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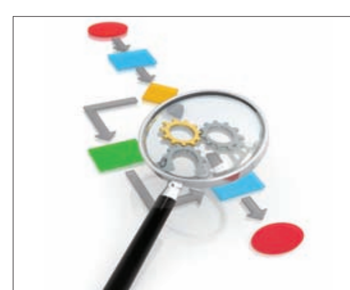

Remembering Edwin L. Bronaugh

Edwin Lee Bronaugh, born in Salina, Kansas on July 22, 1932, passed away on October 18, 2012 in Austin, TX. He was the son of Edwin and Violet Mary (Dryden) Bronaugh. He married Geraldine Kelley, Dec. 10, 1955. He received a BA degree in Physics and Mathematics (with an arts minor in music and language), from East Texas State University (now Texas A&M University), Commerce, 1955 and did graduate work in Physics until entering the U.S. Air Force. In the Air Force, Mr. Bronaugh worked in flight operations as a transport pilot and as a rescue coordinator, and in communications and electronics as a base communications officer and as a command control communications director USAF, 1955, advanced through grades to captain, 1961, various communications, and ops. assignments, 1955-68; major USAFR, 1968; Mr. Bronaugh was awarded the Bronze Star Medal and the Air Force Commendation Medal for his service in Vietnam.

Mr. Edwin L. (Ed) Bronaugh was a Life Fellow of the IEEE, an Honorary Life Member of the EMC Society and a Life Member of the IEEE Standards Association. He had often served on the EMC Society Board of Directors, and is a past president of the Society. He also served as distinguished lecturer on EMC topics. He was a member of the EMC Standards Committee and is a past subcommittee chair and vice chairman of ANSI-Accredited Standards Committee C63®. He was a member of the U.S. Technical Advisory Groups for CISPR, CISPR/A and CISPR/I. The EMC Society awarded him the Certificate of Appreciation in 1979, the Certificate of Achievement in 1983, the Certificate of Acknowledgment in 1985, the Richard R. Stoddart Award in 1985, the Lawrence G. Cumming Award and the Standards Medallion in 1992, a Standards Development Certificate in 1993 and the IEEE Third Millennium Medal in 2000. He was also the recipient of the 2009 IEEE Electromagnetic Compatibility (EMC) Society Hall of Fame award.

He authored a book on EMI measurements (Electromagnetic Interference Test Methodology and Procedures, 1988) as well as authoring over 150 papers in professional meetings and publications. He was a member of the EMI Standards and Test Methods Technical Committee, the Electromagnetic Radiation Technical Committee and the Aerospace EMC Committee of the SAE. He was a senior member of the International Association for Radio, Telecommunications and Electromagnetics (Certified EMC Engineer). He is listed in Who's Who in America, Who's Who in the World, Who's Who in Science and Engineering, Who's Who in the South and Southwest, and Men of Achievement. As a member of the Association of Old Crows, he was President of the Billy Mitchell Club from 1976-78.

He did work in characterization of automotive ignition interference to satellite communications and the hazards of high-strength electromagnetic fields to automotive electronics. Mr. Bronaugh developed specialized EMC instrumentation applying isolated electromagnetic field probes to produce accurate field measurements inside shielded enclosures. He developed optical communications systems using fiber-optic links in specialized EMC instrumentation and applied fiber-optic links to the solution of EMC problems. He developed one of the early automated EMC data acquisition systems with associated computerized data reduction system. He designed radio and telemetry receivers and transmitters and developed solid-state miniaturized multiplex radio relay and repeater systems for remote, unattended operation. He participated in research in the bio-effects of electromagnetic radiation.

Mr. Bronaugh was Principal of EdB EMC Consultants, an independent EMC consulting firm. Previously, he was Lead Engineer for Hardware Design Assurance at Siemens Communication Devices, Austin, Texas; Vice President for Engineering at the Electro-Mechanics Company; Technical Director of Electro-Metrics and Manager of EMC Research at Southwest Research Institute.

Mr. Bronaugh loved music, had a beautiful voice and played the piano, guitar, ukulele, harmonica and as a young man, also the flute and coronet. In addition to music, his hobbies included amateur radio experimentation, camping, automobile mechanics, model railroads, engineering history, learning additional languages, and playing games with family and friends.

He is survived by his wife of 57 years, Geraldine K. Bronaugh, daughter Cecilia Bronaugh and husband, Keith Snodgrass; daughter Dana Weinberg and husband, Stuart Weinberg; grandson, Christopher Bronaugh and wife Lindsey; Bryan Bronaugh and fiancée Michelle Morris; granddaughter Monica Weinberg and fiancée Jason Bray; and grandson, Seth Weinberg.

FCC News

FCC Proposes $5 Million Forfeiture Against Pre-Paid Calling Card Firm

The U.S. Federal Communications Commission (FCC) has proposed a forfeiture penalty of $5 million against a California company for deceptive practices in the marketing of prepaid calling cards to consumers.

In a Notice of Apparent Liability for Forfeiture issued in October 2012, the Commission cited NobelTel, LLC of Carlsbad, CA for targeting immigrant populations with marketing claims that the company's calling cards would provide hundreds of calling minutes to foreign countries for just a few dollars, while failing to conspicuously disclose fees and surcharges that would leave only a fraction of the promised calling minutes available.

According to the Commission, NobelTel is the sixth carrier targeted by the FCC within the past year, with proposed forfeiture penalties totaling $30 million.

The complete text of the Commission's Notice of Apparent Liability for Forfeiture against NobelTel is available at incompliancemag.com/news/1212_01.

The Commission has also issued an Enforcement Advisory which provides consumers with specific information regarding prepaid calling card fraud. The Advisory is available at incompliancemag.com/news/1212_02.

FCC Proposes Changes in Amateur Radio Service Rules

The U.S. Federal Communications Commission (FCC) has proposed changes related to the issuance and renewal of operator licenses under its Amateur Radio Service rules.

According to a Notice of Proposed Rulemaking and Order issued in October 2012, the Commission has proposed the following changes:

- Grant examination credit for an amateur operator applicant who has formerly held a particular class of amateur operator license;
- Shorten from two years to six months the grace period during which an expired amateur operator license can be renewed; and
- Reduce from three to two the number of volunteer examiners required to administer an amateur license examination.

In addition, the Commission is seeking comment on a proposal to allow for the remote administration of the license examination, and what rule changes, if any, should be made to accommodate remote examinations.

Comments on the proposed rule changes are due to the Commission by the end of November 2012.

The complete text of the Notice of Proposed Rulemaking is available at incompliancemag.com/news/1212_03.

The U.S. Federal Communications Commission (FCC) has proposed changes related to the issuance and renewal of operator licenses under its Amateur Radio Service rules.

Enforcement Bureau Takes Action Against Online Sale of Jamming Equipment

The Enforcement Bureau of the U.S. Federal Communications Commission (FCC) has issued citations against at least six individuals found to be offering cellphone signal jamming devices for sale on Craigslist.

The citations were the result of a two week undercover operation by the Enforcement Bureau in early October 2012, in which 23 separate ads on Craigslist were targeted. The undercover operation is part of an aggressive campaign by the FCC to stop the advertising and sale of jamming devices through online marketplaces.

Jamming devices can block all radio communication within a given area, including 911 emergency system calls made from cellphones and urgent communications by public safety officials. For that reason, FCC rules prohibit the importation, advertising or selling of jamming devices, as well as the use of jamming devices by individuals. Monetary penalties for violation of these rules can exceed $100,000 per violation.

The FCC has issued an Enforcement Advisory which details its rules regarding jamming devices.
The Advisory is available at incompliancemag.com/news/1212_04.

News in Compliance

FCC News

FCC Updates Cybersecurity Tools for Small Business

The U.S. Federal Communications Commission (FCC) has released an updated version of its online planning tool to help small businesses protect their information technology systems from cybersecurity threats.

Originally released in November 2011, the FCC's *Small Biz Cyber Planner* was designed to help small businesses develop security plans to protect against threats from online sources. The Planner is an interactive tool that will allow a business to create a customized cyber security guide by answering a series of basic questions. Then, by implementing the plan recommended by the guide, a business can better protect themselves, their information and their customers from cyber threats.

Small Biz Cyber Planner 2.0 now includes details about cyber insurance, best practices on avoiding advanced versions of spyware, steps to take in case of system infection, and recommendations on software that enables users to remotely track and erase the hard drives of laptops and mobile devices that have been stolen.

The *Small Biz Cyber Planner* was created through a partnership between the FCC, industry groups, and some of the leading technology companies, including Microsoft, HP, Symantec and McAfee. The *Planner* is available at incompliancemag.com/news/1212_05.

European Union News

EU Commission Releases Updated Standards List for EMC Directive

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the essential requirements of the EU's directive on electromagnetic compatibility (also known as the EMC Directive, 2004/108/EC).

The EMC Directive applies to "any apparatus or fixed installation," and regulates the "ability of equipment to function satisfactorily…without introducing intolerable electromagnetic disturbances to other equipment."

The provisions of the EMC Directive do not apply to telecommunications terminal equipment, which are covered under the essential requirements of Directive 1999/5/EC (also known as the R&TTE Directive).

The updated list of CEN, CENELEC and ETSI standards that can be used to demonstrate compliance with the EMC Directive was published in October 2012 in the *Official Journal of the European Union*, and replaces all previously published standards list for the Directive.

The complete list of standards can be viewed at incompliancemag.com/news/1212_06.

The One Receiver That Catches Short Duration Transient Disturbances And Scans In Seconds…

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This state-of-the art precision DSP based receiver reduces your valuable test time from days to minutes and changes the playing field in EMC receivers. It is extremely easy to operate with all functions menu driven and displayed on a supplied 23" flat panel LED monitor, so you can adjust the necessary test functions and see the disturbances quickly and easily.

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News in Compliance

European Union News

EU Commission Revises Standards List for R&TTE Directive

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate compliance with the essential requirements of Directive 1999/5/EC, covering radio equipment and telecommunications terminal equipment (R&TTE).

According to the Directive, 'radio equipment' is defined as any product capable of communication via emission and/or reception of radio waves. 'Telecommunications terminal equipment' is any device intended to be connected directly or indirectly to the public telecommunications network. The scope of the Directive also includes certain medical devices and active implantable medical devices.

The extensive list of Cenelec and ETSI standards was published in October 2012 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive. The revised list of standards can be viewed at incompliancemag.com/news/1212_07.

EU Sets Eco-Design Requirements for Household Tumbler Dryers

The Commission of the European Union (EU) has issued a regulation implementing new energy efficiency requirements for household tumbler dryers.

The regulation, which was published in October 2012 in the *Official Journal of the European Union*, is considered an implementation measure under the EU's Eco-Design Directive, 2009/125/EC. That directive gives the Commission the authority to establish minimum efficiency standards for those "energy-related products representing significant volume of sales and trade, having significant environmental impact and presenting significant potential for improvement in terms of their environmental impact without entailing excessive costs."

The new energy efficiency requirements for household tumbler dryers, which come into effect beginning on 1 November 2013, are defined in Sections 1 and 2 of Annex I of the regulation. The requirements are based on the unit's energy efficiency index and its weighted condensation efficiency, which are calculated following the methods described in Annex II of the regulation.

The complete text of the Commission's regulation regarding the eco-design of household tumbler dryers is available at incompliancemag.com/news/1212_08.

Do you have news that you'd like to share with your colleagues in the compliance industry? We welcome your suggestions and contributions.

Send news items to the editor: editor@incompliancemag.com

Barley Genome Sequencing May Result in Better Beer (From Our "You Can't Make This Stuff Up" File)

One visit to any neighborhood liquor store or bar will confirm the seemingly infinite varieties of beer already available. But for those not satisfied with the extensive selection currently on tap, recent research on barley may hold promise for even more and better tasting beer varieties.

An international consortium of scientists has reportedly created a "high resolution draft" of the barley genome. Although this may seem like a paltry accomplishment, given the size of the grain, the barley genome is almost twice the size of the human genome.

In addition to its role as an essential ingredient of beer and other alcoholic beverages, barley is the world's fourth most abundant cereal crop, following maize, rice and wheat. Approximately 75% of harvested barley is used for animal feed, with an additional 20% finding its way into alcoholic and non-alcoholic beverages, and 5% in a range of food products. Barley is particularly high in soluble dietary fiber, which can lead to significant reductions in diabetes, cardiovascular diseases and colorectal cancers in humans.

Scientists hope that the sequencing of the barley genome will lead to the development of barley strains that are more resistant to disease and environmental effects. Further research could even provide a grain that is better suited for beer and brewing.

The research study was published in the journal *Nature* in October 2012, and is available at incompliancemag.com/news/1212_10.

CPSC News

Company To Pay $650k Penalty for Failing to Report Defects

A Mississippi company has agreed to pay a civil penalty of $650,000 to settle allegations that it failed to immediately report defects in its inflatable baby boats.

According to the U.S. Consumer Product Safety Commission (CPSC), the company, Aqua-Leisure Industries, Inc. of Avon, MA implemented a recall in 2001 of 90,000 of its Sun Smart brand inflatable baby boats, following 12 reports of the seats tearing and causing children to fall into the water. However, the company continued to produce different versions of the inflatable boats, and received at least 24 additional consumer complaints between July 2003 and October 2008 in connection with faulty or defective seats in the boats. Aqua-Leisure finally notified the CPSC in May 2009 of these additional reports, and issued a recall of 4 million inflatable baby boats in July 2009.

Federal law requires that manufacturers, distributors and retailers immediately (i.e., within 24 hours) report to the CPSC information that a product contains a defect which could create a substantial product hazard, or pose a risk of injury or death to consumers. In this case, Aqua-Leisure received a total of 31 reports of boat seats tearing, resulting in children falling into or under the water. However, no injuries were reported.

In agreeing to the civil penalty, Aqua-Leisure has denied CPSC allegations that the inflatable baby boats posed an unreasonable risk of injury or death, or that the company violated the reporting requirement of the U.S. Consumer Product Safety Act.

Sharper Image USB Wall Chargers Recalled

Atomi, an importer based in New York, NY has issued a recall for approximately 80,000 Sharper Image brand USB wall chargers manufactured in China. The wall chargers are used to recharge electronic devices, such as MP3 players, through their USB connectors.

The company has reported to the U.S. Consumer Product Safety Commission (CPSC) that the chargers can overheat and smoke, posing both fire and burn hazards to consumers. Atomi has received 13 separate reports of the chargers overheating and smoking, and producing acrid smells. However, there have been no reports of consumer injuries.

The recalled USB wall chargers were sold at Burlington Coat Factory, Tuesday Morning and TJ Maxx retail stores, and on various online websites, from October 2001 to September 2012 for between $8 and $13.

Additional details about this recall are available at incompliancemag.com/news/1212_09.

MR. Static

From Electrostatics to ESD

BY NIELS JONASSEN, sponsored by the ESD Association

I have often been asked, "What's the difference between electrostatics and static electricity?" Well, I believe that if there is a difference, it's mostly historical. A hundred years ago, it was all known only as electrostatics, a well-researched field that formed the basis for the teaching of electricity in general.

INTRODUCTION

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

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

~ The ESD Association

Reprinted with permission from:
Compliance Engineering Magazine,
Mr. Static Column

Electrostatics had its own system of units based on the mechanical units of centimeter, gram, and second, plus the electrostatic unit of charge (esu), defined as the charge that interacts with an equally large charge at a distance of 1 cm with a force of 1 dyne. It turns out that 1 esu equals about $3.3 \cdot 10^{-10}$ C.

Voltage was then, as it is now, defined as field strength times distance. Because *field strength* is force over charge, the electrostatic unit for field strength was 1 dyne/esu, and the unit for voltage, called a statvolt, was 1 dyne/esu x 1 cm or 1 erg/esu, so

$$1\ \text{sV} = 1\frac{\text{erg}}{\text{esu}} \cong \frac{10^{-7}\ \text{J}}{3.3 \cdot 10^{-10}\ \text{C}} \cong 300\ \text{V}$$

It's a peculiarity with the electrostatic system that the unit for capacitance, esu per statvolt, turns out to be centimeter. I was reminded of this recently when a colleague asked me to identify a mysterious component marked 1000 cm. He was somewhat surprised when I told him it was a 1-nF capacitor.

Although electrostatics was an invaluable part of physics, if we are looking for specific applications or inventions based on electrostatic principles, we will not find much. There was a period in the middle of the eighteenth century when electrotherapy was in vogue. Semiparalyzed people were treated with discharges from Leyden jars, but the results of theses treatments were not beneficial. (Oh yes, there was also an electrostatic cigar lighter, but if you have seen a picture of that gadget, you'll understand why it never caught on.) There was, however, one very important electrostatic invention: Ben Franklin's lightning rod (see Figure 1).

The simple construction of this device has changed little over the last 250 years, and it is still in use worldwide. The construction, however, may have certain nationally conditioned variations. For instance, until the 1970s in France, all lightning rods on public buildings, such as post offices and police stations, had tips covered with radium (^{226}Ra). The idea was that the increased ionization around the tip would increase the neutralizing current to the base of a thundercloud. Although this was correct—at least in theory—

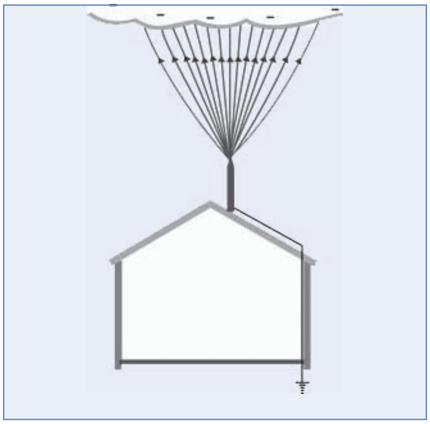


Figure 1: The lighting rod

the rods also produced a little extra radon (^{222}Rn). Because the half-life of radium is about 1600 years, we must hope they had (and still have) a good system for disposing of old lightning rods.

But, with the notable exception of the lightning rod, it wasn't until the beginning of the twentieth century that we found the first industrial application of electrostatics. In 1906, Frederick Cottrell invented the electrofilter or electrostatic precipitator (see Figure 2). The industrial revolution had started to put its black fingerprints on the environment, and the greatest polluters were the smelters and cement mills. The electrofilter was a genuine breakthrough because it trapped ash from coal-burning power plants. It is difficult to imagine what our pollution levels would be like today without this, in principle, very simple but ingenious electrostatic invention.

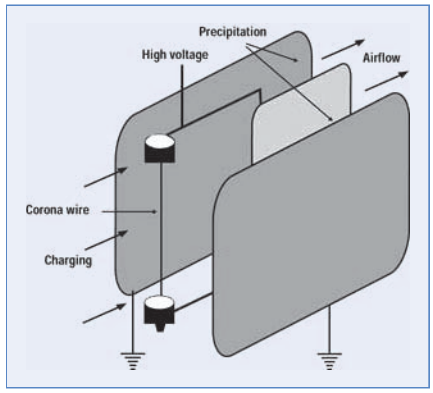


Figure 2: The electrofilter

The precipitator was only the beginning. Soon after, methods were discovered for separating mixtures of widely different types of particles, followed shortly by methods for electrostatic spray painting and for producing dry coatings for the manufacture of grit cloth and sandpaper. All of these inventions were, in principle, very simple. That was not the case, however, with the work of Chester Carlson. With a degree in law and physics, Carlson worked in a patent office and, therefore, understood the need for copies of patent papers. So, he decided to invent a better copier. But

MR. Static

when he chose, as a working principle, a combination of electrostatics and photoconductivity, nearly everyone agreed that this combination was never going to work. And everybody was almost right. After years of honing the experiments, however, the end result was the Xerox process, which has had a great impact on society. Still, all of these processes were known as electrostatics.

In the 1930s, explosions in grain silos were reported at a rate of approximately one per week in the midwestern United States. With this and with increasing explosions in hospital operating rooms and in chemical and pharmaceutical laboratories, people called the cause of these explosions static electricity (see Figure 3).

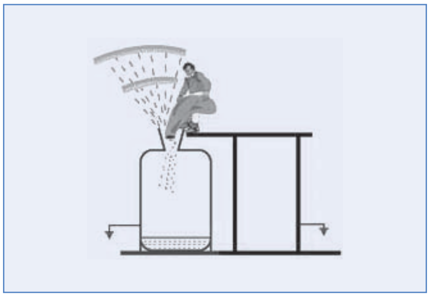


Figure 3: Ignition of explosive vapors

It was quite natural to suspect that an electrostatic discharge was the igniting source in such explosions. But in the 1950s and 1960s, a "new" type of explosion started to appear. Several serious accidents happened when oil tanks were being cleaned with a high-pressure water jet. Although an explosive vapor-air mixture might have originated from the hydrocarbon residue, the ignition source was still unknown. A detailed explanation is too long for this article, but the cause seemed to be a water slug moving in an inhomogeneous field. I've always loved static electricity for its simplicity!

Static electricity was—and still is—a lot more than just explosions. Already in the 1930s, static electricity was a nuisance in the printing industry as well as in the textile industry. Lengths of paper would stick together, and fibers would filter and be hard to control during spinning and weaving. Static electricity made the car radio crackle or caused a minor shock when you handed your nickel to the toll collector. It was these two problems more or less that led to the development in the 1930s of carbon-black-loaded conductive rubber.

With the development in the 1940s and 1950s of all kinds of polymeric materials—such as nylon, orlon, and Teflon—static electricity became a household word. People identified static electricity as the source for why clothing stuck to your body or the reason you got a nasty shock when you touched a water tap. And it was static electricity that made TV screens and monitors dirty. And, according to folklore, static electricity was blamed for headaches and for ruining the "balance between the good negative and the evil positive ions" in the atmosphere.

STATIC ELECTRICITY IN ELECTRONICS

So, by and large, static electricity has always been known as a nuisance. In the 1960s, static electricity spread into a whole new area: the world of electronics. Some people consider the appearance of the metal oxide semiconductor field-effect transistors (MOSFETs) as the start of this period. That is probably an oversimplification. Static electricity had definitely made itself felt in electronics before the MOSFET, but it was little known. Electrostatics, not to mention static electricity, was not really something that fit into the sophisticated electronics world.

However, when the output of sensitive components showed a high percentage of failures and, even worse, when complicated circuits had latent breakdowns, some electronic physicists considered relations between charges in the nC-range and field strengths high enough to cause breakdown, such as that illustrated in the diagram for a human-body-model event (see Figure 4).

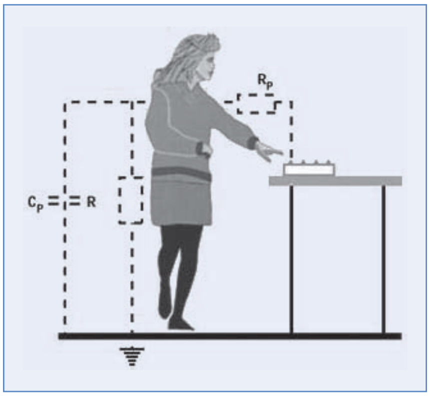


Figure 4: Human-body-model event

Such speculations, of course, didn't do any harm as long as they remained speculations. But when engineers suggested preventive programs, management in electronics companies often balked because such an investment didn't result in an immediate return. The physicists and engineers eventually prevailed, and it is now generally accepted that static electricity constitutes a group of problems to be taken very seriously in almost any branch of electronics.

For many people in the electronics industry, however, the field of static electricity was completely new. Like I've said before, "they Think They Invented It," and since they considered it a new field, they needed a new name, and thus *electrostatic discharge* (*ESD)* was coined.

I first saw ESD in 1983 on an announcement from the EOS/ESD Association, and I learned that it stood for electrostatic discharge. From the name, it appeared that the association was concerned with discharges rather than the charging processes, decay, and other aspects of static electricity. To me, *discharge* has always meant a process where the field creates the charge carriers through an ionization process, as in a spark, a corona, or a brush discharge. When I attended the 1983 EOS/ESD Symposium, I learned that in the electronic industry, ESD referred to any kind of static electric phenomenon. At that time, it was still only in the electronic industry that static electricity was referred to as ESD.

But in the 1990s, the term became a common lexicon. If the pages of a magazine stuck together, it began to be known as ESD, even though such an event was really static cling, a subpart of static electricity, just as electrostatic discharge is a subpart of static electricity. It would be interesting to research the evolution to see how electrostatic discharge came to mean static electricity.

One could also ask, "What do you call a discharge from a charged item when ESD means anything electrostatic?" The electronics industry had an answer to this too. Today, a spark, a corona, or a brush discharge are all known ESD events. Think about this for a minute: means that an electrostatic discharge is an electrostatic discharge event! It's probably too late to correct the language, but couldn't we at least limit the use of the abbreviation ESD to electronic components and circuits. Or, it would be even more better if we only talk about ESD when we truly mean electrostatic discharge.

(the author)

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

ON Your Mark

It's Not a Bunch of Labels – It's a System

BY GEOFFREY PECKHAM

In this column, we'll explore how the safety labels you use on your products should function as a system in order to most effectively improve safety and reduce liability.

As a professional in the electrical engineering field, on a daily basis you're likely striving to stay up-to-date on the latest news and insight related to EMC, product safety, and designing for compliance and regulatory updates. That's no easy task. When it comes to communicating safety, you understand the importance of the safety labels and markings for the products you design or manufacture. Yet this is just one part of your work and areas of responsibility, and as such, you may be looking at your labeling singularly – not as a part of a larger picture of safety. I'd like to introduce to you a concept, a different perspective on safety messaging: Look at your product safety labels as a *system*, specifically a safety communication system.

We typically don't think about safety signs as anything more than a sign on a wall or a product. So, what exactly do I mean by seeing your safety labels as a system? Actually there are three different "systems" at work here:

First, the label (if it's a best practice label based on the latest standards) is a system in and of itself. It's made up of a variety of standardized and tailored elements (color, text, borders, shape, size, and graphical symbols) that are designed to work together to effectively communicate the intended safety message to the intended audience. (See Figure 1.)

Second, each of your safety signs and labels works within a larger system:

- For product safety labels, this "system" is the product itself and all of the other safety labels you may be placing on it.
- For facilities and public environments, the "system" is the context in which each sign is placed and all of the other safety signs you have installed in the location.

For example, a product safety label on a machine near a potential hazard, such as an electrical hazard that could exist if someone needs to service an electrical panel, may refer the viewer to another safety label that details a lockout/tagout procedure. (See Figure 1). Both labels reinforce each other and work as a "system" to convey important safety information.

Another example would be to place a multi-hazard warning label on the machine's control station, and then to place the specific hazard alerting safety label on the machine at the potential point of interaction with the hazard. Again, the two labels work together to reinforce and remind people of potential hazards.

A third example of a systematic way to present safety messages is to use a "Read and understand manual" safety label on the machine, putting the viewer on notice that they should read the machine's operation and/or maintenance manual so they are fully aware of the manual's detailed instructions and precautions so they avoid injury when operating or maintaining the equipment. (See Figure 2). The value of combining the placement of a "read manual" safety label on a machine with a well-written set of instructions that has accurate, embedded safety messages cannot be overstated. I lecture at the University of Wisconsin's Engineering Department's professional development course on warnings and instructions twice a year on this topic and over the last decade, we've seen this practice implemented successfully many, many times. Both accidents are reduced and lawsuits are dismissed because "adequate warnings" were given, both on the equipment and in the equipment's manual.

The third way your labels and signs can work as a "system" has global implications. By using the latest best-practice ANSI and ISO standards to format and communicate your safety messages, you'll be joining the effort to implement a global system for communicating safety information. Consistency is the key here. Using the design principles and graphical symbols that appear in the principle standards having to do with safety signage will include you in this "system." The theory behind standardization in this field is that through the consistent visual presentation of safety information, greater recognition and understanding of safety messages will occur. With greater understanding comes less confusion, better decisions, and fewer accidents. This is an important concept and it's the reason why I dedicate so much time to my work on the ANSI and ISO standards committees. With the implementation of these best-practice standards-based systems on your products and in your facilities, the lives of people now and long into the future will be better protected from harm.

Figure 1: Best practice safety labels communicate complete hazard information – using components like color, text, and symbols that all work together as a system. (Label design ©Clarion Safety Systems.)

Figure 2: Safety labels can reinforce one another, and reinforce critical safety messages, with consistent communication and best-practice, uniform design principles. (Label designs ©Clarion Safety Systems).

When you recognize that your safety signs and labels are not just solitary messages but belong to a wider system of safety communication, you can literally participate in having a positive impact on the world. So when it comes to developing the labels that are going to appear on your products and the signs that go in your facilities, ask yourself these questions:

- Does each of your signs and labels use the right system of standardized and/or tailored components to most effectively communicate the safety message at hand?
- Do they fit within the larger system of safety information (other safety signs, labels and markings) that are present on your product or posted in your facility?
- And do they use the proper international system of formatting and graphical symbols that's been established by the latest global standards – standards that are establishing a worldwide safety language meant to protect people from harm?

Saving lives…. there's no greater reward for our efforts.

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

(the author)

GEOFFREY PECKHAM

is CEO of Clarion Safety Systems and chair of both the ANSI Z535 Committee and the U.S. Technical Advisory Group to ISO Technical Committee 145-Graphical Symbols. Over the past two decades he has played a pivotal role in the harmonization of U.S. and international standards dealing with safety signs, colors, formats and symbols. This article is courtesy of Clarion Safety Systems

As-Found: Out-of-Tolerance What to do next?

BY PHIL MISTRETTA

When calibrated test equipment is found in an out-of-tolerance condition, there is additional risk to all products on which it was used. It is important to understand the magnitude of the potential risk because it can lead to dangerous consumer situations and additional business costs.

Typically quality systems have a procedure for handling non-conforming material, however, this is non-conforming instrumentation used in a process, not material produced by a process. There is little guidance available describing how to evaluate out-of-tolerance conditions leaving engineering and quality personnel to develop their own process. When faced with an As-Found: Out-Of-Tolerance (OOT) condition, a systematic approach to identify what the out-of-tolerance values were, when, where and how the OOT unit was used, will help concentrate your efforts to identify those areas that will need further analysis.

NON-COMPLIANCE

What does out-of-tolerance mean? Calibration is a comparison of a metrology laboratory's standard, with a known value and uncertainty, to the unknown behavior of a unit submitted for calibration. When the unit under test (UUT) does not meet the expected test limits, it is considered to be Out-of-Tolerance. The type of measurement data and calibration information provided can vary widely, depending on the type of metrology laboratory performing the calibration. For instance, at the National Metrology Institutes (NMI), such as NIST, the metrology laboratory

It is up to the instruments' owner to perform any analysis and determine the compliance status of each individual piece of calibrated equipment.

may provide the comparison data only and not utilize any test limits and not make any statement of compliance. It is up to the instruments' owner to perform any analysis and determine the compliance status of each individual piece of calibrated equipment. For the typical NMI customer, this process is relatively easy to handle because they are staffed with highly knowledgeable metrology professionals who are responsible for a limited quantity of lab standards. However, if this is the only information received by a manufacturing environment customer, who has significant quantities of test and measurement equipment, monitoring the behavior of each individual piece of equipment is impractical at best! Fortunately, the manufacturers of test equipment have done most of the analysis work. This is accomplished through the manufacturers' published specifications which describe what type of behavior can be expected for the *majority* of the units manufactured, following a *typical* calibration interval. It is from the Original Equipment Manufacturers' (OEM) published specifications that purchasing decisions are made. It is also from these published specifications that a commercial calibration provider will *most likely* determine the allowable tolerances, or test limits for the calibration process. Many commercial calibration providers offer a default service that uses the OEM's published specifications; however, it is the responsibility of both the customer and the calibration lab (internal or external), to agree upon the specifications which will be used in the calibration process. A customer can request their equipment to be calibrated against any specification they provide. Once the calibration specifications have been agreed upon, the laboratory can calculate the test limits against which the laboratory results can be compared and a statement of compliance can be determined.

STATEMENT OF COMPLIANCE

Most commercial calibration customers are looking for the calibration laboratory to make a statement of compliance for the As-Found condition of the Unit Under Test (UUT). On the surface, making this determination appears rather straight forward and simple, however, upon closer examination, it becomes more complex; there are no perfect instruments and no perfect measurements. All measurements have some degree of uncertainty and how to deal with these uncertainties with respect to making a statement of compliance differs greatly. There are several different approaches which could be used when making compliance statements. Some labs will not make a statement at all; some labs will mark the data that does not meet the limits with an asterisk or some other means, but not make a compliance statement; still other labs will make a compliance statement, quantify the results with an uncertainty value and provide additional consumer risk information. In any case, it is critical for the customer to understand the decision rules used by the laboratory in making any compliance statements.

The statement As-Found: In-tolerance is generally assumed to mean that the entire instrument, all functions, parameters, ranges and test points - are within the calibration specifications at the time of calibration, for the stated conditions at the location where the calibration took place. An As-found: in-tolerance condition is a good indication the UUT was performing within expectations since the last calibration was completed. For the commercial calibration customer who has hundreds or thousands of calibrated items, the statement of compliance may be the single most important piece of information on a calibration certificate. In essence the metrology laboratory, staffed with measurement experts, has completed an initial data evaluation and concluded the unit to be performing within the agreed upon specifications so the customer does not have to spend very much additional time reviewing the calibration. Likewise an As-Found: Out-Of-Tolerance (OOT) condition indicates that at least one data point in the data report drifted or shifted beyond the allowable tolerance limits and the measurements it was providing may not have been accurate at some point since the previous calibration. Again, the laboratory measurement experts have indicated that this unit had a problem and needs further analysis *by the customer*. The As-Found: Out-Of-Tolerance statement of compliance is the flag or trigger for many quality or manufacturing engineering departments to start an investigation, evaluation or analysis.

THE PROCESS

The object of the OOT evaluation process is to identify the at risk products the Out-of-Tolerance units touched. The following approach is not very difficult and follows a logical

ROHDE&SCHWARZ

Reducing your EMI test times

Electromagnetic compatibility (EMC) is the capability of an electrical device to operate in its environment without disturbing or being disturbed, making it an important criterion of product quality. To ensure EMC of a product in the most economical way, appropriate measures must be taken early in the design phase. Even then, the planning and implementation of practice-oriented EMC test systems requires a great deal of specialized knowledge and experience. It can also be costly and time consuming, and EMC test labs are under constant pressure to increase their test throughput and efficiency. As a result, tools with built-in intelligence and a faster measurement speed is of the essence.

Figure 1: R&S®ESR EMI Test Receiver

Yes, it's that fast

Rohde & Schwarz, technology leaders in the field of EMI test receivers, recently introduced the R&S®ESR test receiver (Figure 1). This receiver features time domain scan, an FFT-based (Figure 2) receiver technology that allows it to perform measurements up to 6000 times faster than traditional EMI test receivers. Standard-compliant EMC measurements which took hours in the past, can now be completed in just seconds, saving users valuable time during product development and certification. This also applies to measurements across wide frequency ranges, as well as small step sizes, or to disturbance voltage measurements using quasi-peak and average weighting. This measurement method offers significant advantages when the DUT can only be operated for short periods for testing, i.e. in the automotive and lighting industry. The R&S®ESR measures conducted and radiated disturbances in the frequency range from 10 Hz to 7 GHz in compliance with the CISPR 16-1-1 standard.

Two for one, in real-time

Besides offering functionality for EMC conformance testing, the R&S®ESR also functions as a full featured powerful signal / spectrum analyzer with real-time spectrum analysis capability opening up totally new analysis capabilities and providing new diagnostic tools such as a spectrogram, persistence mode and frequency mask trigger. The spectrogram function seamlessly displays the analyzed spectrum over time and records measurements for up to five hours, allowing developers to detect hidden or sporadic signals and analyze their causes. The frequency mask trigger responds to specific events in a spectrum. If the mask is violated, a trigger is activated. The measurement is stopped, and the user can analyze the exact cause and effect of the signal. The persistence mode allows users to clearly differentiate between pulse interferers and continuous interference. It displays the probability distribution of occurring frequencies and amplitudes in various colors, making it possible, for example, to detect narrowband interferers that are hidden by a strong broadband disturbance signal.

Figure 2: FFT-based time domain scan for ultra-fast measurements

Intelligent operation

The R&S®ESR not only features outstanding functionality, it also scores top marks for ease of operation and its clearly structured touchscreen. The various measurement modes are distinctly separated, and the operating mode can be switched at the press of a button. Users can quickly and easily configure complex measurements and automated test sequences directly on the touchscreen. In addition, the R&S®EMC32 software can be used to remotely control the R&S®ESR and integrate it into complex EMC systems for automated measurement sequences.

For more information on the R&S®ESR test receiver, visit rohde-schwarz.com/product/ESR

White Paper

Increase the speed of CISPR 16 compliant EMI measurements using time-domain measurements. Learn how. **Scan the QR code or visit http://goo.gl/8mVSn to download.**

The first thing to do when faced with an out-of-tolerance unit is to read through the calibration certificate and data to get a firm understanding of what specifically failed calibration.

thought process; however there are a few pitfalls to be aware of and to avoid. This is an investigation; I caution against having the end result already in mind. It is tempting to want the conclusion to show that there were no at risk products because of the work involved. The answers to the questions in the process will lead you to the appropriate conclusion. The approach here is to eliminate products without risk and to narrow down the pool of at risk products.

WHAT IS OUT-OF-TOLERANCE?

The first thing to do when faced with an out-of-tolerance unit is to read through the calibration certificate and data to get a firm understanding of *what* specifically failed calibration. A *complete* set of As-Found and As-Left calibration measurement data is essential for a proper out-of-tolerance evaluation. A Calibration Certificate without data is never a good idea, but when faced with an out-of-tolerance unit, the lack of measurement data will significantly impact the ability to conduct an analysis and quantify any potential risk. If the metrology laboratory provides an out-of-tolerance report that only shows the out-of-tolerance data you have something on which to conduct an evaluation, but even this limited information does not provide a complete picture. A review of all the calibration data should be done to identify what functions, parameters, ranges and test points were found out-of-tolerance. For example, let's say a voltmeter has a full scale range of 1000 V, a resolution of 1 V, and an accuracy of ± 5 V, and the unit was found to read 1006 V at full scale (out-of-tolerance) and in-tolerance at all the other readings which were taken every 200 V. This means that during the use of the voltmeter, over its most recent calibration cycle, any measurements between 800 V and the full scale 1000 V were likely giving erroneous values to the user of the meter for the measurements taken. Again, a full set of data will be very helpful at this point in answering questions like: how many points within a range were out-of-tolerance; was the entire range out of tolerance; were all the ranges even checked; was there a linearity issue; was only the zero out-of-tolerance; or only the full scale reading out of tolerance; were other relevant test points close to or at their limits? The quality of the calibration and quantity of data available can have a tremendous impact on narrowing the scope of the evaluation at this point.

WHEN DID IT HAPPEN?

The next step should be to identify the *time frame* during which questionable measurements may have been taken. This objective is to identify a specific time when the instrument was last known to be taking correct measurements. Often, this is going to be the previous calibration date; the historical calibration certificate will have this date. Basically, the unit was known to be measuring correctly when it left the metrology lab through its As-Left measurement data on the most recent calibration certificate. This will provide a starting point to work from, and most likely the longest period to examine. If you are fortunate to have a well developed measurement assurance program, you might have collected additional data during the period in question which can reduce the evaluation time frame. Most metrology laboratories follow good metrology practices (GMetP) and conduct mid-cycle checks, tests, and inter-comparisons, also called cross-checks, to determine the "health" of their measurement processes and provide confidence in the quality of the measurement process. If these checks are documented and have measurement data, you may be able to reduce the period of questionable measurements. For example, let's say the voltmeter in a production cell was found out-of-tolerance during its annual calibration, but you have a process where a precision voltage source is used to verify the performance of the voltmeter every quarter. A review of this data may allow you to conclude the voltmeter was performing accurately 3 months ago, so the questionable period is only going to be the last 3 months instead of 12 months which significantly reduces the pool of potential at risk products. A schedule of cross-checks and inter-comparisons is often developed for critical measurements or high volume processes in order to reduce risk, liability, and evaluation time.

WHERE IS IT USED?

The objective at this point is to identify *where* this instrument has been used during the questionable period. This is where the really big challenges can start. Typically, this is where the last link in the chain of traceability is often broken, linking the actual calibrated instrument to the processes, products and services provided. The ease of identifying potential impacted product depends upon the design of the end users processes and systems.

In a large facility test equipment can move around without tracking its location. This is especially true of handheld instruments and bench level instruments. A robustly designed system with strict instrument control procedures will be able to identify exactly where any given instrument was located for any given time frame. Nearly all companies have a system that assigns an identification number to each instrument, and some even track its assigned department or location, but few systems track the movement of equipment within the facility and even fewer log the date and use of instrumentation. The maintenance of such an instrument movement log must be strictly followed, any hole or missing location data will bring any evaluation to a halt. Imagine a facility with 50 identical instruments that move around different production cells without any control. It would be impossible to identify what measurements or products it touched and what errors went undetected. With a robust tracking system that indicates if and when this instrument moved, you should be able to identify where this instrument was at any given time.

HOW IS IT USED?

The last step in the out-of-tolerance information gathering process is to identify how the out-of-tolerance instrument was being used. Determine exactly what measurements were being made at a given location, during the time frame in question. This information will likely be found in the end users procedures, or the operator's work instructions, or an engineering specification. The objective at this step is to determine whether the out-of-tolerance instrument *could* have affected any of the products manufactured or services provided by this instrument, in this time frame, in this location, for these measurements. This can be accomplished by reviewing the process documentation, and all revisions that were in effect during the time frame in question, for the out-of-tolerance measurements that were identified in the first step. Were any of the out-of-tolerance functions, parameters, ranges and test points used to make the measurements listed in the process documentation? If the answer is no, congratulations, your evaluation has ruled out the potential risk to product. Now you just have to completely document the steps you have taken, your conclusion and justification, as any auditor will tell you, if it isn't written, it didn't happen, you must produce objective evidence.

ANALYZING THE IMPACT

If the process documentation indicates that measurements *were* taken using any of the out-of-tolerance functions or ranges, then you have to go further and quantify the severity of the impacted products or services. Now comes the most difficult part of the process, quantifying the impact on products and services. In order to effectively complete this analysis, a thorough understanding of the affected process is necessary and a working understanding of tolerances and the application of uncertainties is extremely helpful. Due to the wide variety of applications and situations possible, a few sample cases will be used to illustrate the analysis process for common situations likely to occur.

Case 1: No Impact

Let's say the process documentation states that the voltmeter is used to measure a 600 V on a product with a process tolerance of ± 10 V. Since our process measurement was *not* in the out-of-tolerance portion of the meter (800 V to 1000 V), we can conclude with reasonable confidence that no product was affected.

All this evaluation and analysis is a tremendous amount of work. However, it does not have to be difficult. A well thought out electronic system linking instrumentation to processes and product traceability as part of a measurement assurance program can ease the burden.

Case 2: Impact Evaluation Using Ratios

In Case 2 we will use accuracy ratios in our analysis. An analysis by ratios can help quantify the potential impact by a rough order of magnitude, but may not be sufficient. For instance, a ratio change from 100:1 to 80:1 may be fairly insignificant, but a ratio change from 4:1 to 2:1 could have quite the impact on the end products. A ratio analysis may be a quick way to rule out potential recalls if the ratios involved are sufficiently high. However, if the ratios are low, then additional evaluation becomes necessary. This method may also be the only option available if there isn't any historical process measurement data to review. For example in this case, the process documentation states that the voltmeter is used to measure a 1000 V on a product with a process tolerance of ± 50 V. Since our process measurement *was* in the out-of-tolerance portion of the meter (800 V to 1000 V), product *might* have been negatively impacted. We need to go a step further and compare our process tolerance to the magnitude of the out-of-tolerance data. The process tolerance in this case was ± 50 V, so our process limits are 9950 V to 1050 V. The accuracy of the meter was ± 5 V which means the meter is 10 times more accurate than our process tolerance giving us a Process Accuracy Ratio (50 V / 5 V) of 10:1. Now the calibration report stated the meter was reading 1008 V when the calibration lab injected a precision 1000 V into the meter, which basically means the meter behaved as if it had an accuracy of ± 8 V which drops our Process Accuracy Ratio (50 V/ 8 V) to 6.25:1. Is the risk due to a reduced process ratio acceptable? That comes down to a business decision.

Case 3: Impact Evaluation Using As-Found Calibration Data

In this case, the process documentation states that the voltmeter is used to measure a 1000 V on a product with a process tolerance of ± 50 V. Since our process measurement *was* in the out-of-tolerance portion of the meter (800 V to 1000 V), product *might* have been negatively impacted. We need to go a step further and compare our process tolerance to the magnitude of the out-of-tolerance data. The process tolerance in this case was ± 50 V, so our process limits are 9950 V to 1050 V. The out-of-tolerance data indicated that the meter was reading 1008 V, or out of specification, beyond the upper tolerance limit of 1005 V, by +3 V. This additional 3 Volt error is well below our ± 50 V process tolerance, so there wasn't a problem…. or was there? You might want to jump to that conclusion, and you would be correct as long as your process stayed centered on 1000 V, but what if your process moved around and didn't stay centered? Isn't that why process tolerances are created to begin with! To figure out what is going on here, go back to the fact that the meter was reading high by +8V; the meter has a total +8 V bias or offset. The meter was actually delivering process limits of 9958 V to 1058 V. Which means any measurements greater than 1042 V during the time frame in question actually exceeded the upper process limit. With this information, you should review any historical process measurement data you have and identify any products that had measurements greater than 1042 V. You have now identified the specific units that might have been impacted by the out-of-tolerance unit and may have to be recalled. But wait, there's more! Remember, no measurement is perfect, so what about the metrology labs measurement data, doesn't that have some error in it too? Why yes, yes it does….

Case 4: Impact Evaluation Using As-Found Calibration Data and the Lab's Uncertainty

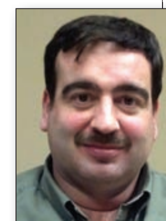
Continuing with Case 3 information, let's say the metrology lab reported their uncertainty for the measurement: 1008 V ± 7.1 mV. That means the value they report lies somewhere between 1007.9929 V and 1008.0071 V. This additional uncertainty will carry on down to the process tolerance calculation. So in the worst case the meter was actually delivering process limits of 9957.9929 V to 1058.0071 V, which in our case is insignificant because the resolution of the meter is not sensitive enough to see this small difference in voltage. It is interesting to note that in this situation the metrology lab had an uncertainty of ±7.1 mV for the calibration against the unit's tolerance of ± 5 V which provides a calibration Test Uncertainty Ratio of 704:1 (5 V / 7.1 mV) meaning the calibration lab standards were over 704 times more accurate than the meter being calibrated. Here is where the value of that pesky Test Uncertainty Ratio those metrology guys are always talking about comes into play. Had the metrology laboratory's uncertainty been ± 1.25 V, their reported measurement would have been 1008 V ± 1.25 V, and the TUR would have been 4:1 (5 V/ 1.25 V) meaning the meter would have actually been delivering process limits of 9957.675 V to 1059.25 V, which when rounded by the resolutions of the meter become 9958 V to 1059 V. Now this additional count might not seem like a big deal, but it does increase the size of the potential recall and increase the potential risk and cost.

Again, here is where a complete calibration report with As-Found and As-Left data becomes very helpful. This is also the point where the Test Uncertainty Ratio (TUR) and the Uncertainty of the Calibration Laboratory come into play and why all calibrations should include uncertainties for every measurement. The laboratory's uncertainty information on the measurements they provide will give you the information to further refine your evaluation and subsequent analysis. Every bit of measurement information at your disposal allows you to make additional distinctions, observations, calculations and improves the quality and confidence in your conclusions and recommendations for further actions. The cost of a single product recall will far exceed the additional cost associated with a complete calibration which includes As-Found and As-Left data with uncertainties.

As cases 2, 3, and 4 illustrate, an out-of-tolerance instrument that could affect the end product or service can lead to a tremendous amount of work because the analysis will need to be completed for each product or service identified. This could lead to hundreds or thousands of calculations! As you can imagine, any effort spent in the four steps (what, when, where, and how) in the evaluation process which eliminates additional products to be analyzed is well worth the time. When faced with an As-Found: Out-Of-Tolerance (OOT) condition, a systematic approach to identify what the out-of-tolerance values were, when, where and how the OOT unit was used, will help concentrate your efforts to identify those areas that will need further analysis. The objective is to filter out as many possible items that do not need closer analysis so you can get to the ones where detailed analysis is required in order to quantify the impact to the products or services provided.

All this evaluation and analysis is a tremendous amount of work. However, it does not have to be difficult. A well thought out electronic system linking instrumentation to processes and product traceability as part of a measurement assurance program can ease the burden of out-of-tolerance evaluations and analysis. A measurement assurance program is more than a calibration program; it is a thought process to link and relate measurements through the entire produce life cycle, from concept to end product. Hopefully this approach and general guidelines will ease the burden to solving one of the most dreaded situations in the measurement world: the evaluation of an out-of-tolerance instrument and its potential impact.

(the author)



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Emerging Scanning Technologies for EMC

MICHAEL HOPKINS

Electronic products are designed and tested to a variety of EMC requirements. Although specific requirements and test methods can vary by industry, ESD, transient immunity, RF immunity and RF emissions are evaluated for most products – certainly for all products that require a CE Mark. In order to assist with meeting EMC requirements, new technologies are emerging to help engineers to both locate and correct EMC problems and to assist in design to insure later compliance. These new technologies include tools to pinpoint areas of potential sensitivity, identify emissions with reasonable correlation to far field measurements, and current visualization techniques to track currents flowing into a circuit. Each will be discussed in the following article.

BACKGROUND

To simulate the **effect of an** ESD event during Immunity scanning, a magnetic loop probe is used to subject the DUT to a magnetic field which can then couple into ICs, traces and connecting cables. Before we get into the scanning techniques, it's important to understand why injecting a magnetic field into a circuit to simulate an ESD or other transient makes sense. Further, also electric fields can be used, for example on an LCD display touch screen and the distributed circuit is often sensitive to rapidly changing E-fields.

An ESD event induces currents into a system via cables or a direct discharge to a system, sub-system, or external module. As these currents travel through various paths magnetic fields are generated, which in turn, develop voltages along the way. Large currents that develop large voltages can cause hard failures – device damage --- from which recovery isn't possible and the fault is easy to find (smoke!); smaller currents produce smaller voltages that cause upset but no damage. The system can typically be re-set, re-booted, or may even have self- recovery routines to bring the system back on-line. And it's these failures that are hard to predict or troubleshoot. Scanning with E or H fields does the trick.

ESD events can cause currents of more than 50A to flow directly into a port or via a cable, along a chassis or onto a PCB via secondary discharges. Upset of a system can occur either

The basic technology isn't new: IEC and other standards require testing for upset and when an upset occurs it's necessary to find out why and fix the problem.

from direct effects --- the ESD current flows on a path along a chassis and voltages are developed that can damage components, or from indirect effects where small currents develop fields that in turn, develop small voltages that can cause upset.

As an example of the direct effect of the high ESD current flowing, one needs to remember:

$V = L(di/dt)$

Where V= the voltage developed, L=inductance of the path and di/dt is the rate of change in the amplitude of the current. ESD events have very fast rising currents that are in the picosecond to nanosecond range, so it doesn't take much inductance to develop a significant voltage.

An example of V=L(di/dt) effects can be made as follows:

Assume a poor connection between a USB cable shield and chassis, say a 2nH connection inductance. If we also assume a 5kV ESD event having a current rising to about 20A in 1ns[1]: V=L(di/dt) = 40V! The 40V spike will appear inside the enclosure and drive a current into a board.

ESD upset in a system is often the result of small currents producing localized fields that in turn, are generating small voltages. To give you an idea of voltages required to cause upset in a device, some logic threshold voltages are shown in Figure 1.

Logic threshold levels today can be as low as 0.3V. One can see it wouldn't take much of an ESD event to produce enough voltage to re-set a device if the voltage appeared in the right place.

ESD/EMC IMMUNITY SCANNING

The basic technology isn't new: IEC and other standards require testing for upset and when an upset occurs it's necessary to find out why and fix the problem. Sometimes operator re-set is

Logic Threshold Voltages

TTL	2 to 5V (rarely used today)
CMOS	1.8 volts and less
GTL	<1V

Figure 1: Logic Threshold Voltages

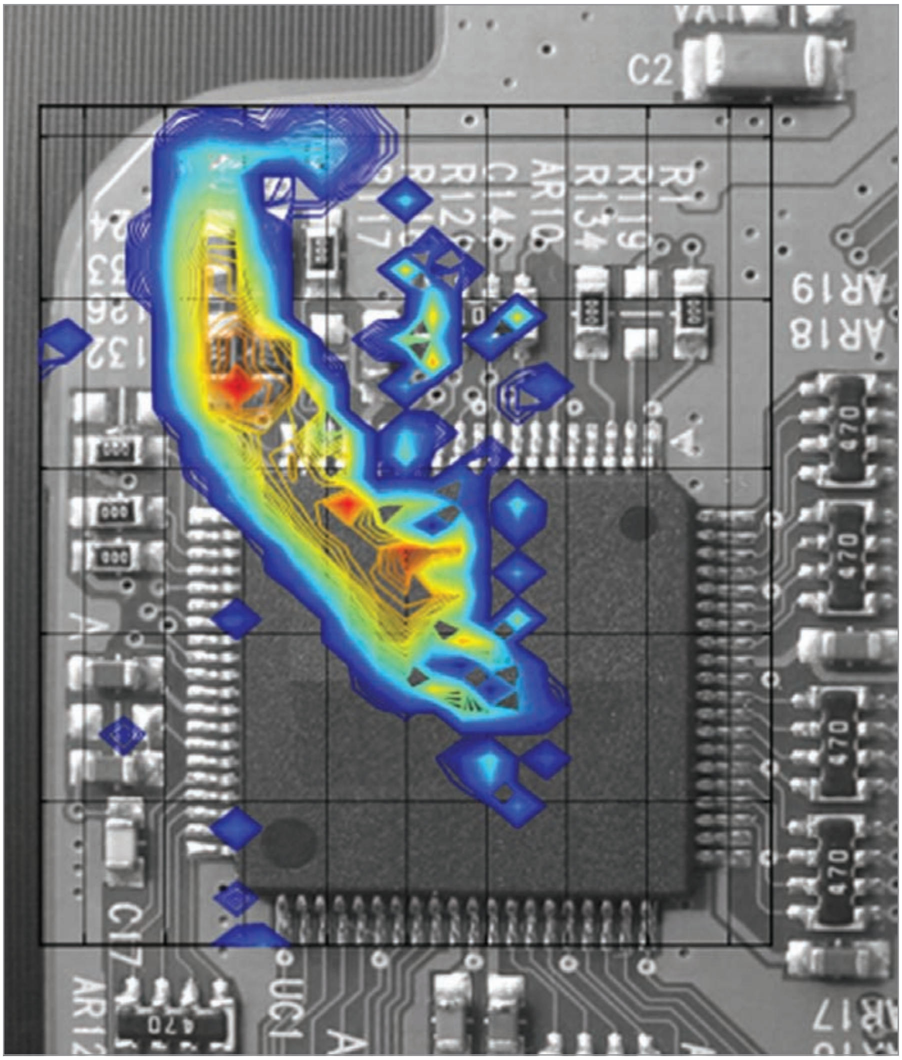

Figure 2: Scan of a sensitive device, colors indicate sensitivity levels, with red being most sensitive *(Courtesy of Amber Precision Instruments)*

1 IEC values are 1.2ns risetimes at 3.75A/kV; therefore a 5kV discharge would provide a current of 18.75A.

Engineers have been using probes to inject fields into a circuit in order to locate trouble spots for some time. Historically, these have been large probes with fields covering a wide area.

allowed, but never for critical systems in avionics, automotive applications and certain medical devices.

Engineers have been using probes to inject fields into a circuit in order to locate trouble spots for some time. Historically, these have been large probes with fields covering a wide area. It's possible to determine an area of a board that is sensitive but difficult to pinpoint the problem device or circuit. Todays crowded circuit boards and physically small components reduce the usefulness of this method significantly.

To get around the size problem, new scanning technologies using very small loops, less than 1mm in diameter, precise positioning and iterative scanning at different levels provides a 3 dimensional display that allows an engineer to not only identify a sensitive component, but also which pins and associated components are involved . Figure 2 is an example of a scan done on a sensitive circuit.

In Figure 2, the source of the disturbance is a pulse induced via a small H-Field loop close to the surface of the board. The resulting voltages and currents are responsible for the device upset. This is, in fact, the mechanism for most ESD caused upsets.

ESD/EMC scanning is done by stimulating a location on a board and observing the system response, taking care to NOT cause circuit damage. An example of an automated system for ESD/EMC scanning is shown in Figure 3.

Upset is automatically detected by monitoring key functions of the system under test. Optical monitors are used to detect changes in a display, V/I monitors for reset lines, audio detectors for some circuits, data streams, etc… almost any key function can be monitored automatically for testing.

Re-set is also a requirement for automated scanning. When a failure is detected, the system being tested needs to be brought back to a known operating state before testing can continue. This can easily be done for most products using external switching to re-set and/or re-boot a system. More complicated systems may require more complex monitoring, such as re-boot, send an instruction to the system to set it in a known condition and then exercise the system to make sure it's functional again.

RF IMMUNITY SCANNING

RF Immunity scanning is a useful tool for locating nodes in a circuit that are susceptible to specific frequencies or ranges of frequencies.

This is basically a sub-set of the EMC immunity scanning described in the previous section. The fully automated scanning system shown in Figure 4 is easily adapted to RF immunity scanning; however, there are some differences in required hardware.

An RF immunity scan requires an RF Sweep generator capable of covering the frequency range of interested as well as the necessary amplifiers to drive the probes. In addition, levels need to be

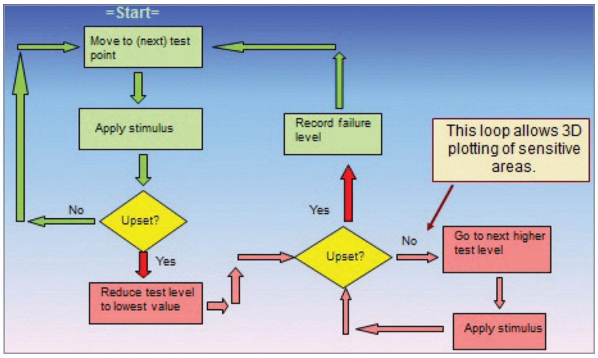

Figure 3: Algorithm for an automated scanner

Figure 4: Fully Automated ESD/EMC Scanner

Using a well-controlled current source and specially designed probes, it is possible to make measurements over an entire DUT and produce a video that shows how the injected currents flow.

automatically adjusted to compensate for the frequency response of the probes. This isn't difficult and is being done all the time with antennas in large chambers used for RF immunity testing of a full system. Numerous software routines and calibration procedures exist and can easily be modified for use with RF Immunity scanning.

All the RF instrumentation and software required for this test is readily available.

EMI SCANNING

The basic scanning system used ESD/EMI Immunity and RF immunity scanning can be used to locate and quantify radiation originating in a circuit. Near-field (NF) EMI scanning is a technique used by several manufacturers to evaluate boards for radiation. This is a useful tool for locating the source of RF radiation and its relative amplitude, but correlation to a far-field (FF) test is difficult. Most EMI scanners provide only NF results, which can be useful, and some scanners use algorithms to estimate the far field but to do it properly and have correlation with FF tests requires having the phase information associated with radiated field.

Maxwell's equations tell us that knowledge of the near field in magnitude ***and phase*** is sufficient to reconstruct a model of the source and obtain the far field emissions. This information significantly improves modeling for RFI analysis, which can be used to predict RFI coupling within a system and in turn, be used to qualify IC's and modules to reduce the chance of RFI problems later in product design.

RESONANCE SCANNING

Resonances in a circuit increase the coupling from an external field at the frequencies of resonance. This is critical for EMC since increased coupling equals an increased transfer of energy from the external field to a resonant circuit and thereby increases the chances of upset or circuit failure. The amount of coupling enhancement due to resonance depends on the Q of the circuit.

Circuit upset due to RF sources generally occurs at specific frequencies and not over a broad spectrum. If an engineer could determine what resonances exist in a design – location, frequency and Q – steps can be taken to minimize the potential for RF Immunity problems.

Resonance scanning can take it one step further by helping to determine the ***likelihood*** of an RF problem in addition to location, frequency and Q. This is done by first doing a resonance scan with the system unpowered to determine location, frequency and Q of a circuit. Since one cannot reasonably test every point at every frequency it ***is*** reasonable to only test at those locations and frequencies where resonances were detected. This is a way to reduce the test time for an RF immunity scan significantly.

Once the RF immunity scan at resonant locations is complete, we then have a complete set of information: location, frequency, Q ***and*** the relative sensitivity at each location and therefore the likelihood that any resonant location will be a problem.

CURRENT SCANNING

Current Scanning is a method of visually re-constructing the current flow on a board caused by a transient event.

Using a well-controlled current source and specially designed probes, it is possible to make measurements over an entire DUT and produce a video that shows how the injected currents flow with a resolution of better than 100ps. This can be extremely useful to determine the performance of protection components and aide in determining where protective devices may need to be located.

In the example of Figure 5, the bulk of the current is diverted through a primary protection device located at the input to a DUT but residual current can be seen traveling toward a semiconductor device that probably has an internal protector. In addition, currents may be observed moving in unexpected directions providing an invaluable tool to the engineers.

SUMMARY

New technologies for EMC can provide significant advantages to design, compliance and test engineers by providing information not previously available: precise location of ESD and RF sensitive circuits and

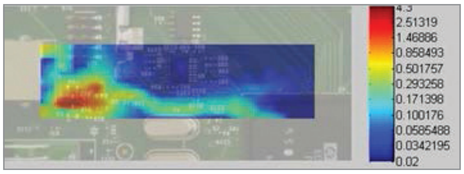

Figure 5: Snapshot of injected current through a TVS device and towards a protected IC

New technologies for EMC can provide significant advantages to design, compliance and test engineers by providing information not previously available.

components, emissions data including phase measurements for far field characteristics, the location of resonant structures on a PCB and last but not least, the ability to produce an actual video of transient current flow into a board. The data provided from these new technologies will allow more accurate modeling for the design engineer and the ability to locate and correct problems found in the field and in compliance testing.

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MICHAEL HOPKINS

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Applied Safety Science and Engineering Techniques (ASSET™)

The Evolution of Hazard Based Safety Engineering into the Framework of a Safety Management Process

BY THOMAS LANZISERO

Applied Safety Science and Engineering Techniques (ASSET) merge hazard based safety engineering and safety science principles in an overall framework of a safety management process to achieve, maintain and continuously improve safety. The ASSET process has been synthesized from current, industry-standard risk assessment and risk management guidelines, including recent ISO, IEC and ANSI publications.

Basic relationships are explored among hazards, exposure and harm to persons, property and the environment. Various potential approaches to protect against harm are then explored in the framework of safety management, systems engineering, quality management systems, concurrent engineering, human factors and other relevant principles.

This ASSET Safety Management process has potential application in virtually any industry and product segment to support informed decisions on solutions to difficult safety issues, using sound safety science and engineering experience and judgment. This article for the 2011 IEEE PSES symposium covers the ASSET safety management process, its guiding principles and objectives.

ASSET OBJECTIVE

The objective of the ASSET Process of Safety Management is to utilize Applied Safety Science and Engineering Techniques (ASSET™), together with existing standards, codes and regulations, to achieve, maintain and continuously improve the safety of products, processes and services for safer living and working environments. ASSET™ (Applied Safety Science and Engineering Techniques) is a trademark of Underwriters Laboratories Inc.

BACKGROUND

This article follows the introductory article *Applied Safety Science and Engineering Techniques (ASSET™): Taking HBSE to the Next Level* (*In Compliance,* Novmber 2012) which was presented at the 2010 ISPCE of the IEEE Product Safety Engineering Society, and had established the case and set the stage for ASSET.

> The ASSET process has application in areas including the development of safety standards, codes, and regulations, and the design, evaluation, compliance, certification and safety management of products, processes and services.

A similar article was published by the American Society of Safety Engineers in their SH&E (Safety Health and Environment) Standards Digest, a publication of their Engineering Practice Specialty. ASSET also reflects concepts of the ANSI/ASSE Z690 series, the US national adoption of ISO 31000, ISO/IEC 31010 and ISO Guide 73, initiating membership on the ISO TAG on Risk Management.

Certain ASSET principles have been applied and presented in recent conferences including the 2009 NASA Aerospace Battery Workshop ("*FTA {Fault Tree Analysis}/FMEA {Failure Modes and Effects Analysis} Safety Analysis Model for Lithium-ion Batteries*"), ASEAN/ ACCSQ 2010 ("*ASEANUS Enhanced Partnership Workshop on Hazard-Based Engineering Principles for the Electrical and Electronic Equipment: A Risk-Based Approach Applied to Li-Ion Battery (LIB) Hazards*"), as well as ICPHSO 2011 (International Consumer Product Health and Safety Organization, "*Hazard Analysis: Hazard Based Safety Engineering & Fault Tree Analysis*"). The ASSET Safety Management process will also be presented for the IEEE and Argonne National Lab, 2011 Today's Engineering Challenges – Tomorrow's Solutions Technical Conference and Exhibition, November in Chicago.

With essential technical input and development of Bob Davidson and strategic leadership of Dan Bejnarowicz, ASSET was developed in the safety management process framework. Notification has just been made that this ASSET work has earned a 2011 IEEE Region 1 Award (Northeastern US) in the category of "*Technological Innovation (Industry or Government): For significant Patents, for discovery of new devices, development of applications or exemplary contributions to industry or government.*"

ASSET is now the subject of a 2-day workshop to put your skills to the test by applying ASSET analysis to example products and prepare to address difficult safety issues using a multi-disciplined, team-oriented approach, supported by science as well as your own experience and judgment.

ASSET APPLICATION

The ASSET process has application in areas including the development of safety standards, codes, and regulations, and the design, evaluation, compliance, certification and safety management of products, processes and services. As such, ASSET applies to functions and responsibilities including safety designers, regulatory compliance, product safety certifiers, standards/ codes developers and product and program safety managers. ASSET can also help to integrate and address the needs of various stakeholders including regulators, AHJs, standards developers, trade and professional organizations, consumer groups, government agencies and the public.

For example, relevant safety requirements are generally determined by first establishing the scope of the product, process, or service in question. This scope is then compared to the scope of identified standards, codes and/or regulations that may potentially apply. The scope and context of the assessment itself is also established, including boundaries, and scope alignment on all three counts is sought. In this early stage and throughout the process, potential gaps need to be identified and bridged. A gap may exist for example, if a product, process or service – in the context of its application – does not fall completely within the scope of existing safety standards. Another gap may exist whereby a product, process or service falls within the scope of a safety standard, but involves features, functions, technologies or applications that may (a) introduce a safety hazard, and (b) not be anticipated or addressed by the requirements in the standard.

ASSET AND STANDARDS

ASSET provides a process and methodology for (a) complementing existing standards in evaluating the safety of products, processes or services, (b) assisting in the evaluation of products, processes or services not within the scope of existing standards, (c) evaluating product features (materials, constructions), functions, technologies or applications not anticipated or covered by existing standards. In these situations, ASSET can be applied to (1) help identify hazards not anticipated or covered by existing standards and the need for additional requirements to meet the safety objective (intent) of the standards, and (2) help identify alternative protective measures not anticipated by the standard but which can achieve an equivalent level of safety to the protective measures specified in the standard, thereby meeting the safety objective (intent) of the standard.

In fact, the ASSET process stages include repeated "specchecks", whereby the initially identified requirements are assessed at each stage.

ASSET SAFETY MANAGEMENT PROCESS

The ASSET process of safety management was developed as the evolution of hazard-based safety engineering principles and safety science into an overall framework of a safety management process. Hazard Based Safety Engineering (HBSE) was originally conceived by HP/Agilent, and targeted typical types of hazards and forms of injury involving electronics products, such as information technology and office equipment.

The ASSET process is based on a number of acknowledged risk management/risk assessment principles and processes, for example those found in publications including but not limited to ISO/IEC Guide 51, IEC Guide 116, ISO 31000, ISO/IEC 31010, ISO 14121, ISO 14971, IEC 60300-3-9 and ANSI/ASSE Z690.

This process involves stages to (a) formulate the right types of questions to identify the scope of the product, system or service to be evaluated for potential harm, (b) identify and analyze hazards (potential sources of harm), (c) identify, analyze and evaluate protective measures to reduce the risk of harm (e.g., risk of injury from products), (d) assist in the determination of whether or not an acceptable level of safety is achieved, (e) understand and apply methods to maintain and continuously improve safety. This can help explain, apply and enhance existing requirements, and help address emerging technologies, products and applications.

This ASSET process was developed to address a broad spectrum of applications, and each stage has different needs and significance for the assessment of different products, processes, services in different applications. The following provides a brief look at each ASSET process stage and its objectives.

Determine Scope/Context

The goals of this stage are to determine and attempt to align the scope and context of the following: the product, process or service to be assessed, the assessment itself and the initially identified requirements. Relevant topics include (a) the subject of the assessment, including systems aspects of materials, components, subsystems, environment and boundaries with interfaces and interactions, (b) intended implementation, operation, use, users and others affected (c) conditions and requirements for installation, (d) recommended procedures for maintenance and repair, (e) potential effects of packing, shipping and storage, (f) reasonably foreseeable misuse (using a sub-process developed to determine degrees of reasonable foreseeable misuse and associated guidance) , (g) other conditions or factors of potential impact, and (h) applicable standards, codes and/or regulations.

Identify/Analyze Hazards

The goals of the stage are to (a) identify potential types and sources of harm

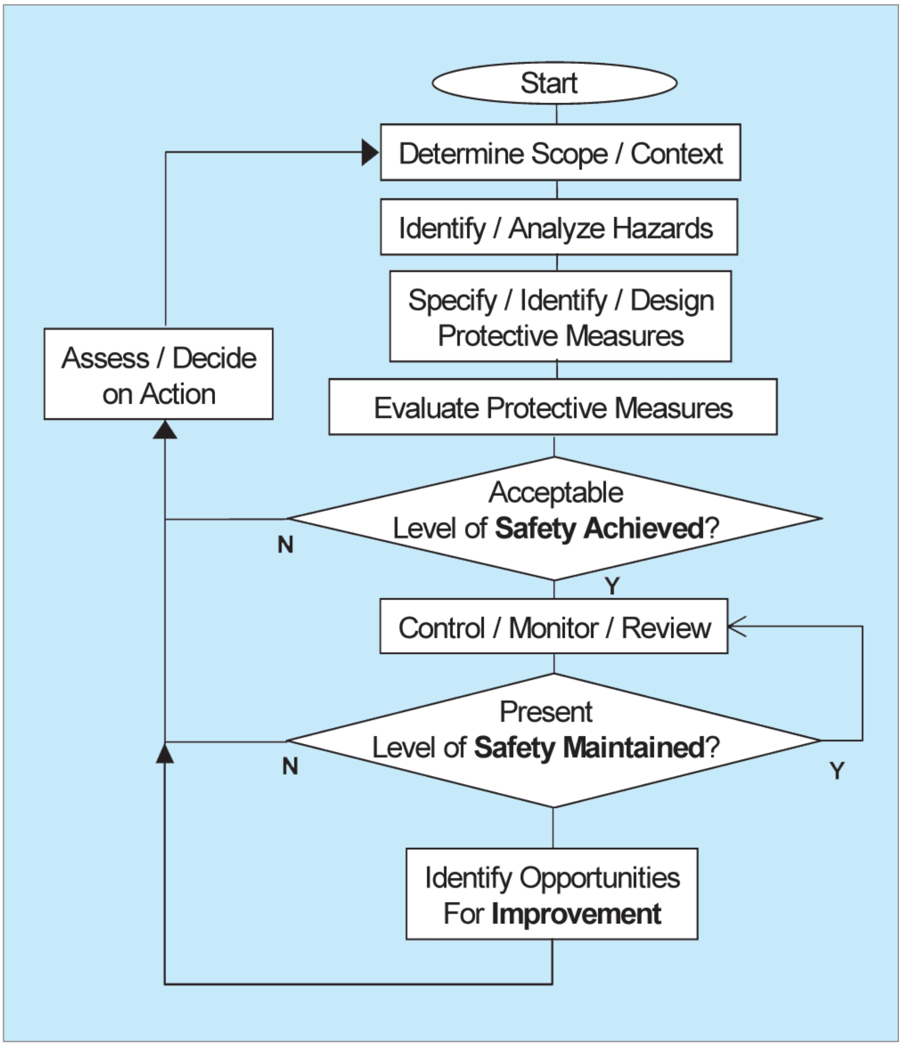

Figure 1: ASSET Process of Safety Management

These stages generally involve activities such as hazard based safety engineering, safety research, safety design, conformity assessment and new standards development.

(hazards), (b) determine how harm can occur (hazardous situations, hazardous and harmful events) and the severity of the harm, (c) sort consequences by the level of severity (initial consequence evaluation akin to worst case scenario, with guidance on severity factors, and consideration of extent and exposure of harm), and (d) determine if the applicable standards, codes and/or regulations address the identified hazards, or if there are gaps that need to be addressed.

Specify/Identify/Design Protective Measures

In this stage, protective measures are specified, identified or designed, depending on the given function and responsibility being fulfilled. For example, a protective measure may be specified by developers of standards, codes and regulations, designed by a manufacturer or identified by an evaluator. This stage has goals to (a) establish the safety objective(s), (b) determine the need for protective measures, (c) identify the potential protective measure strategies, categories and mechanisms, (d) analyze and prioritize protective measures, and (e) specify, design and implement the protective measures.

Evaluate Protective Measures

The goal of this stage is to determine whether protective measures are adequate and effective by (a) evaluating whether and how protective measures meet specific safety objectives, (b) identifying safety attributes that are being relied upon and need to be controlled, and (c) evaluating those safety attributes. In order to determine if the goal of this stage is achieved, key questions are asked which include the following:

- Have all the hazards been identified?
- Have the safety (risk reduction) objectives been determined?
- Have the protective measures intended to address the hazards and achieve the safety objectives been identified and designed?
- Have tests and evaluations been conducted to demonstrate that the protective measures are capable of achieving the safety objectives with acceptable results?
- Have the constructions, components and materials that are relied upon for the protective measure to meet the safety objectives been identified?
- Have their safety-related characteristics (safety attributes), factors which may degrade those characteristics, and the tests and evaluations needed to determine their adequacy been identified?
- Have the necessary evaluations/tests been performed with acceptable results?

Through this point in the ASSET process, these stages generally involve activities such as hazard based safety engineering, safety research, safety design, conformity assessment and new standards development. It is also noted that the evaluation of certain protective measures, including life safety devices, may effectively begin at this stage.

Decision Gate: Acceptable Level of Safety Achieved?

There are two basic outcomes of this safety decision. If it is determined that an acceptable level of safety has been achieved, then there is a need to control, monitor and review to maintain safety. However, if an acceptable level of safety has not been achieved, there is a different need to assess and decide on action. This may involve revisiting earlier process stages or discontinuing.

This point of the ASSET process generally involves conformance and compliance activities.

Control/Monitor/Review to Maintain Safety

At this stage, if determined that an acceptable level of safety has been achieved, the goal is to ensure that safety is then maintained by (a) establishing controls throughout the life cycle, up the supply chain, to ensure that safety is maintained, (b) monitoring field performance down the supply chain and factors that may impact safety by means of surveillance and follow up, and (c) periodically reviewing and assessing results and deciding on appropriate actions.

Decision Gate: Present Level of Safety Maintained?

Similar to the prior decision gate, there are also two basic outcomes of this safety decision. If determined that the present level of safety is being maintained, then there is a need to continue to control, monitor, and review. However, if the present level of safety is not being maintained, there is a different need to assess and decide on action. Again, this may involve revisiting earlier process stages or discontinuing.

This point of the ASSET process generally involves activities including certification, market and conformity surveillance, follow-up for certification mark integrity, updates in regulations, standards and codes, and assessment of new/emerging technologies that may either benefit or threaten safety.

Identify Opportunities for Improvement

The goal of this stage is to monitor and identify the opportunity, or the need, for improvement in (a) safety and safety standards and (b) the processes, methods and tools used to determine whether and how safety is achieved and maintained. These opportunities are then assessed to decide on action, which may involve revisiting earlier process stages.

Activities involved in this stage of the ASSET process include improvements in regulations, standards and codes, as well as improvements in safety assessment processes, methods and tools.

MEETING THE OBJECTIVE

The stated objective of the ASSET Process of Safety Management is to utilize Applied Safety Science and Engineering Techniques (ASSET™), together with existing standards, codes and regulations, to achieve, maintain and continuously improve the safety of products, processes and services for safer living and working environments.

By this we mean to a) achieve an acceptable level of safety (once determined, based on specific safety objectives), b) maintain that present level of safety (throughout the entire lifecycle of the product, process or service, under all anticipated conditions, considering upstream (suppliers) and downstream (users and all affected) the supply chain), and c) continually seek and assess opportunities for improvement (based on the availability, need or demand for improvements).

ASSET stresses the importance of assessing the sources, causes and conditions of harm (as did HBSE before it), as well as the risk of harm (severity, likelihood, extent, exposure). ASSET also addresses different forms of potential harm to various entities, including persons (injury or health risk), property, the environment and even continuity of critical operations and functions. Sources are categorized in terms of energy or matter/substance that may be harmful, from different sources in various forms, conversions or conditions. The standard HBSE tools (3-block energy transfer model for injury, HBSE process to evaluate a safeguard and standard injury fault tree) are adapted and expanded.

Then the most effective protective measure strategies can be determined, with appropriate identification, evaluation and control of safety attributes -the very properties and characteristics of protective measures relied upon to achieve, maintain and improve this level of safety.

The ASSET process supports informed decisions using the best available information, data and other resources, based on the best available knowledge and experience, at progressive stages of development. This can help identify the degree of confidence in the decision and the relative need and value of additional inputs or analysis. ASSET can also serve as a tool for effective communication and interaction to share information, as needed by various stakeholders.

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REFERENCES

1. Risk management - Principles and guidelines, ISO 31000, First edition, 2009-11-15
2. Risk management - Risk assessment techniques, IEC ISO 31010, Edition 1.0, 2009-11
3. Risk management - Vocabulary, ISO Guide 73, First Edition, 2009
4. Risk Management Series: ANSI/ASSE Z690.1-2011 Vocabulary for Risk Management (identical national adoption of ISO Guide 73:2009); ANSI/ASSE Z690.2-2011 Risk Management -Principles and Guidelines (identical national adoption of ISO 31000:2009); ANSI/ASSE Z690.32011 Risk Assessment Techniques (identical national adoption of ISO/IEC 31010:2009)
5. Safety aspects, Guidelines for their inclusion in standards, ISO IEC Guide 51, Second edition, 1999
6. Guidelines for safety related risk assessment and risk reduction for low voltage equipment, IEC Guide 116, Edition 1.0, 2010-08
7. Hazard Based Safety Engineering, Student Guide, 2nd Ed (B.03), Hewlett-Packard Company, Agilent Technologies, Inc., Underwriters Laboratories Inc., 2001
8. Hazard Based Safety Engineering (HBSE) UL Supplement, Underwriters Laboratories Inc., 2003
9. Risk Assessment Guidelines for Consumer Products, Official Journal of the European Union: OJ L22 Vol 53, 26 January 2010, Part IV, Appendix 5
10. Dependability Management, Part 3 Application Guide - Section 9 Risk Analysis of Technological Systems, IEC 60300-3-9, First Edition
11. Safety of machinery - Risk assessment - Part 1: Principles, ISO 141211:2007

12. Medical devices - Application of risk management to medical devices, EN ISO 14971

13. W. Hammer, Product Safety Management and Engineering, 2nd ed, 1993

14. Fault Tree Handbook, NUREG-0492, Nuclear Regulatory Commission, Washington D.C., 1981

15. Fault Tree Handbook with Aerospace Applications, NASA, Washington D.C., 2002

16. Potential Failure Mode and Effects Analysis in Design (Design FMEA), SAE J1739, 2009

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ASSET and HBSE workshops are available through UL.

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This and related hazard analysis and risk assessment work has been extensively published and presented, including keynote presentation on the safety of consumer electronics into the future at the 2012 International Conference on Consumer Electronics (ICCE) by the IEEE CES, 2012 Advanced Product Safety Management course at St. Louis University, 2010 and 2011 International Symposium on Product Compliance Engineering by the IEEE Product Safety Engineering Society, 2011 IEEE Chicago Argonne National Laboratories Technical Conference, International Consumer Product Health and Safety Organization (ICPHSO 2011), Association of Southeast Asian Nations (ASEAN), Asia Pacific Economic Cooperation - Joint Regulatory Advisory Council (APEC JRAC Risk Assessment Workshop), American Society of Safety Engineers (ASSE) and NASA (2009 NASA Aerospace Battery Workshop).

An IEEE Senior Member, Tom is Founding Chair of the Long Island, NY Chapter of the IEEE Product Safety Engineering Society (PSES) and Vice Chair of the IEEE Risk Assessment Technical Committee (RATC). He serves as technical expert in committees for electric shock protection and risk management, including US National Committee Technical Advisory Groups (USNC TAGs), the International Electrotechnical Commission (IEC TC64 MT4) and the International Organization for Standardization (ISO 31000 / ANSI Z690). He can be contacted at +1.631.546.2464 or thomas.p.lanzisero@us.ul.com.

Phase Stability, Loss Stability, and Shielding Effectiveness

BY PAUL PINO

This article addresses phase stability, loss stability, and shielding effectiveness in cable assemblies exceeding 20 feet. Stability and shielding effectiveness behavior of long length assemblies are not well documented and lack standardized test procedures. Phase and loss repeatability is addressed within this writing as a sub-topic of stability.

This document offers basic performance information pertaining to one specific type of microwave coaxial assembly which would typically be used in a test environment where occasional coiling/uncoiling and random movement would occur. Information contained within this piece is for reference purposes only and does not constitute a performance specification for any particular microwave/RF cable assembly.

TEST SUBJECT

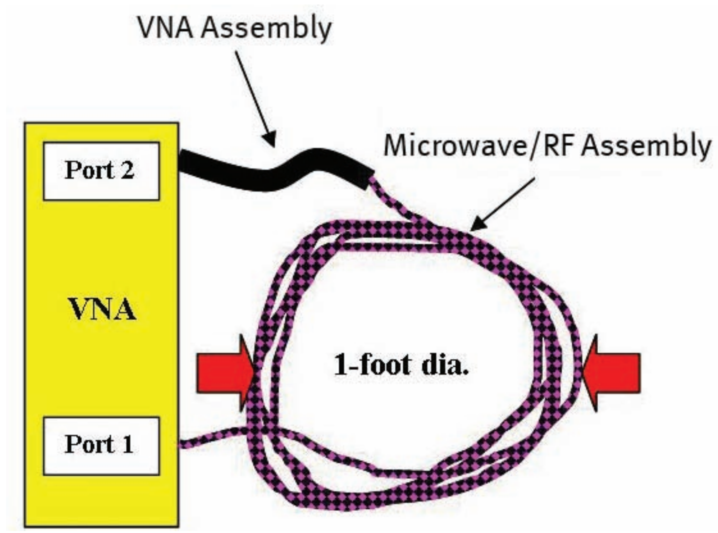
Testing was performed on a microwave/RF Test assembly, 50 feet in length, having the following specifications:

Cable Type: internally ruggedized, enhanced phase stability cable

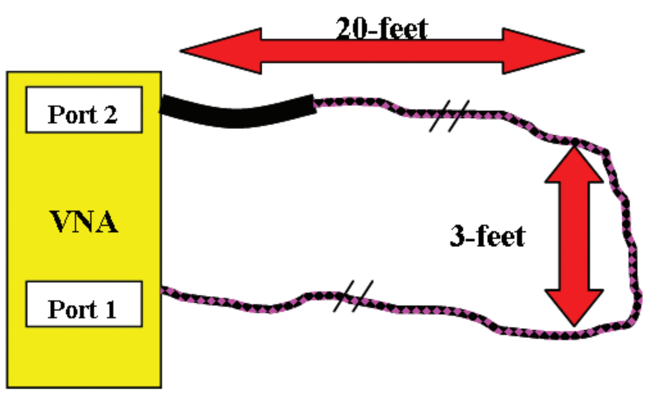
- 18 GHz maximum frequency
- Nominal cable outer diameter: 0.305 inches
- Stranded center conductor
- Minimum bend radius: 1.0 inches
- Crush strength: 250 lbs./ linear inch

Connectors:

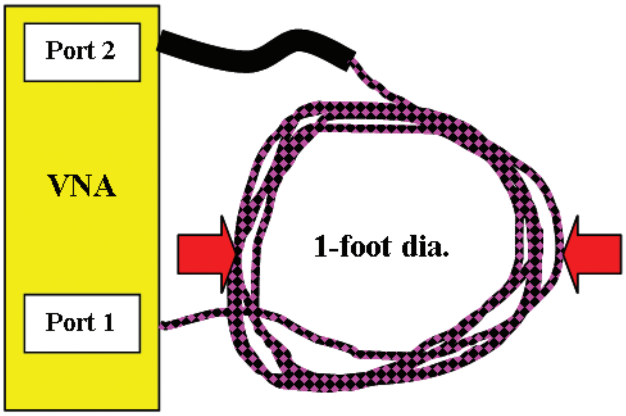
- Connector A-side: precision 3.5 mm pin
- Connector B-side: precision 3.5 mm socket



(1) "Initial Coil" Test Configuration



(2) "Uncoiled" Test Configuration



(3) "Return Coil" Test Configuration

Diagram 1

Assembly Length: 50 feet, measured from connector A-side reference plane to connector B-side reference plane.

TEST EQUIPMENT

Testing was conducted using the following equipment:

Vector Network Analyzer: Agilent Technologies 8510C with 8517B S-parameter test set.

Calibration Kit: Agilent Technologies 85052B 3.5 mm kit with Agilent Technologies 911E and Agilent Technologies 911D sliding loads, 3 – 26.5 GHz frequency range.

Vector Network Analyzer Cables: utilized on port 2 of the network analyzer.

Spectrum Analyzer: Agilent Technologies 70000 series.

Mode Stirred Chamber:

- Custom-built by Global Partners in Shielding, Inc.
- Chamber dimensions: 8 feet x 8 feet x 8 feet

Note: all tests were performed at ambient temperature (approximately 20 degrees Celsius) and pressure (sea level).

PHASE AND LOSS STABILITY TESTING

Stability testing was conducted using the following procedure as seen in Diagram 1. A full 2-port calibration of the network analyzer was performed using a stepped frequency range of 0.066 GHz to 26.5 GHz, 801 points. The cable assembly was coiled and uncoiled several times before being tested to simulate normal handling. Finally, the cable assembly was coiled with loops approximately 1 foot in diameter. The coiled cable assembly was connected to the network analyzer (3.5 mm socket to port 1, 3.5 mm pin to port 2) and s-parameter data was collected. This data set was labeled: "**Initial Coil Data**."

The cable assembly was disconnected from port 2 only, then uncoiled and laid out in a large "U" shape across the laboratory floor. The connection at port 2 was then restored and s-parameter data was collected. This data set was labeled: "**Uncoiled Data**." The cable assembly was disconnected from port 2 of the network analyzer and again coiled with loops approximately 1 foot in diameter. Re-coiling was performed in the same direction as was done when the cable assembly was initially coiled. The connection at port 2 was once again restored and s-parameter data was collected. This data set was labeled: "**Return Coil Data**."

The *uncoiled* and *return coil* s-parameter data were normalized by the *initial coil* s-parameter data set. Phase and loss information was extracted from the normalized s-parameter data. By choosing the initial coil data set as a baseline, one may observe how the phase and loss characteristics of the cable assembly deviate from a known state. Any deviations are assumed to have resulted from physical manipulation of the cable assembly under test.

SHIELDING EFFECTIVENESS TESTING

Shielding effectiveness testing was accomplished through the use of Gore's own mode stirred chamber. Tests were conducted from 1.0 to 18.0 GHz (1 GHz steps) in accordance with MIL-STD-1344A, method 3008. The noise floor of the test environment was verified before each test, as was instrument dynamic range. Efforts were made to keep the bulk of the test cable and its connectors within the working volume of the mode stirred chamber.

The following test procedure was employed as seen in Diagram 2. The cable assembly was coiled with loops approximately 1 foot in diameter. The coiled assembly was placed atop a non-conductive pedestal in the middle of the mode stirred chamber. In this configuration two sets of test data were collected. One data set was collected while the cable assembly connectors were wrapped in a fine-grade steel wool, another set collected while the cable assembly connectors were left unwrapped. Steel wool serves as a supplementary shielding material when wrapped around the cable assembly connectors; this technique is used purely for test purposes. By comparing the shielding effectiveness performance of an assembly with connectors wrapped versus unwrapped, one may more easily determine if the major contributor to RF leakage is connector or cable.

As a final test, the cable assembly was hung in loose loops over a nonconductive line strung within the mode stirred chamber. Test conditions were as stated above. Data was collected for tests with and without connectors wrapped in steel wool.

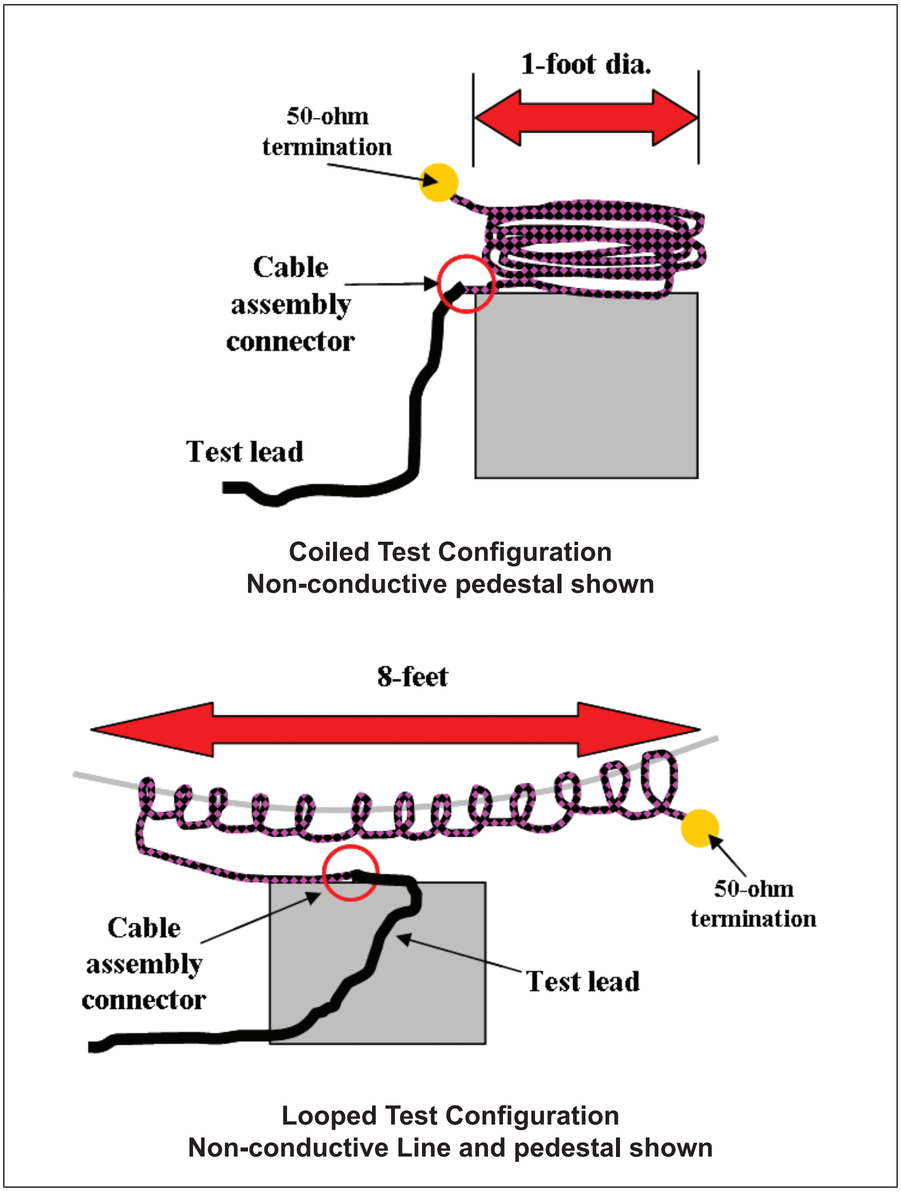


Diagram 2

TEST DATA: PHASE AND LOSS STABILITY/ REPEATABILITY

Figures 1 through 6 show test data.

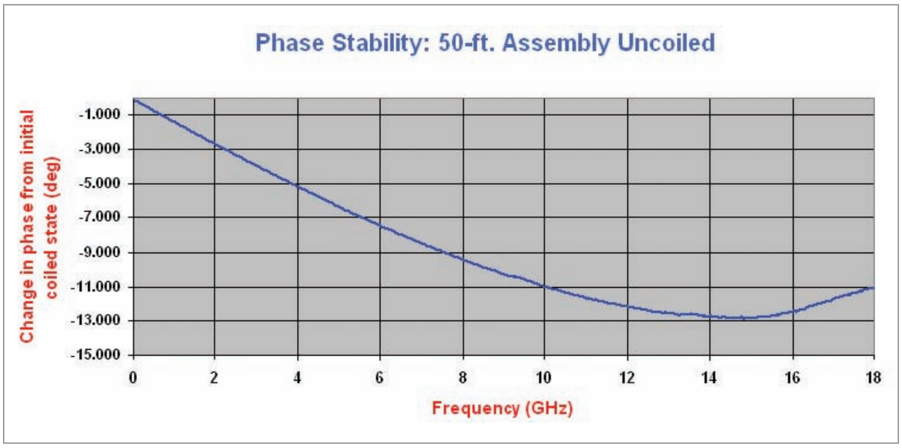


Figure 1: Normalized phase response of uncoiled cable assembly

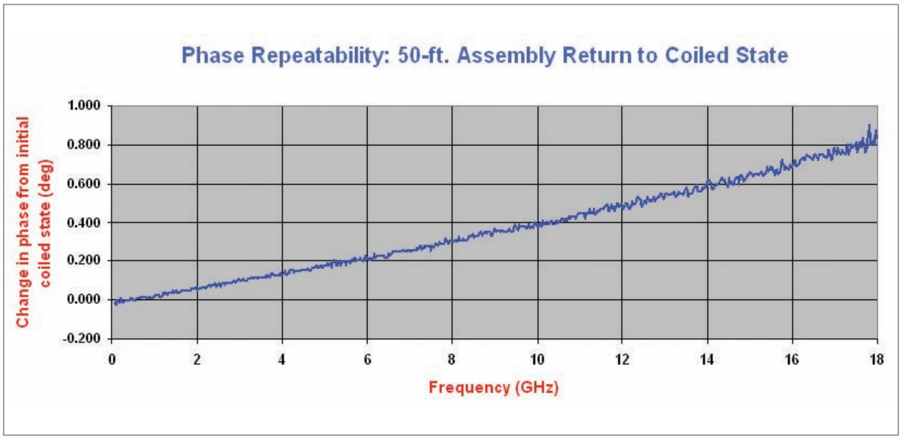


Figure 2: Normalized phase response of cable assembly when returned to coiled state

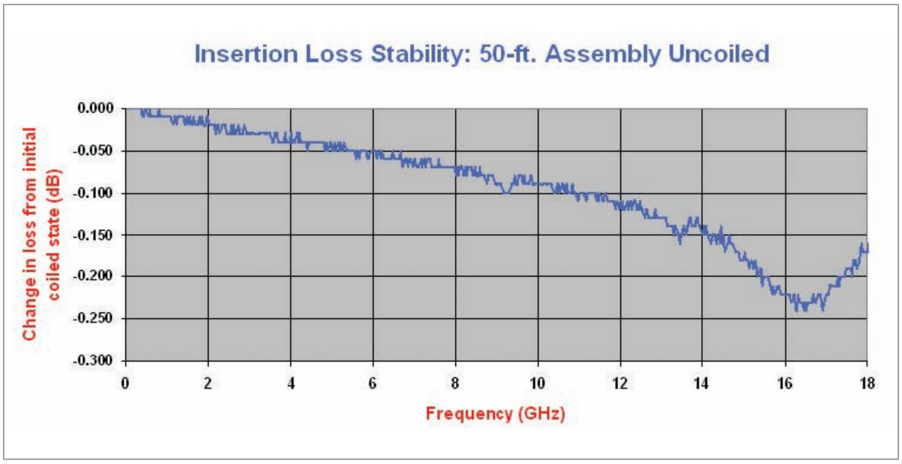


Figure 3: Normalized loss of uncoiled cable assembly

CONCLUSION

Phase Stability and Repeatability

Figure 1 illustrates the phase stability of the test assembly when going from a coiled state to an uncoiled state. It may also be noted that the behavior is essentially linear through 8 GHz. Choosing an arbitrary frequency of 10 GHz, the indicated phase change from an initially coiled state is -11.0 degrees. If one considers that a 10 GHz continuous wave signal will cycle through 219,546 degrees over a 50 foot cable, the 11.0 degree figure represents 0.005% of the assembly's phase length.

A high-performance microwave cable assembly must possess excellent phase repeatability. Phase repeatability refers to an assembly's ability to duplicate its original, or initial phase behavior when the cable has been flexed (or disturbed) then returned to its original, unflexed (or undisturbed) state. Figure 2 illustrates the phase repeatability of the cable assembly. Providing a practical example will highlight the importance of repeatability. The 50 foot test assembly is uncoiled and connected to its respective instrumentation. The necessary calibration procedures are followed and phase is noted at 10 GHz, after which the assembly is disconnected, coiled, and stored for future use. A short time later the cable assembly is uncoiled and reconnected to this same instrumentation and phase is noted. Referring to Figure 2, the user can expect to observe a change in phase of approximately 0.400 degrees at 10 GHz (20 degrees Celsius ambient temperature).

Loss Stability and Repeatability

Figure 3 depicts the loss stability of the test assembly when going from a coiled to an uncoiled state. At 10 GHz, a -0.080 dB change is indicated, which correlates to 0.54% of the test assembly's insertion loss at this frequency. At 2 GHz, a -0.015 dB changes is indicated, correlating to 0.24% of the test assembly's insertion loss at this frequency.

Figure 4 illustrates the test assembly's loss repeatability. Changes in loss from the initial coiled state vary no greater than 0.030 dB from 0.066 GHz through 18 GHz. The practical example provided for phase repeatability can be applied to loss repeatability as well; one may expect a change in loss of approximately -0.010 dB at 10 GHz (20 degrees Celsius ambient temperature).

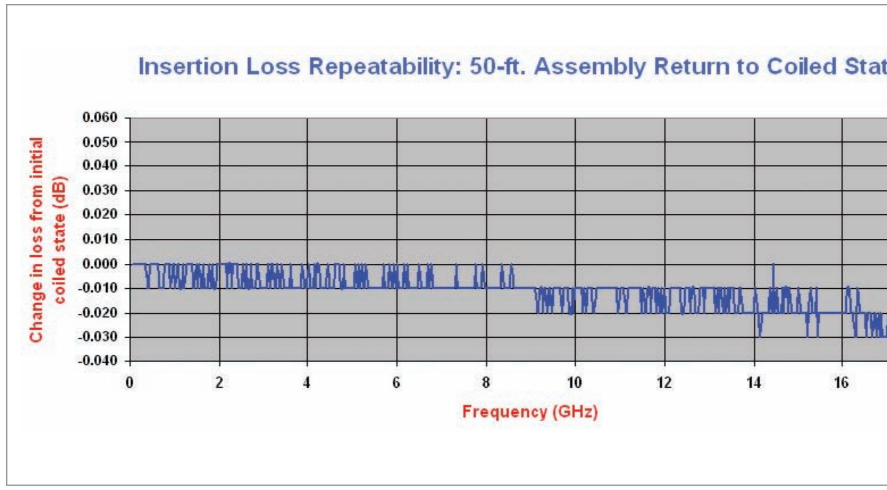


Figure 4: Normalized loss of cable assembly when returned to coiled state

Shielding Effectiveness

Shielding Effectiveness (S.E.) was the only area where a standardized test procedure was used (see Diagram 2 for details). Referring to Figure 5 the S.E. performance of the test assembly is recorded for several different configurations. In all configurations, the S.E. values of test assembly were consistently at or approaching those of the chamber noise floor.

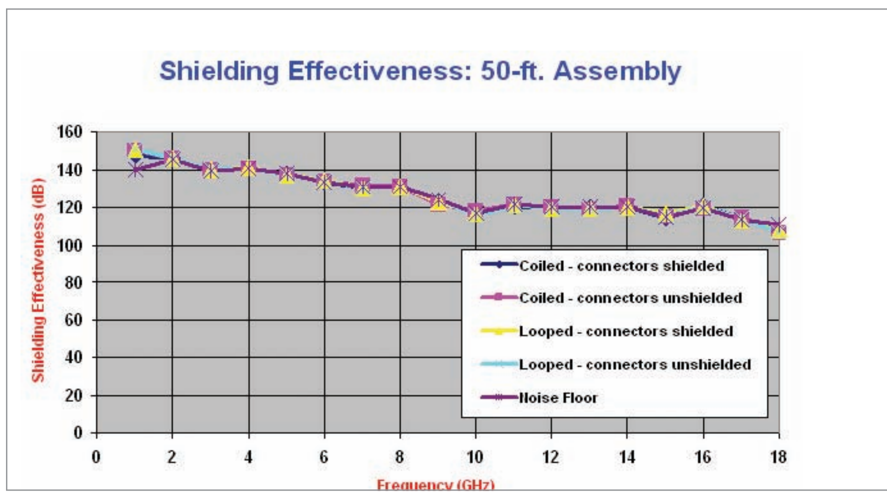


Figure 5: Shielding effectiveness of cable assembly in various configurations

Performance through 18 GHz was notable, producing in excess of 100 dB of shielding effectiveness. Figure 6 was provided to demonstrate that data supplied in Figure 5 was merely not a measurement of the chamber ambient noise level. Figure 6 displays the contrast in S.E. behavior when one connector, at the test assembly/test lead interface, is properly torqued versus loosened by one-quarter of a turn.

This article has not been reviewed by the ICM Editorial Advisory Board.

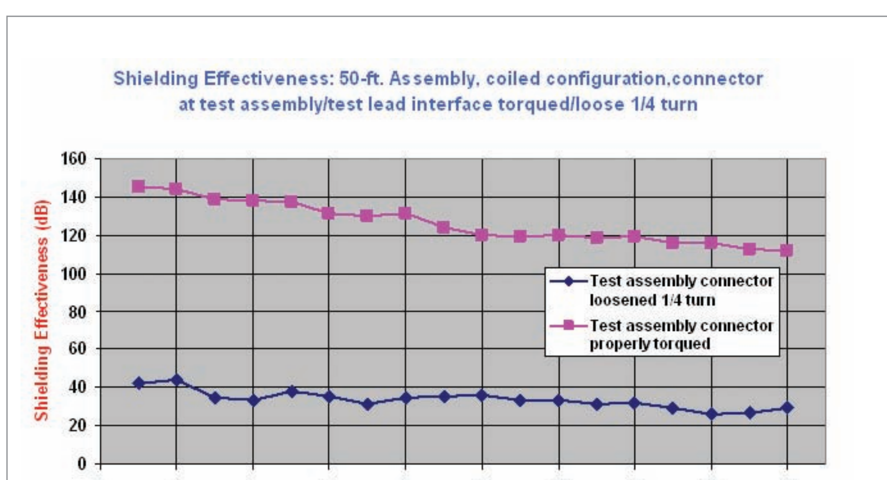


Figure 6: Contrasting shielding effectiveness of cable assembly with connector torqued and loosened ¼ turn

(the author)

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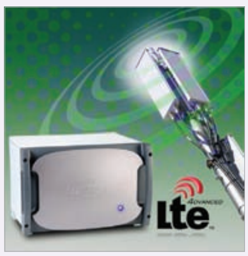
BUSINESS News

Aeroflex Adds Support for TDD Carrier Aggregation to TM500 LTE-A Test Mobile

Aeroflex has announced the TM500 LTE-A test mobile now supports carrier aggregation for Time Division Duplex (TDD) in addition to Frequency Division Duplex (FDD) capability.



The TM500 is capable of supporting all the carrier aggregation scenarios specified in 3GPP Release 10.

For more information, contact your local Aeroflex sales office at (800) 835-2352 or by e-mail at info-test@aeroflex.com.

EMC Partner's TRA3000 Immunity Tester Now with 5kV EFT Pulses

EMC Partner has announced their TRA3000 Immunity Tester now offers the ability to test to 5kV EFT pulses as new product standards have added this requirement.

The enhanced EFT module with the same physical footprint fits directly into the existing TRA3000 mainframes allowing users to extend test capabilities with on-site upgrades to 5kV EFT pulses.

For more information, contact EMC Partner at sales@emc-partner.ch.

ETS-Lindgren Refocusing U.S. Manufacturing Locations for Better Customer Response

ETS-Lindgren has announced a refocusing of its U.S. manufacturing facilities to increase vertical integration, the ability to provide a greater control of in-house processes and an improvement in logistics efficiency. These changes will be implemented over the next six months. Customers and suppliers will not see a change in the company's business policies or practices, but are expected to benefit from this organizational change.

For more information, visit www.ets-lindgren.com.

Newage® MT91 Hardness Tester Offers Speed, Accuracy and Easy Setup

The Newage MT91 automatic microhardness transverse testing system offers unrivalled testing speed – as fast as 6 seconds per test cycle – and a precise Rockwell type testing method that requires no manual interpretation of the impression.

The newly released MT91 modular system is a cost-effective solution for applications that require advanced microhardness functionality such as case depth transverses.

For more information, visit Newage Test System online at www.hardnesstesters.com or contact via e-mail at newage.info@ametek.com.

ON Semiconductor Expands its High Performance Trench Field Stop IGBT Portfolio

ON Semiconductor has expanded its NGBTxx family of 1200 volt trench field stop insulated gate bipolar (IGBT) devices with nine new energy efficient solutions.

These new devices improve overall system efficiency, lower power dissipation and improve system reliability. The devices are suitable for motor control, solar and uninterruptable power supply applications.

For more information, visit www.onsemi.com.

Reliant EMC: The Authorized North American Distributor for LaPlace Instruments, OnFILTER and York EMC Services

Reliant EMC has announced they are the authorized North American distributor for LaPlace Instruments, OnFILTER and York EMC Services. Reliant EMC provides cost effective and practical solutions for EMC testing. Located in San Jose, CA, the company offers first class support for emission and immunity testing requirements.

For more information about Reliant EMC and their product lines, visit www.reliantEMC.com.

PRODUCT Showcase

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Schurter Compact Filter Inlets Boasts Maximum Attenuation

Schurter has announced its new 5123 series filtered inlets featuring enhanced filter performance to the already successful standard 5120 series. The new 5132 series filter combines an IEC power inlet and a line filter, designed for nominal currents up to 15A. The higher attenuation meets the continually increasing demands for interference suppression of IT, medical, test and measurement and industrial equipment.

E-mail info@schurterinc.com for more information.

TDK Introduces EPCOS E Series Varistors for Automotive Applications

TDK Corporation has announced their expanded product range of EPCOS multilayer varistors with the new E series. This new series is compliant to AEC-Q200 with an extended stress test and are even more rugged and reliable than before. The operating voltage of the series ranges from 14V DC to 40V DC and can operate up to 150°C. The E series is ideal for use in ESD protection of bus systems for automotive electronics.

Visit www.epcos.com/varistors for more information.

Teseq Holding AG Acquires IFI Furthering Expanding Its RF Amplifier Capabilities

Teseq Holding AG has announced the acquisition of Instruments for Industry (IFI), a leading designer and manufacturer of solid state and traveling wave tube (TWT) amplifiers. The acquisition expands Teseq's amplifier offerings up to 40 GHz and power levels up to 10 kW. By uniting the capabilities of IFI with those of the recently acquired MILMEGA, Teseq has broadened its product line in the RF amplifier market, offering customers the very best solutions in a wide variety of commercial, industrial automotive, military, defense and communication applications.

Visit www.teseq.com for more information.

(Authors)

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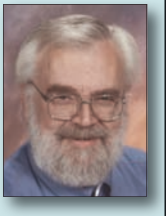
Michael has over 30 years experience with EMC and ESD as an independent consultant, an employee of Thermo Fisher Scientific working with the KeyTek product lines, EM Test USA. and Amber Precision Instruments. For Mike;s full bio, please visit page 31.



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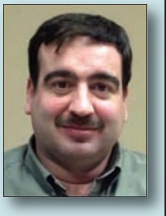

NIELS JONASSEN, MSC, DSC,
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