounded by the big mismatch in properties (e.g. modulus, elongation, and coefficient of thermal expansion) between the plastic substrate and metal coating.

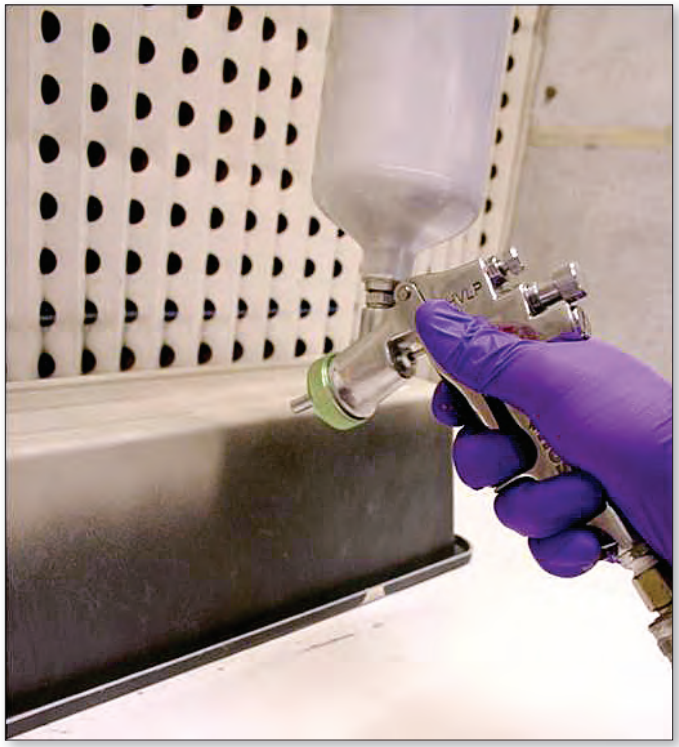
As an alternative to metallic enclosures and electroless plating, many manufacturers are using dense, conductive coatings that are sprayed onto the thermoplastic enclosure. The coatings consist of a thermoplastic or thermosetting resin, such as polymethylmethacrylate and epoxy, respectively, that is highly loaded with metallic particles such as silver, copper, silver-copper, nickel, or hybrid combinations thereof. Although the coatings do provide high shielding effectiveness, their high densities can lead to sacrifices in properties such as adhesion, flexibility, weight, and/or cost.

Another possibility for making thermoplastics EMI-proof is filling the thermoplastic material with conductive particles. While this approach eliminates the need for a conductive coating after the plastic is injection molded, the resultant enclosure is still far less conductive than achieved by either electroless plating or via a dense conductive coating.

Application of highly conductive epoxy spray coatings onto plastic substrate.

HIGHLY CONDUCTIVE EPOXY COATINGS

Electronic manufacturers are seeking a conductive coating for thermoplastics that delivers the equivalent shielding performance of electroless plating without the safety, environmental, and cost issues inherent in the plating process. To meet this demand, new highly conductive epoxy coatings are entering the market. Moreover, these coatings overcome the tradeoff of shielding effectiveness and performance properties that are commonly seen with traditional high-density coatings. The new coatings, based on a novel combination of epoxy resin, curative, and conductive fillers, are capable of self-assembling into a unique structure during curing. This structure inherently is very conductive, yet still is largely polymeric in nature. Ultimately, this leads to a lightweight coating with very high levels of EMI shielding. Specifically, the self-assembling coatings offer 85+ dB of shielding at 25 micron (1 mil) thickness over a broad range of frequencies. Because of its polymeric nature, the coatings can also achieve higher levels of adhesion and flexibility. In addition, they are resistant to high temperature, humidity, and salty environments to which electronic applications are often exposed.



Flexible version of the highly conductive adhesive cured into a 1 mm thick disk.

This efficient performance is especially significant for manufacturers who want to swap out their hazardous, electroless plating process with a coating that delivers at least 85 dB or higher at approximately the same thickness. Moreover, traditional coatings at the same density and thickness as the aforementioned self-assembling ones will not deliver more than 85 dB of EMI shielding. Given this, manufacturers are reluctant to apply thicker coatings owing to cost and/or weight restrictions.

The distinctive base chemistry of the coatings allows the material to be adapted into several useful product forms including coatings, adhesives and films. As a spray coating, it can be easily applied manually or with automated equipment. The spray handles just like paint and can be applied onto very complex thermoplastic shapes by using a high-volume, low-pressure (HVLP) spray gun. For precise control of thickness across a part, the coatings can be ap-

plied via robotic systems. Moreover, it has an indefinite shelf life at room temperature.

The room-temperature stability or latent nature of the coating enables the base chemistry to be manipulated into the form of a liquid-dispensable adhesive, thus permitting it to be used as a traditional adhesive but with EMI shielding properties.

In its film form, the base material can be sheeted into large pieces of film for sizeable applications. This form is particularly useful in the aerospace industry where it can be applied to large areas of an aircraft during assembly, offering protection from both EMI and lightning strikes. Lastly, depending on the mechanical requirements, the base material, whether in a spray, adhesive, or film form, can be formulated for rigid or flexible applications.

For repair procedures, the highly conductive epoxy coatings are available in a pressurized spray can. This simple delivery method allows the coating to be applied in field applications, without needing a spray gun, compressed air system or hose lines. For example, if an enclosure or part gets scuffed or nicked in the field, the damaged section can be touched up by simply spraying it. If an external section of an aircraft becomes damaged causing part of the epoxy coating to be removed, the repair technician can spray the coating on top of the damaged or repaired section.

With highly-conductive epoxy coatings, manufacturers have a material that is predominantly a polymer that behaves similar to a metal, over a very broad range of frequencies. Industry-wide applications have proven that these coatings typically yield more than a 50% cost savings over electroless plating of plastics and other highly-filled, high-performance acrylic systems. As manufacturers increasingly use lighter weight materials in their designs, highly-conductive coatings can provide efficient, economic EMI shielding that meets industry expectations.

AUTHOR BIO

Dr. Tim Fornes is a Senior Staff Scientist in the Chemical Research Department of LORD Corporation. He is responsible for the design, creation, characterization, and modeling of novel polymer-based adhesives and coatings that have commercial relevance in the electronics, aerospace, and automotive industries. Fornes is the author or co-author of 19 peer-reviewed technical publications and is a co-inventor on six patents (two issued, four pending). He holds Chemical Engineering degrees from North Carolina State University (B.S.) and The University of Texas at Austin (M.S. and Ph.D.).

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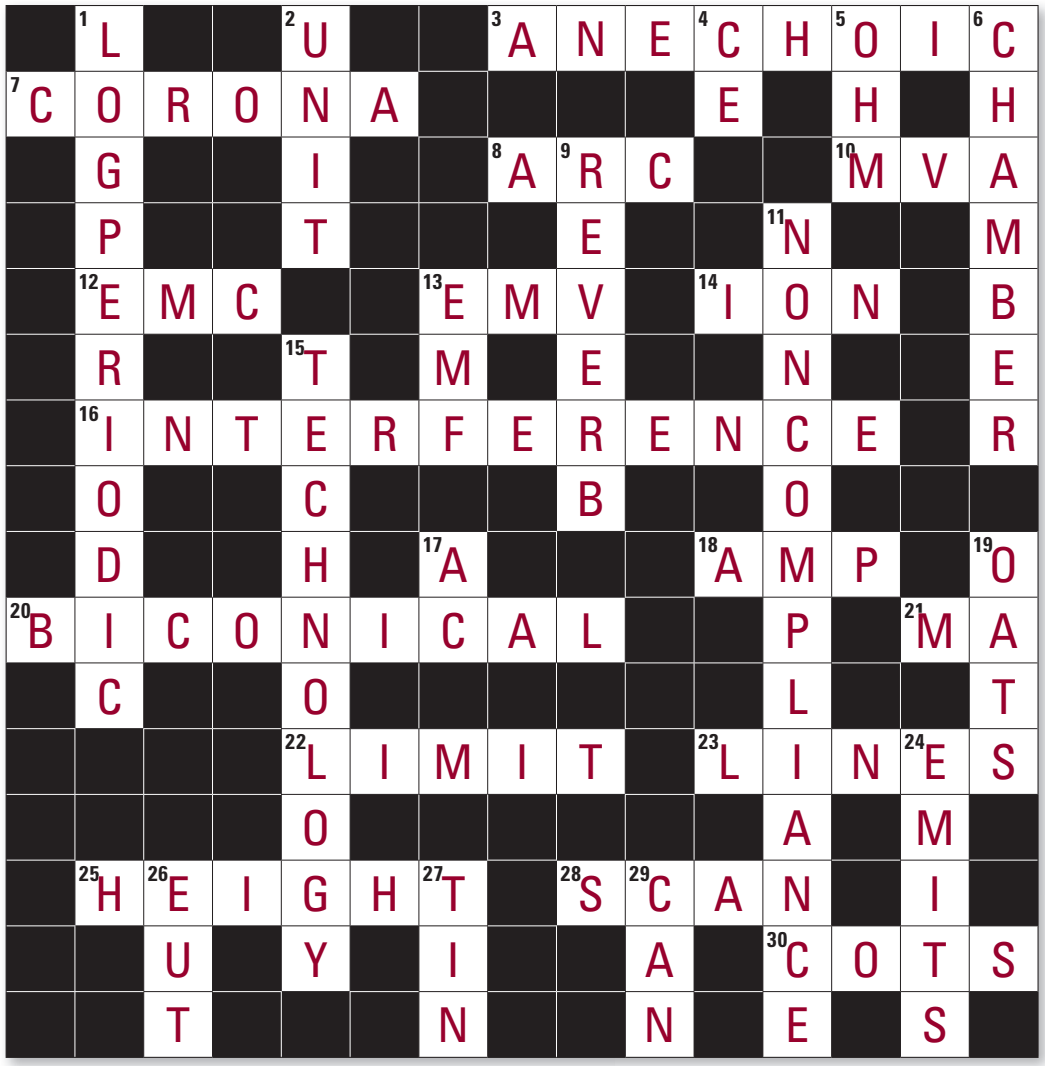

Observations in EMC Education

Continued from Page 6

Now interviews at our employer were known to be fairly rigorous – typically, three technical interviews and three personality interviews. Two candidates were BSEEs and one was a MSEE. None even came close to making the cut. Largely, the issue was lack of basic circuit design knowledge – for example, "sketch out a simple J-K flip flop circuit", etc. They all seemed knowledgeable in some narrow field, but lacked the breadth that we required as a design engineer. After all, you need to be well versed in basic product design in order to understand EMC engineering.

I ultimately ended up calling one of the professors at the University of Missouri EMC Laboratory and hiring one of their Ph.D. students. It seemed to me at the time that university educations weren't near the same quality as when I graduated in the mid-1970s.

I wish universities and colleges would do more to prepare their engineering graduates for real-life challenges in product design – not just for EMC, but for fields like marketing, sales, reliability, environmental test, and another regulated field - product safety. However, university and college faculty and administrations appear to be fixated on classical academics, rather than real-world engineering. What I feel would help a great deal is by attracting experienced engineers to teach higher education classes in real world engineering. However, the current politics of the academic institutions seems to frown on this intrusion into their territory. Until major change is instituted in our educational system, I guess it continues to fall on the shoulders of industry to "re-educate" recent graduates?

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