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JULY 2014

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Lessons Learned Through

## Pre-certification Testing

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**New Development Tools  
and EMC Strategies  
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**Fundamentals of ESD  
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**Reality Engineering  
AI's Notebook**



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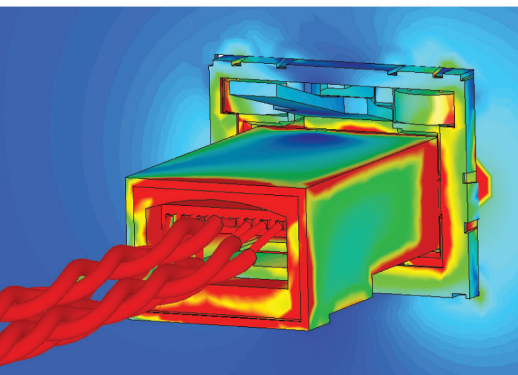






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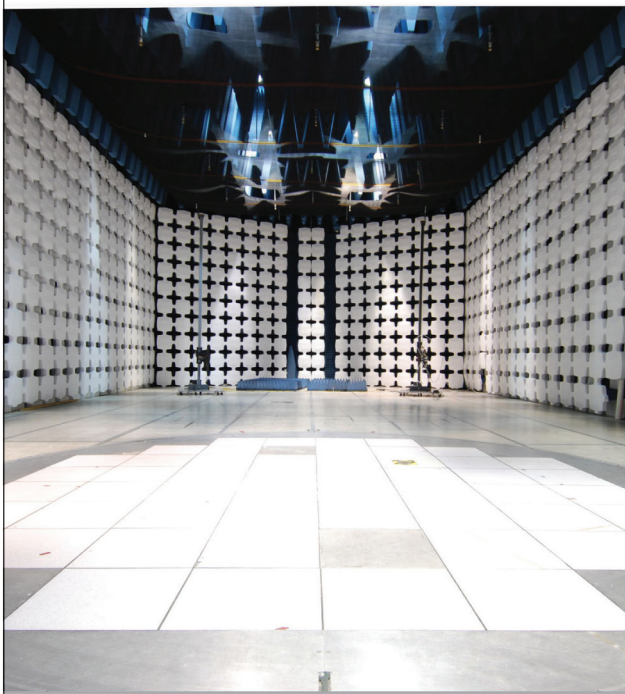
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## IN COMPLIANCE

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## 32 Lessons Learned Through Pre-certification Testing

Reading EMI test results from a test lab is very much like a radiologist reading a CT scan or MRI results. To the novice, it may seem very hard to decipher what is what, but to the trained eye, the test results provide a road map to not only the frequencies of the outages, but also an indication of what or where the outages more than likely are emanating from.

**Robert Ydens and Dr. Brett D Robinson**

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## 38 New Development Tools and EMC Strategies in Step with Practical Electronics

Imagine for a moment that you are trying out a brand new car: you slide into one of the ergonomic seats, start the engine and, to make things perfect, would like to listen to some music. However when you switch this on, you suddenly notice interesting side effects. The light comes on in the passenger compartment, for example. Or the radio starts whistling and whimpering.

Gunter Langer



## 48 Fundamentals of Electrostatic Discharge

Part Four: Training and Compliance Verification Auditing

Your static control program is up and running. How do you determine whether it is effective? How do you make sure your employees follow it?

The ESD Association







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# Electromagnetic Compatibility Engineering

a course in noise and interference control in electronic systems

September 23-25, 2014 | Sheraton Baltimore North | Baltimore, M

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

## COURSE CONTENT

### **CABLING**

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

### **GROUNDING PRINCIPLES**

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

### **DIGITAL LAYOUT & GROUNDING**

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

### **HIGH SPEED DIGITAL DECOUPLING**

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

### **DIFFERENTIAL-MODE EMISSION**

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

### **COMMON-MODE FILTERING**

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

### **TRANSMISSION LINES**

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

### **MIXED SIGNAL PCBs**

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

### **RF & TRANSIENT IMMUNITY**

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

### **CONDUCTED EMISSION**

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

### **SHIELDING**

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



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MD



## Who Should Attend

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

## EMC EXHIBITS AND EVENING RECEPTION: WEDNESDAY, SEPTEMBER 24, 2014

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

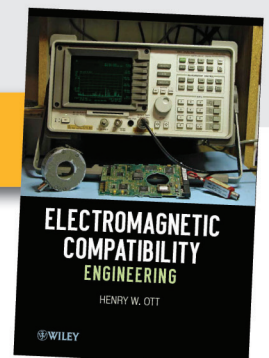


**Henry W. Ott** is President and Principal Consultant of Henry Ott Consultants, an EMC training and consulting organization. He has literally "written the book" on the subject of EMC and is considered by many to be the nation's leading EMC educator. He is the author of the popular EMC book Noise Reduction Techniques in Electronic Systems (1976, 1988).

The book has sold over 65,000 copies and has been translated into six other languages. In addition to knowing his subject, Mr. Ott has the rare ability to communicate that knowledge to others. Mr. Ott's newly published (Aug. 2009) 872-page book, Electromagnetic Compatibility Engineering, is the most comprehensive book available on EMC. While still retaining the core information that made Noise Reduction Techniques an international success, this new book contains over 600 pages of new and revised material.

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

**COURSE DATES/TIME:** September 23-25, 2014  
Tuesday and Thursday 8:30 a.m. to 4:30 p.m.  
Wednesday 8:30 a.m. to 5:00 p.m.

**COURSE LOCATION:** Sheraton Baltimore North  
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**COURSE FEE:** \$1,495 (\$1,295 until 8/15/2014). Fee includes notes, textbook\*, breakfast, luncheon and beverage breaks. Payment required prior to course. Hotel accommodations are NOT included.

**CANCELLATION POLICY:** You may cancel your registration up to two weeks prior to the course and receive a full refund. For cancellations received after this time there will be a \$100 cancellation fee, or you can send a substitute, or use the registration for a future course. No-shows will not receive a refund; however the seminar fee may be applied to a future course.

**TO REGISTER:** Call 973-992-1793, fax 973-533-1442

**HOTEL RESERVATIONS:** Call the Sheraton Baltimore North at 1-888-627-7147 or 1-410-321-7400. Room rates start at \$139 per night (tax not included). Book by August 29th to receive this rate. Rate is based on availability. You must mention **HOC EMC Seminar** when making reservations to get this special rate. The hotel is holding a limited block of rooms.

REGISTRATION

## FCC News

### FCC Proposes Fine for Jamming Cellphone Calls

The U.S. Federal Communications Commission (FCC) has proposed that a Florida man pay a fine of nearly \$50,000 for illegally jamming cellphone calls during his daily commute to work.

According to a Notice of Apparent Liability for Forfeiture issued by the Commission in April 2014, Jason Humphreys of Seffner, FL regularly operated a cellphone jamming device during his commute along Interstate 4 near Tampa, Florida. Humphreys was identified following complaints from a local cellphone provider about cellphone interference during the morning and evening commuting periods, and the subsequent electronic tracking of interference by agents of the Commission's Enforcement Bureau.

Humphreys was finally stopped in May 2013 by deputies of the Hillsborough County Sheriff's Office, who found the jamming

device in his vehicle. Humphreys admitted to authorities that he had operated a cellphone jammer for the prior 16-24 months to "keep people from talking on their cellphones while driving." Deputies on the scene reported that communications with police dispatch were interrupted by his jamming device as they approached Humphreys' vehicle.

It is illegal in the U.S. to import, market, sell or use electronic devices that intentionally block, jam or interfere with cellphone calls and other authorized forms of communication such as GPS systems, Wi-Fi networks and first responder communications. Consumers who use signal jammers can be subject to fines of up to \$16,000 for each day of use, up to a maximum forfeiture of \$112,500 for any single act or failure to act. In this case, the Commission determined that Humphreys was responsible for three separate violations, hence the \$48,000 proposed forfeiture.

The complete text of the Commission's Notice of Apparent Liability for Forfeiture is available at [incompliancemag.com/news/1407\\_01](http://incompliancemag.com/news/1407_01).

### FCC Proposes \$3 Million Fine for Robocalls to Cellphones

The U.S. Federal Communications Commission (FCC) has proposed that a New Mexico company pay a fine of more than \$2.9 million for making illegal computer-generated phone calls ("robocalls") to mobile phones.

According to the FCC's Enforcement Bureau, the company, Dialing Services LLC of Roswell, New Mexico, reportedly made more than 4.7 million robocalls to consumer mobile phones without permission during the period of the 2012 election. The FCC cited the company in March 2013 for that activity, warning that future

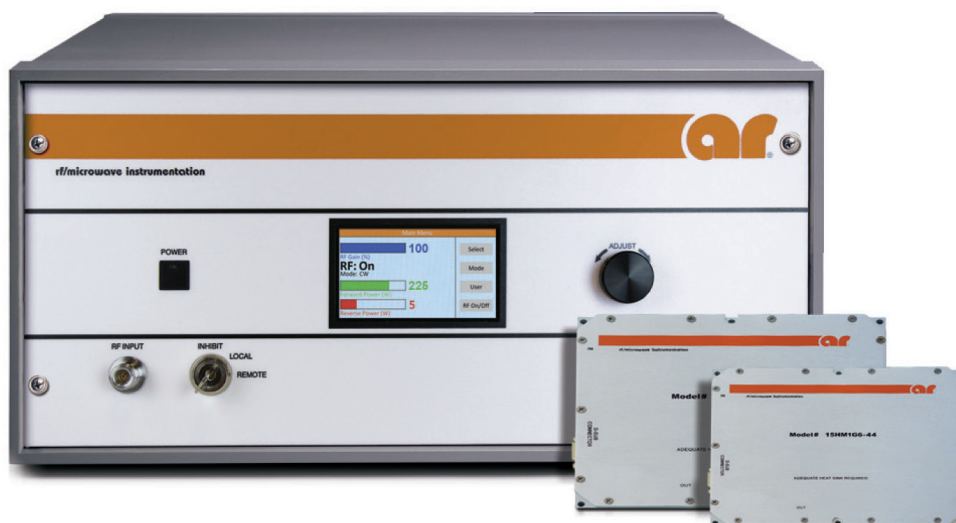


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## FCC News

violations could result in further enforcement actions. However, the company allegedly made at least 184 additional robocalls subsequent to the Commission's warning, which resulted in the proposed financial penalty.

The Telephone Consumer Protection Act prohibits robocalls to mobile phones except for emergency purposes and in cases where a consumer has provided prior consent for such calls. Unlike landline phones, to which political campaign calls are exempt from do not call regulations, there is no exemption for political calls made to mobile phones.

The complete text of the Commission's Notice of Apparent Liability for Forfeiture is available at [incompliancemag.com/news/1407\\_02](http://incompliancemag.com/news/1407_02).

### Online Retailer Cited for Sale of Illegal Smartphones

A California online retailer of electronic products has been cited by the U.S. Federal Communications Commission (FCC) for importing and marketing counterfeit smartphones that falsely claimed FCC certification.

According to an FCC investigation, Panasystem Corporation imported counterfeit Samsung and Blackberry smartphones bearing identifier labels indicating compliance with the FCC equipment authorization process. However, the identifier labels were either invalid or unauthorized, making it illegal to market the phones in the U.S.

FCC regulations require that smartphones be certified as

compliant with FCC technical standards before being marketed for sale in the U.S. In addition, certified smartphones must be labeled with a unique FCC Identifier that verifies a product's certification. Violation of these requirements can result in financial penalties of up to \$16,000 for each model per day for each violation. Continued violations can also result in seizure of uncertified equipment and criminal sanctions, including imprisonment.

Under the terms of the Citation, Panasystem must immediately cease the importation and marketing of unauthorized devices, or be subject to further FCC enforcement action.

The complete text of the Commission's Citation and Order is available at [incompliancemag.com/news/1407\\_03](http://incompliancemag.com/news/1407_03).

## You Can't Make This Stuff Up

### Justices Technologically Out of Touch

Many of us have a hard time keeping up with today's technology. But it seems that the justices of the U.S. Supreme Court may need a brief tutorial on current technology terminology and habits.

According to Reuters News Services, the high court's justices are making a number of technology gaffes during oral arguments in cases brought before the court, including

the recent case involving TV online startup company Aereo. One justice referred to online movie reseller Netflix as "Netflick," while another was apparently unaware that HBO is a channel on cable television.

Supreme Court pundits and watchers reportedly give Justice Sonya Sotomayor high marks because of her familiarity with Roku. Justice Antonin Scalia was at the other end of the scale (he was the one who didn't know HBO was a cable channel). But Justice Stephen

Breyer apparently makes frequent references to "phonographic records," and Chief Justice John Roberts has a hard time believing that many people carry more than one cellphone at a time.

Perhaps the most amusing comment was made by Justice Anthony Kennedy in a software patent case. According to Justice Kennedy, software code can be written "by any computer group of people sitting around a coffee shop."



## European Union News

### EU Commission Updates List of Standards for Medical Device Directive

The Commission of the European Union (EU) has issued a revised and updated list of standards that can be used to demonstrate conformity with the essential requirements of its Directive 93/42/EEC concerning medical devices.

The Directive defines a 'medical device' as "any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including the software necessary for its proper application....to be used for human beings for the purpose of: 1) diagnosis, prevention, monitoring, treatment or alleviation of disease; 2) diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap; 3) investigation, replacement or modification of the anatomy or of a physiological process; or 4) control of conception."

The revised list of CEN and Cenelec standards was published in May 2014 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards for the EU's Medical Device Directive is available at [incompliancemag.com/news/1407\\_04](http://incompliancemag.com/news/1407_04).

### Updated Standards List Published for the EU's Electrical Safety Directive

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the essential requirements of its directive relating to electrical equipment designed for use within certain voltage limits (2006/95/EC).

The Directive defines 'electrical equipment' as any device designed for use with a voltage rating

of between 50 and 1000 V for alternating current, and between 75 and 1500 V for direct current.

The updated list of standards that can be used to demonstrate compliance with the Directive was published in May 2014 in the *Official Journal of the European Union*, and replaces all previously published standards lists.

The complete list of standards can be viewed at [incompliancemag.com/news/1407\\_05](http://incompliancemag.com/news/1407_05) (note that the list runs nearly 100 pages).



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## CPSC News

### USB Mobile Power Bars Recalled Due to Fire Hazard

The DGL Group of Edison, NJ is recalling nearly 100,000 of its Vibe-brand USB mobile phone power bars manufactured in China.

The company reports that the recalled power bars can overheat, posing a fire and burn hazard to consumers. To date, the DGL Group says it has received reports of six separate incidents involving melted parts, smoking, leaking batteries and fires, resulting in bursting power bars and minor property damage in some cases. However, there have been no reports of injuries.

The recalled power bars were sold at Five Below stores nationwide from January 2014 through March 2014 for about \$5.

Further details about this recall are available at [incompliancemag.com/news/1407\\_06](http://incompliancemag.com/news/1407_06).

### Heating and Cooling Thermostats Recalled

White-Rodgers of St. Louis, MO has recalled about 740,000 of the company's digital home heating and cooling thermostats manufactured in China.

White-Rodgers says that the alkaline batteries used in the thermostats can leak onto the circuit board, creating a potential fire hazard. The company has received seven separate reports of burn damage to the thermostat, including two incidents involving minor property damage. However, there have been no reports of injuries associated with the recalled thermostats.

The thermostats were sold through heating ventilation and air conditioning (HVAC) equipment manufacturers and distributors, and at hardware retailers nationwide from January 2006 through December 2013 for between \$30 and \$70.

In addition to the recall of units sold in the U.S., White-Rodgers is also recalling about 400,000 thermostat units sold in Canada.

More information about this recall is available at [incompliancemag.com/news/1407\\_07](http://incompliancemag.com/news/1407_07).

### Nest Recalls Smoke Alarms

Nest Labs of Palo Alto, CA has issued a recall of about 440,000 of its Nest Protect-brand smoke and CO alarms manufactured in China.

The recalled alarms are equipped with a feature that allows consumers to shut off false alarms with the wave of a hand. However, according to the company, activity near the alarms during an actual fire can actually prevent the alarm from immediately sounding when this feature is enabled.

Nest says that it has not received any reports of incidents or injuries

## You Can't Make This Stuff Up

### Trains Too Wide

Apparently, railroad officials in France have never heard of the carpenter's maxim, "measure twice, cut once."

According to Reuters News Service, the French national rail company, Société Nationale des Chemins de fer Français (SNCF), has ordered

2000 new trains for an expanded regional service network that are too wide for many of the station platforms along the route.

The mistake allegedly occurred as a result of outdated information on platform dimensions transmitted to the SNCF, the operators of rail network, from Réseau Ferré de France (RFF), the owners of

the network. The RFF provided dimensions of platforms that had been built within the past 30 years. But most of the country's 1200 station platforms were built in the 1960s or earlier and are too narrow to accommodate the new trains.

Repair work on the older stations has already cost a reported \$110 million.



## CPSC News

related to the recalled alarms, but has initiated this voluntary product recall to prevent possible incidents in the future.

The recalled Nest alarms were sold in Best Buy, Home Depot and other retailers nationwide, and online at Nest.com, Amazon.com, BestBuy.com and HomeDepot.com from November 2013 through April 2014 for about \$130.

More information about this recall is available at [incompliancemag.com/news/1407\\_08](http://incompliancemag.com/news/1407_08).

## Erratum

## Erratum in June's "Millibels in the Wind"

Keen-eyed reader Dana Whitlow, Microwave Receiver Specialist at the Awesome Arecibo Observatory in Puerto Rico, pointed out the error in my math.

A noise temperature of 0.2K is equivalent to 0.0027dB or 2.7 milli-decibels, not just millibels. It makes the point even sharper that a fraction of milli-fraction of a dB is significant at these receiver sensitivities.

Thanks Dana! - Mike Violette

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# REALITY Engineering

## Al's Notebook

BY MIKE VIOLETTE

*I love fools' experiments. I am always making them.*<sup>1</sup>

Charles Darwin

To discover anything new, one has to be ready to be fooled, as sometimes the experiment fools the experimenter. One, too, must be ready to be surprised and draw new inferences when results don't quite work out the way one had hoped. A real fool doesn't change perspective when faced with facts.

Tucked away in the Library of Congress lies a thin, yellowing volume of just over 100 pages. "Experiments Made by A. Graham Bell, (Vol. 1)" is in the *American Treasures Archive* of the Library and it chronicles the trials and errors of experimentation in telephony. The first entry in this particular treasure was writ simply thus: "October 1875."

Bell was drawn to the difficulties of the deaf and hard-of-hearing by his wife and his mother's ailments. He was keen to understand the pathology of deafness and its remedies. This, eventually, led him to investigate the connection between electric current and acoustic energy.

*Al's Notebook* provides the great reveal.

The opening illustrations show some kind of arrangement of electromagnets,

and the placement of a horseshoe magnet in proximity to a wound coil solenoid is meant to induce some reaction in the electromagnet connected some distance away. I take

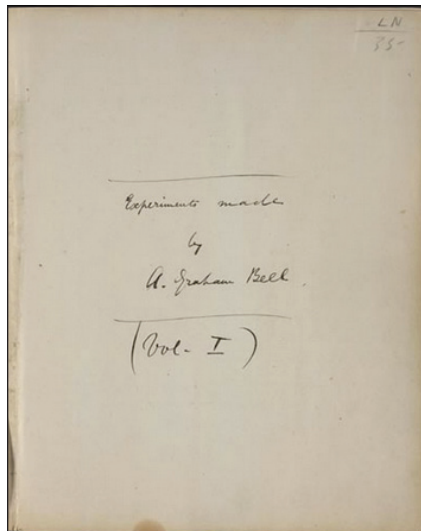


Figure 1

it that he was trying to stimulate the current flow in the circuit to act on the distant electromagnet. (Figure 2)

Batteries, by that time, had been around for three-quarters of a century, invented in 1799 by the Italian Count Alessandro Volta, who invented the *voltaic pile* to provide a continuous source of electric current. Volta, curiously, had not intended to create a device to create DC, but "merely wanted to show his friend Luigi Galvani was wrong." (Typical engineer-type) Galvani believed that the electricity by which he had made dead frogs' legs twitch came from animal tissue but Volta thought it was generated by chemical reaction between different metals in a circuit.<sup>2</sup>

Like all great tinkerers and natural philosophers, Bell tried all kinds of common materials: metal, wood, fibers and stuff that might be available at the local apothecary. He collected all manner of materials and was peripatetic; one entry, late in the notebook, Bell "visited various stereotyping and electrotyping establishments in Boston in search of ideas."

Inventors were only bound by their imagination and availability of material. This was pre-quantum mechanics, of course, but new elements were being found at a rapid rate and used in the



Like all great tinkerers and natural philosophers, Bell tried all kinds of common materials, metal, wood, fibers and stuff that might be available at the local apothecary. Inventors were only bound by their imagination and availability of material.

early applications of material science. The Washington Monument was being constructed during this period. Aluminum, so common we toss it in the trash when our beer is gone, was a rare and precious material and so dear (more so than gold at the time) that the top of the Monument is capped with a pyramid of the metal.

Bell sketched out various arrangements, tinkering on paper and in his head, with many drawings depicted in pseudo-3D, a mix of schematic representation and shaded shaped objects.

His first measure of success involved a brass strip, a cork, a bowl of water and an electromagnetic with a strip of metal as the speaker. "It is difficult to describe the noise heard as it is unlike any sound I have heard from magnet before. It partakes much of the character of a kiss." (Figure 3)

His entries pay no mind to the days of the week and many notations are made on a Saturday or a Sunday. *Al's Notebook* covers his efforts from October 1875 to his last entry on April 16, 1876 (a Sunday). Other persons mentioned in the running script include his assistant Mr. Watson, a Professor Hartford and a fellow named Stanley.

The arc of his efforts can be tracked from his opening idea, notably, early in the notebook, this phrase: "Yesterday Mr. McMahon suggested a device for a new transmitting style for autograph telegraph."

Now the telegraph had been *dash-dotting* for forty years already and transmission lines were strung between major metropolitan areas throughout the world. Samuel Morse codified his famous digital representation of letters and various versions of the telegraph, including one that sent a pulse of energy that burned a piece of paper on the receiving end.

Bell wanted to send sound.

His experiments commenced with reproducing the action of the telegraph using various devices and connections. He laboriously recorded his measurements, using different numbers of battery cells, materials and even mimicking and sketching AC behavior versus time, looking much like an early screen-shot of an oscilloscope. (Figure 4)

His notion of sending pulses of energy, with some kind of transducer on the other end acting as a receiver, is first laid out on page 23, which records a flurry of activity starting on February 22, 1876.

*He knew he was getting close.*

Bell's large achievement was to deduce that an acoustic to electrical transducer was key to his invention of the telephone. Equally important was the electrical to acoustic transducer on the receiver end.

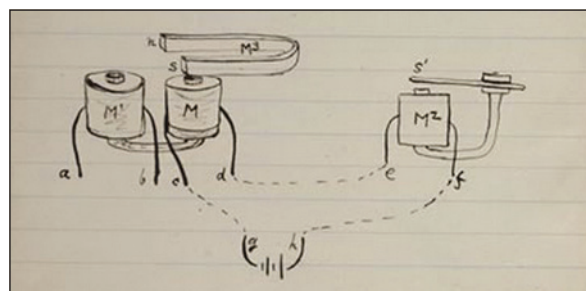


Figure 2

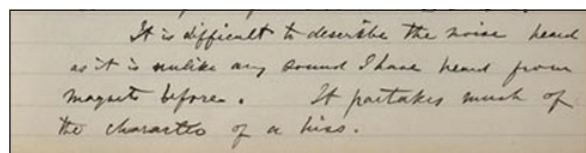


Figure 3

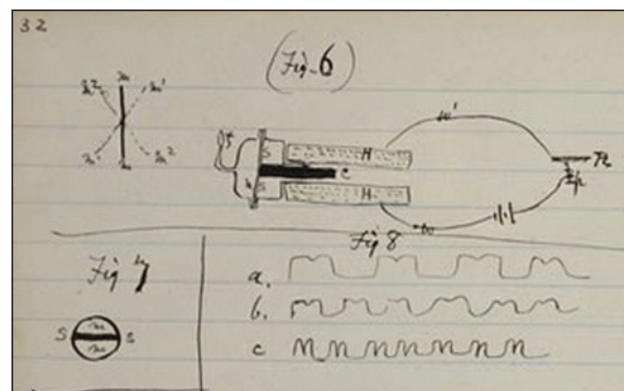


Figure 4

# REALITY Engineering

To this, as suggested by the illustration in Figure 5, he put his efforts.

The text dated March 9, 1876 goes “The apparatus suggested yesterday was made and tried this afternoon. A membrane (M) Fig 1, was stretched across the bottom of the box (B). A piece of cork (C) was attached to the center of the membrane (M) forming a support for the wire, W, which projected into the water in the glass vessel (V). The brass ribbon (R) was immersed in the water also.”

His notion, it seems, was to amplitude-modulate the direct current that was flowing in the circuit. (One imagines the low levels of current he was trying to command.)

He continues: “Upon singing into the box (B), the pitch of the voice is clearly audible from S, which later was placed in another room.”

On this page the text seems dense and tight with phrases crossed out, as if he was struggling to find the words to describe what he was observing—and creating, Bell’s excitement flowing from the pages of the notebook.

“When Mr. Watson counted—I fancied I could perceive the articulations ‘one, two, three, four, five’—but this may have been fancy, as I knew beforehand what to expect. However that may be, I am certain that the inflection of the voice was represented.”

What is remarkable about this moment in time is the ability to conjure a working demonstration—his “apparatus” from wire, water, cork and brass. Not unlike his contemporaries plucking an engineered item out the nature of energy, electricity and simple matter.

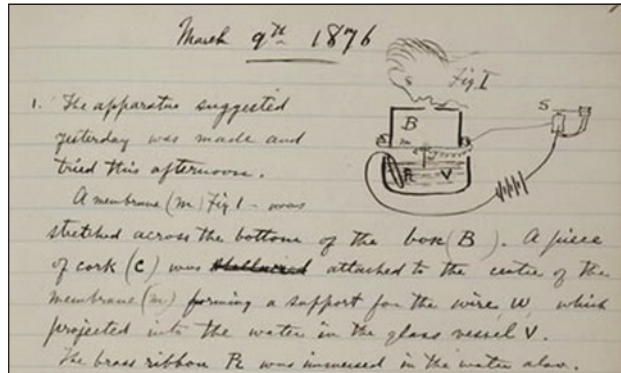


Figure 5

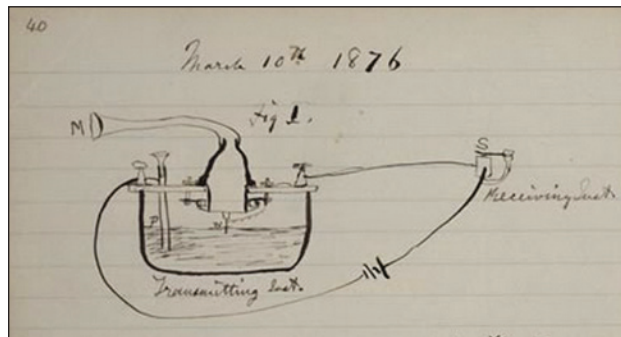


Figure 6


The Eureka moment came on March 10, 1876. Bell had just turned twenty-nine years old. (Figure 6)

“I then shouted into M [the mouthpiece] the following sentence: ‘Mr. Watson—come here—I want to see you.’ To my delight he came and declared that he had heard and understood what I said.”

And like the good experimenter he was, Bell “asked him to repeat the words ‘You said “Mr. Watson—come here—I want to see you.”’”

“Mr. Watson—come here—

The notebook continues for another sixty pages, with refinements in Bell’s setups and musings on the underlying physics of what he was observing. He played with different solutions in the bowl, including cod liver oil (no

sound), cod liver oil + SO<sub>4</sub> (no sound), salt water (loud sound), mercury (complete contact—no good) and “the liquor” (loud sound). 

## ENDNOTE

Alexander Graham Bell worked in many other areas during the golden age of industrialization. His areas of interest included optics and aeronautics and he collaborated with the early innovators in aviation. He is also credited with building the first metal detector.

Ironically, he would not have a phone in his study as he did not want to be interrupted. I wonder if he’d respond to a text message?

All of the images from *Al’s Notebook* can be found at the following website: [www.loc.gov/exhibits/treasures/trr002.html](http://www.loc.gov/exhibits/treasures/trr002.html)

## NOTES

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2. Mahon, Basil. *The Man Who Changed Everything*. West Sussex, England: John Wiley & Sons, 2003.

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# TECHNICALLY Speaking

## The Hazards of Multiple Grounding

Product Safety Newsletter - November/December 1988

BY RICHARD NUTE

Dear Readers,

*Over the past couple of years many of you have requested that we include more product safety related information in our issues. Of particular interest has been Rich Nute's series of "Technically Speaking" articles. And so... Mr. Nute has graciously agreed to work with us to bring you that series! Look for his column each month. We hope you enjoy the addition of "Technically Speaking" to the pages of In Compliance.*

One of my colleagues has a desk drawer full of I/O boards that have been burned quite severely. Why did they burn? The I/O boards are in energy-limited SELV circuits. There should be no possibility of fire.

When we closely examine the boards, we find that the ground trace from the I/O connector is the trace that was overheated. It can only overheat when it conducts lots of amps. But, we all know that the ground is not a current-carrying conductor. At least, it is not a current-carrying conductor under normal conditions.

How can the trace overheat when there is no current?

There must have been a fault condition.

Can we determine what it was?

When we check out the circuit with an ohmmeter and a voltmeter, we find everything is okay: zero ohms, and zero volts.

My colleague performed the traditional grounding continuity test using a 30-amp source. It passed.

Well, my colleague went a step further. He attempted to duplicate the failure with a new board. He kept

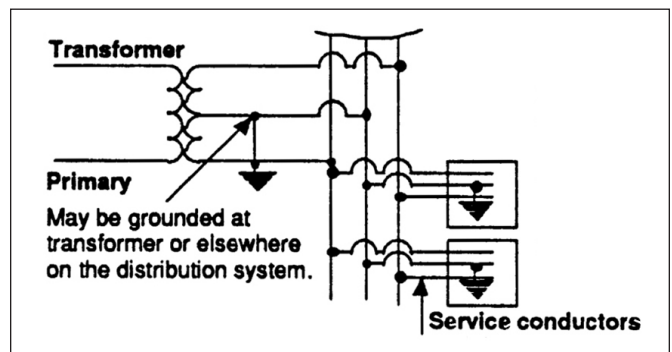
cranking up the current until the board burned just as his drawer full of boards. It took 100 amps!

There is no way to get 100 amps through a 120 volt cord-connected product on a 20 amp branch circuit.

The board did burn. It did take 100 amps to bum the board. Those 100 amps had to come from somewhere.

Before we explore this, let's turn to a different phenomenon.

Have you ever measured the potential difference between the neutral and the ground? You probably measured a couple of volts.



**Figure 1: 3-wire 120/240-V AC single-phase secondary distribution system (From 1987 NEC, Fig. 250-7.)**

On a 2-wire or 3-wire single-phase ac secondary distribution system, grounding connections are made on the secondary side of the transformer and on the side of the service disconnecting means.



To get a few volts potential difference, there must be a few amps of current passing through a resistance, somewhere.

Since the ground has no current, the current must be in the neutral. When we make this measurement, the ground wire acts as a remote contact to the end of the neutral wire. So, we are measuring the voltage drop across some portion of the neutral conductor.

Now, let's return to the original issue: How can current get into the ground under normal conditions? Normal conditions are the only conditions in which we can get continuous current in the ground conductor.

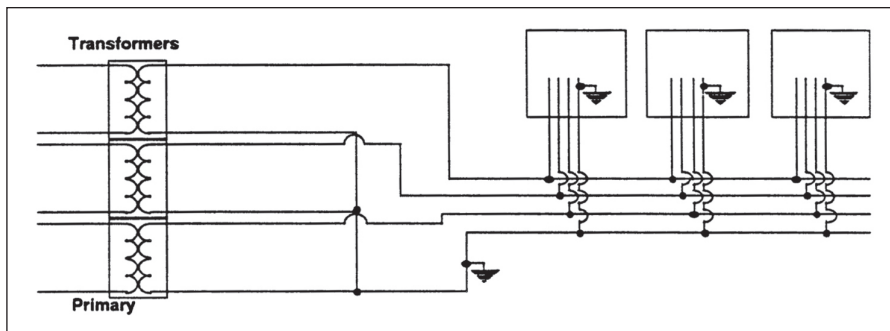
The answer is found in the *National Electrical Code Handbook*. One neutral may be grounded at more than one point! See Figures 250-7 and 250-8 (pages 193 and 194 of the 1987 Handbook) and Figures 1 and 2.

## WHAT DOES THIS MEAN?

If the neutral is connected to ground at more than one point, then the neutral and ground are connected in parallel between those two points. In accordance with Kirchhoff's laws, such connection makes the ground a current-carrying conductor under normal conditions!

## WHAT DOES THIS MEAN FOR THE I/O BOARD?

The I/O includes a signal ground. When the I/O is connected to another piece of equipment which is grounded at another location, then the signal ground wire, because it is grounded at two points, parallels the ground and neutral wire! Thus, the neutral current gets divided into three paths: the neutral wire, the ground wire, AND the signal ground! VIOLA! Lots of amps in the signal ground wire! The  $I^2R$  causes the traces on the boards to burn. Depending



**Figure 2: 4-wire, 3-phase 208Y/120-V secondary distribution system (From 1987 NEC, Fig. 250-8.)** The neutral is grounded at each service and also on the secondary side of the transformer on this 4-wire, 3-phase, 208Y/120-V secondary distribution system. When 3-wire, 3-phase service equipment is installed for power purposes on this type of ac system, the grounded (neutral) conductor is required to be run to the service equipment.


on the distribution transformer size, the distance between I/O ports, and wire sizes and lengths, it is indeed within the realm of possibility to have 100 amps in the signal ground wire!

And, we have a fire hazard.

Two or more neutral ground points necessarily connect the ground in parallel with the neutral. Signal grounds are always in parallel with the ground. Whenever the neutral is grounded at two or more points, the signal ground between two points, especially remotely located units, may be in parallel with the neutral. When

this occurs, some portion of the neutral current will be in the signal ground. If the neutral current is high enough, it can cause overheating on the I/O board.

## WHAT CAN BE DONE TO PREVENT THIS SITUATION?

In order for a grounding conductor to not be a current-carrying conductor in parallel with the neutral, the neutral must be limited to one grounding connection. Fortunately, single point grounding is permitted by both the NEC and the CEC. 

(the author)

### RICHARD NUTE

is a product safety consultant engaged in safety design, safety manufacturing, safety certification, safety standards, and forensic investigations. Mr. Nute holds a B.S. in Physical Science from California State Polytechnic University in San Luis Obispo, California. He studied in the MBA curriculum at University of Oregon. He is a former Certified Fire and Explosions Investigator.

Mr. Nute is a Life Senior Member of the IEEE, a charter member of the Product Safety Engineering Society (PSES), and a Director of the IEEE PSES Board of Directors. He was technical program chairman of the first 5 PSES annual Symposia and has been a technical presenter at every Symposium. Mr. Nute's goal as an IEEE PSES Director is to change the product safety environment from being standards-driven to being engineering-driven; to enable the engineering community to design and manufacture a safe product without having to use a product safety standard; to establish safety engineering as a required course within the electrical engineering curricula.



## Environmental ESD: Part 2

### Thunderstorms and Lightning Discharges

BY NIELS JONASSEN, sponsored by the ESD Association

The properties of thunderstorms and lightning discharges as related to the atmospheric electric circuit are discussed.

#### INTRODUCTION

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

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

~ The ESD Association

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A thunderstorm can be considered an electric generator in which positive and negative charges are separated and stored in different regions of the cloud. As the charges are separated, the field will grow between opposite charges in the same cloud or in different clouds, or between a cloud and the ground. When the breakdown field strength is exceeded, an electric discharge will take place, sometimes in the form of a lightning flash. As further charges are separated, the process is repeated but normally at different places.

The mechanism of a thunderstorm is, in principle, very simple. But in spite of this and the many years of thunderstorm research, a detailed knowledge of the processes responsible for the charge separation and the discharges is still not at hand. There are, however, a series of known processes that actually do take place in thunderstorms and that may cause charges to separate.

To evaluate if a given process may play a role in the electrification of a thundercloud, it is necessary to determine not only if the process is able to separate charges and distribute the polarities in a way corresponding to what is measured in actual clouds but also if the rate of charge separation can explain the time variations observed in, for instance, the intervals between lightning flashes.

Direct observations from aircraft as well as radar measurements have shown that a thundercloud consists of one or more active cells with high vertical velocities. Rain and hailstones, as well as lightning activity, are formed in the cells. A particular cell may have a total lifetime of about an hour, whereas the precipitation and lightning activity may last only 15–20 minutes. A fully developed cell may have a horizontal extension of 2–10 km and a height of some 10 km, with the base of the cloud at maybe 3 km above ground (see Figure 1). The vertical velocities



are typically in the order of  $5\text{--}10\text{ m}\cdot\text{s}^{-1}$ . In special cases, however, velocities of  $30\text{--}40\text{ m}\cdot\text{s}^{-1}$  have been measured.

The temperature in a thundercloud varies from about  $0^\circ\text{C}$  at the base of the cloud to about  $-40^\circ\text{C}$  in the upper layers. At the top of the cloud is a region with predominantly positive charge, whereas the negative-charge region is located at the base. Often, a smaller region with positive charge is also found at the base.

A thundercloud can be considered a vertical dipole (often double), and a lightning discharge can partly be described as a change in the dipole moment. The magnitude of this change is in the order of  $100\text{ C}\cdot\text{km}$ , corresponding to a charge of  $20\text{--}30\text{ C}$ . As an average thunderstorm produces a lightning flash every  $10\text{--}20$  seconds, a charging current of about  $1\text{--}2\text{ A}$  is required. The first lightning flash is normally registered about 20 minutes after the precipitation has started. Assuming that the precipitation is necessary for the electrical activity, a rough estimate of the charge that has to be separated in a volume of about  $50\text{ km}^3$  in about 20 minutes (i.e., with a rate of about  $1\text{ C}/(\text{km}^3\cdot\text{min})$ ) would be approximately  $\pm 1000\text{ C}$ . It should be mentioned that some thunderstorm specialists claim that, instead of precipitation, convective activity is the prerequisite for charge separation.

Turning to the actual mechanisms of charging, several processes may be responsible for the charge separation. It has been shown that regions with temperatures below  $0^\circ\text{C}$  are often the seat for the most active charging processes. However, it has also been shown that considerable charge separation may take place in warm clouds.

In the thundercloud, there are big ice particles in the form of hailstones

formed by glazing, that is, the freezing of subcooled water by contact with a cold body. The ice formed is amorphous and glassy and has the same content of impurities as the cloud particles from which it is formed. The glazing process can take place only in the temperature interval from  $0^\circ$  to  $-15^\circ\text{C}$ . At lower temperatures, the water vapor freezes out and forms pure ice crystals.

In addition, the hailstones will have a somewhat higher temperature than the ice crystals, partly because of the latent heat released by the freezing of the water. If a hailstone and an ice crystal happen to come into frictional contact with each other, the more conductive, impure hailstone will become positive and the pure ice crystal will become negative. Calculations and measurements (laboratory and field) both seem to show that this process might give charging rates in the order of  $10\text{ C}/(\text{km}^3\cdot\text{min})$ , which should be sufficient to cause lightning activity.

A similar process takes place when subcooled water drops hit ice particles. The drops will partly freeze onto the ice particles in a glazing process. Because of the released latent heat, part of the water will stay liquid, moving away with a positive charge and leaving the heavier ice particles negatively charged. The collisions between ice particles and subcooled water drops may also result in the expulsion of light ice splinters, again leaving the ice particles with a negative charge. The charging rate of these processes seems to be about  $1\text{ C}/(\text{km}^3\cdot\text{min})$ , the

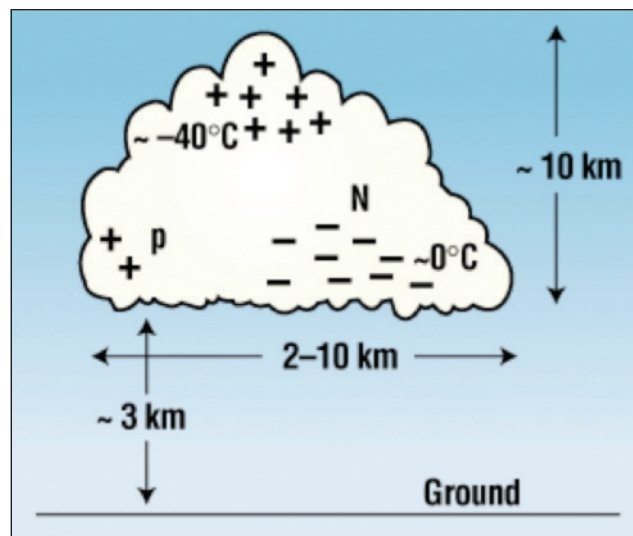


Figure 1: Typical thundercloud

estimated critical value for lightning activity.

Other possible charging processes are inductive charging in an inhomogeneous field of solid or liquid particles that come in contact with each other and are subsequently separated by gravity, and thermoelectric charging by asymmetric friction or other causes. A common feature of these theories is that they all assume the presence of precipitation elements and that the processes typically take place in a temperature region below  $0^\circ\text{C}$ .

According to another theory, the strong vertical air movements in the thunderclouds may play a vital role in the charging process. The theory maintains that, in the lower atmosphere, the air has a small excess of positive ions and that a cloud formed in this region will therefore initially be positively charged and attract negative ions from the upper atmosphere. The negative ions may be caught by a downdraft and on their way attach themselves to droplets or other elements of precipitation. In this way, a negative charge is formed at the cloud

base, and the resulting field may be strong enough to cause corona discharges at sharp points on the ground. Positive ions will be attracted to the cloud but may be caught by an outside updraft and carried to the top of the cloud, increasing the field so that more negative ions are attracted from the upper atmosphere, thereby amplifying the charging process until lightning activity starts.

It is not possible to point to one of these theories (or others) as being mainly responsible for the charge separation in thunderclouds. Probably the charging is a result of more than one and not always the same processes.

## CURRENT BALANCE IN THE ATMOSPHERE

It has already been mentioned that the fair-weather current and the charge brought to ground by elements of precipitation account for a positive current density of about  $4 \cdot 10^{-12} \text{ A} \cdot \text{m}^{-2}$ . To evaluate whether this can be balanced by the effect of thunderstorms, the contributions from lightning discharges and from the current induced by the fields below and above the thunderstorms must be looked at separately.

As far as the lightning discharges are concerned, it is estimated that about 1800 thunderstorms are active at any one moment. Each of these storms produces about 60 lightning flashes per hour, each carrying about 20 C, with approximately 80% of the flashes bringing negative charge to the ground. This will then correspond to a total current of about  $-1.3 \cdot 10^6 \text{ C/hr}$ , or  $-360 \text{ A}$ , which corresponds to  $-0.7 \cdot 10^{-12} \text{ A} \cdot \text{m}^{-2}$ .

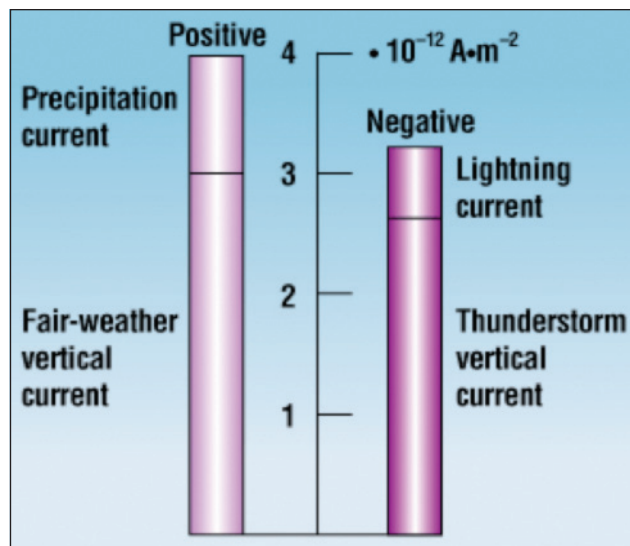


Figure 2: Atmospheric current balance

The current caused by the fields below and above the thunderclouds can be estimated in two different ways. The current below a thundercloud has been measured at  $-10^{-8} \text{ A} \cdot \text{m}^{-2}$ . With about 1800 simultaneously active storms, each with an approximate horizontal dimension of  $50\text{--}60 \text{ km}^2$ , this corresponds to an average current density for the earth as a whole of  $-2.3 \cdot 10^{-12} \text{ A} \cdot \text{m}^{-2}$ . It should be mentioned that it is extremely difficult with any degree of accuracy to measure the vertical current density during a thunderstorm. In another method, the current above the thunderclouds is measured to have an average of about  $-0.8 \text{ A}$  per thunderstorm. Using the same assumptions as in the previous argument, this corresponds to an average current density of about  $-2.8 \cdot 10^{-12} \text{ A} \cdot \text{m}^{-2}$ .

The contributions from the various processes can be summarized as shown in Figure 2. It appears that about  $-0.7 \cdot 10^{-12} \text{ A} \cdot \text{m}^{-2}$  is lacking in order to make the current budget balance. It should, however, be kept in mind that the calculation of the two negative contributions

is based on very uncertain estimates of the number of active thunderstorms and the average lightning rate. It has, for instance, been suggested that the number of thunderstorms active at any one moment might be closer to 3000 than the figure of 1800 used above, but this higher figure could also include a number of weaker systems with lower lightning rates and possibly weaker fields. Despite the uncertainties, the estimated values of the atmospheric electric parameters seem to fit the circuit reasonably well.

## LIGHTNING DISCHARGES

Although lightning discharges contribute rather modestly to the current balance in the atmosphere, these same discharges have such violent (direct and indirect) effects and properties that a short survey of this phenomenon would be appropriate.

A lightning discharge is a transient current of high intensity spanning several kilometers. Lightning may be produced by sandstorms and snowstorms or by erupting volcanoes, but the most common cause is the activity in cumulonimbus clouds (thunderclouds). Although the most common type of lightning discharge takes place entirely within the cloud (intracloud strokes), the discussion will be limited to the discharges between a cloud and the ground.

Any cloud-to-ground discharge is made up of a series of partial discharges separated in time by  $40\text{--}50$  milliseconds and lasting about  $200$  milliseconds for the total flash. Figure 3 on page 24 shows some of the characteristic features of a cloud-to-ground stroke as it would appear on a streak-camera photograph.



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**The Stepped Leader.** Each lightning discharge starts with a predischARGE or leader that propagates from the cloud to the ground in weakly luminous steps. The predischARGE may start as a local discharge between the N and p regions in the base of the thundercloud (see Figure 1), converting part of the negative charge bound in the base into highly mobile electrons, which will be carried to ground in a negatively charged column. The column appears to move in luminous steps about 50 m in length, with a time between steps of about 50 microseconds, during which time the intensity of the steps is too weak to be observed.

The predischARGE moves with a velocity of about  $1.5 \cdot 10^5 \text{ m} \cdot \text{s}^{-1}$  ( $>500,000 \text{ km/hr}$ ), and because the base of a thundercloud is typically at an altitude of 3 km, it takes about 20 milliseconds for the predischARGE to reach the ground. The negative charge in a predischARGE is about 5 C, and the average current is therefore approximately 100 A. The diameter of the discharge has been measured photographically to be between 1 and 10 m, but it is assumed that the actual charge transport takes place in a narrow core surrounded by a luminous corona sheath, which is what is actually observed.

**The Main Stroke.** When the predischARGE brings the negative charge at high potential close to the ground, the field strength at ground level may be high enough to cause ionization and make the discharge move from the ground to the leader. When the two discharges meet, the leader is effectively grounded and its conductive channel will support a very luminous main or return stroke.

The return stroke differs in many ways from the leader stroke. The strongly ionized wave front moves with a velocity of about one-tenth of the speed of light, covering the distance from the

ground to the base of the thundercloud in about 70 microseconds.

The region between the wave front and the ground is traversed by strong currents that bring the excess negative charge in the leader channel to the ground. Measurements at ground level have shown currents in the main discharge of 10–20 kA during the first few microseconds, falling off to half the initial value in 20–60 microseconds, but with currents of hundreds of amperes to flow for several more milliseconds.

During the main stroke, considerable amounts of energy are dissipated in the discharge channel, and the temperature will be higher than during the predischARGE. Because the gas density cannot change instantaneously, the pressure in the channel will be higher than in the surroundings, and the channel will expand supersonically, producing a shockwave that gives rise to the sound of thunder. The shockwave phase lasts about 5–10 microseconds, during which time the gas density in the channel behind the shockwave will decrease until a state of equilibrium is reached between the channel with high temperature and low density and the surrounding air with low temperature

and high density. In this state, the discharge channel has a diameter of a few centimeters.

**The Dart Leader.** The lightning discharge is not necessarily finished even if the current in the main discharge has decreased to zero. The main discharge has provided a conductive trail, and if extra charge from the N region is available less than some 100 milliseconds after the main stroke, this charge may move through the channel as a continuous discharge or dart leader. The dart leader appears as a luminous section of the channel about 50 m long moving toward the ground with a velocity of about  $2 \cdot 10^6 \text{ m} \cdot \text{s}^{-1}$ , or about 10 times as fast as the stepped predischARGE. The dart leader reaches the ground in about 1 millisecond and carries a charge of about 1 C. During this charge transfer, the ionization of the channel has increased and a new main stroke is possible. This process may be repeated (normally about 3–4 times), but much larger numbers (up to 26) of return strokes have also been observed.

The first return stroke, the actual main discharge, is strongly branched downward as in the preceding stepped

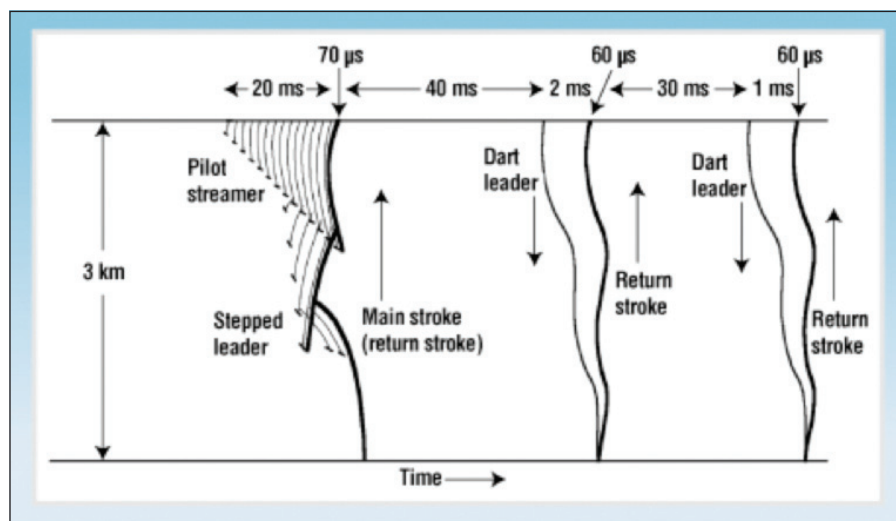


Figure 3: Typical lightning flash



It naturally follows that a relatively short review such as this one has to be rather summary. A series of relationships between the various elements have therefore been bypassed or only mentioned superficially, which may give the impression that the atmospheric electric circuit is a simpler phenomenon than is actually the case.

leader. The subsequent return strokes, following the dart leaders, are only slightly branched. The first return stroke transfers more charge than do later return strokes, but because a more or less continuous current is flowing in the time between the two return strokes, the total charge transferred by a lightning flash is about twice that of a single-stroke flash.

**Positive Strokes.** Occasionally, stepped leaders bringing positive charges to the ground have been observed, but in such cases, the leader current is carried by negative charges (electrons) flowing out of the top of the leader into the positive region of the cloud and thereby charging the channel positively. The charge transferred by positive strokes may be about three times that of negative strokes, with maximum values of about 300 C. Positive strokes rarely have more than one return stroke.

**Upward Leaders.** If the field strength at ground level is particularly high (e.g., at very high structures or mountain tops), the ionization may start here, with the leader developing upward.

**Charge Balance in Thunderstorms.** As the majority of lightning flashes from a thundercloud to the ground carry a negative charge, it is expected that a thundercloud would eventually get an excess positive charge, reducing the possibility of bringing further negative charge to the ground. However, this

tendency is counterbalanced both by positive discharges from the top of the cloud to the surrounding air and by the vertical current above the cloud often being greater than that below the cloud.

## EFFECTS OF LIGHTNING DISCHARGES


This article primarily addresses the electrical phenomena and processes taking place in the atmosphere, but it does seem appropriate to briefly mention the effects on buildings, installations, and human beings brought about by the lightning discharges.

If the lightning strikes a conductor, an amount of heat approximately proportional to the charge is dissipated in a relatively small volume around the point of impact. The material may melt and be thrown around because of magnetic and pressure forces. Furthermore, the lightning current will dissipate heat and create magnetic forces on any conductor through which the charge is led to ground.

The lightning may also create overvoltages in installations and even along the ground. These overvoltages may appear in the medium itself because of resistive coupling or, in conductive surroundings, because of inductive coupling through the magnetic field or capacitive coupling through the electric field.

Finally, humans may be fatally injured and suffer brain damage by being hit directly by lightning strokes. Burns and damage to organs are rather rare because the discharge normally runs on the surface of the body, leaving lightning figures on the skin. However, nearby strokes may create overvoltages dangerous to human beings up to about 100 m from the point of impact.

## CONCLUSION

It naturally follows that a relatively short review such as this one has to be rather summary. A series of relationships between the various elements have therefore been bypassed or only mentioned superficially, which may give the impression that the atmospheric electric circuit is a simpler phenomenon than is actually the case. 

(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.





## Designing Effective Product Safety Labels: Your Guide to Content

BY GEOFFREY PECKHAM

Designing product safety labels that help to prevent injuries and save lives is a multi-faceted task. This month, we'll focus on another key element to consider: content.

In the last column, we underscored the benefit of using symbols on your product safety labels. In my mind, there's no question that the use of symbols is the state of the art when it comes to safety communication. They not only draw attention to your safety label – they also have the ability to communicate across language barriers. Often, though, a product safety label's message is more involved than a single symbol can communicate. That's where the use of additional symbols and/or text comes into play. In this article, I'll outline the elements you should take into account when defining product safety label content to communicate information that protects both people from harm and your company from product liability litigation.

### ANSI Z535.4—YOUR STARTING POINT FOR CONTENT

In the U.S., we're fortunate to have a national standard – ANSI Z535.4 – that describes the content options for

product safety signs and labels. I say we are "fortunate" because if you follow this standard, your defense in a product liability lawsuit should be strengthened, especially when it comes to allegations of "inadequate warnings" or "failure to warn." Honed over the past 20+ years, the ANSI Z535 standards represent the U.S. best practices in communicating safety on signs, labels, tags and in manuals.

ANSI Z535.4 is a good starting point for defining the content of your safety labels because the standard makes it very clear what should be conveyed. The following is what ANSI Z535.4 states about the proper message on hazard alerting product safety signs (and labels):

***"Hazard alerting sign:** Sign directly related to a hazard that identifies the hazard, the level of hazard seriousness, the probable consequence of involvement with the hazard, and how the hazard can be avoided. When information on consequence, avoidance, or type of hazard is readily inferred, this*

*information may be omitted from the message panel (see Annex B3.1)."*

When it comes to communicating this information through an ANSI Z535.4-compliant label, there are three visual elements used:

1. Signal word
2. Symbol(s)
3. Word message

The main role of the signal word (a topic I'll focus on in more depth in my next column) is to communicate the degree or level of seriousness of the hazard. The other two elements – symbol(s) and word message – are then left to identify the hazard, the probable consequence of involvement with the hazard, and how the hazard can be avoided.

### TO OMIT OR NOT TO OMIT CERTAIN INFORMATION

Note that the definition quoted above states that some of the information may

be omitted. Yet, the referenced note in Annex B3.1 states that:

*"Many factors must be considered when determining whether to omit consequence, avoidance, or type of hazard information in the word message. Factors to consider include whether the message can be inferred from a symbol, other text messages, user training, or the context in which the safety sign is used."*

As a product safety engineer, I believe you should understand that, in practical terms, the ANSI Z535.4 standard has set the expectation for the proper content for a safety label for the past two decades. As I understand things, this definition for the content of a safety label originally came from U.S. court precedents that defined the function

of a safety label in product liability litigation. These "content elements" were then picked up and placed into the early drafts of the ANSI Z535.4 standard back in the 1980s. The fact that they have withstood the test of time – including five revisions to the standard and being routinely used in today's product liability litigation that is focused on warnings – is proof, in my opinion, that the Z535 committee did a good job of defining the proper content of a warning. Yes, the standard says you don't have to have all of this information on your label – and there may be good reason not to. But generally speaking, my advice is always to consider communicating all of this information on your labels if you can.

Having said this, there are times when omitting some of the Z535.4 defined label content can make sense, including:

- Space restrictions on a product, which can make content-heavy labels unreadable.
- The presence of too many hazards in one place, which can make it difficult to clearly define every hazard and every avoidance procedure on a single label.
- Choosing to communicate in ISO-compliant, symbol-only formats.
- Choosing to refer to another source for more information (such as a manual or a separate instructional label).

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## HOW COMPLETE CONTENT DRIVES COMPLIANCE WITH SAFETY MESSAGES

So why does ANSI Z535.4 recommend including ALL of the content outlined above? Why isn't identifying the hazard alone enough? Human factors studies have shown that people often benefit by having more information given to them. Applying this theory to product safety labels, the viewer benefits from having communicated both what your product's hazards are and how to avoid them.

For example, consider Figure 1: at left is a label saying "Danger – High Voltage", used on a machine that needs to be serviced. This overly simplistic content gives you an abbreviated understanding of the hazard – presumably electric shock. It does not tell you how to avoid the hazard, whether you have to disconnect the power, if there are two sources of power, whether a full lockout procedure is necessary, or similar hazard avoidance information. You can see how its incompleteness introduces unnecessary risk. Identifying both the nature of the hazard and the proper avoidance procedure (see the ANSI-style label to the right) is needed if your goal, here, is to control the risk of electrocution.

Similarly, see Figure 2. At left is a label that only identifies the hazard avoidance procedure, "Do Not Operate with Guard Removed." This label is one that Clarion often replaces because it does not tell the viewer what the hazard is that they need to avoid. Is it a danger of entanglement, a pinch point, a crush hazard or electrocution? Put yourself in the viewer's shoes. Wouldn't you rather see the label to the right which provides fuller information on what the hazard is and the consequence of interaction with it? Not only will you be better informed but, according to

human factors experts, you will also be more likely to obey the message. An understanding of all three content items (what the hazard is, the consequence of interaction with the hazard, and how to avoid the hazard) provides the viewer with the information they need to make a wise decision.

My final example, see Figure 3, illustrates how all three items of

content could be communicated in symbolic form. Here, Clarion's label design uses ISO-formatted symbols (meaning symbols in ISO colored surround shapes) to communicate the existence of a crush hazard, the need to lockout the equipment and read and understand the maintenance manual before performing maintenance on the product. Such labels are often backed up with explanations in the product's

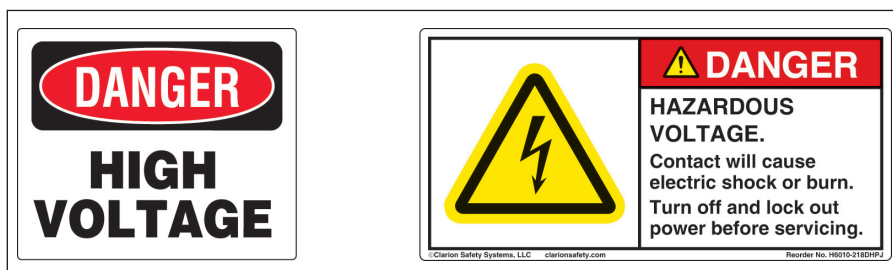


Figure 1: At left, an OSHA-style "Danger – High Voltage" label. At right, an up-to-date ANSI Z535.4 counterpart. (Design at right ©Clarion Safety Systems. All rights reserved.)



Figure 2: At left, an OSHA-style "Caution – Do Not Operate with Guards Removed" label. At right, an up-to-date ANSI Z535.4 counterpart. (Design at right ©Clarion Safety Systems. All rights reserved.)



Figure 3: A Clarion symbol-only safety label. (Design ©Clarion Safety Systems. All rights reserved.)




manual that elaborate on the safety aspects involved with the situation. The point here is that reliance on words to convey safety messages on on-product warnings is not an absolute given. The ANSI Z535.4 standard allows for a portion or all of a label's message to be conveyed with symbols; this format is in complete compliance with the standard. If you decide to go this route, the design of the symbols and the credentials of their origins will be important.

When it comes to creating the content for your safety labels, you have several options to choose from and a number of aspects to consider. A future article on this topic will focus on special layout considerations including accommodating translations and multi-hazard formats. Amid all of the choices

that we've outlined above, remember: using the latest standards and best practices in considering the elements of your label means that clear and concise messaging is possible – as well as visual consistency – which ultimately should help your safety labels to be more easily seen and understood.

Preventing accidents and saving lives from tragedy is the goal. Stay tuned for

the next article in this year's *On Your Mark* series which will explore another aspect of effective on-product hazard communication: visually defining risk severity levels. 

## REFERENCES

The American National Standards Institute (ANSI) *Z535.4 Standard for Product Safety Signs and Labels*, 2011.

(the author)

GEOFFREY PECKHAM

Geoffrey Peckham, CEO of Clarion Safety Systems, is chair of both the ANSI Z535 Committee for Safety Signs and Colors and the U.S. Technical Advisory Group to ISO Technical Committee 145 - Graphical Symbols, and member of the U.S. Technical Advisory Group to ISO Project Committee 283 - Occupational Health and Safety Management Systems. 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 © 2014. All rights reserved.



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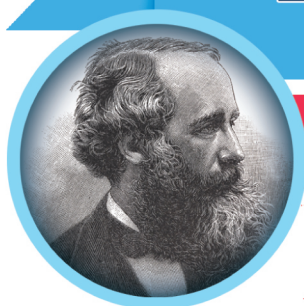
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Wide adoption of wireless technologies in today's electronic, computer, and communication systems presents new challenges for our EMC society. EMC and noise interference issues, especially those tightly related to the performance of wireless subsystems, can occur at both the system and the intra-system levels. This special session, sponsored by SC4 EMC for Emerging Wireless Technologies, will provide a good opportunity for the EMC engineers to understand the general issues, challenges, and recent developments, through a wide range of topics including component level testing, system-level evaluation, innovative component concept, as well as characterization methodologies.

#### Numerical Methods for Signal and Power Integrity

This special session will present numerical techniques for analyzing the signal channels and power distribution networks in high-speed electronic systems; a broad range of topics highlighting efficient numerical techniques will be covered. The applications include optimization of design structures, stochastic simulation, macro-modeling, and hybrid electromagnetic extraction and simulation.

#### Nanotechnology in EMC

Currently, Nanotechnology is the most powerful motor of innovation, turning cutting-edge research into novel commercial products. Nanotechnology has already found its way into various EMC applications. New materials such as single- and multi-phase composites filled with nanoparticles, nanotubes, or graphene sheets have been designed and tested for gaskets and absorbing screens with outstanding performance. Innovative nanostructured shields have shown multifunctional properties and higher efficiency than commonly used materials. Carbon nanotubes and graphene nanoribbons are widely investigated to replace copper for high speed interconnects and high density integrated systems. This special session will provide an overview of the most advanced developments in nanotechnology applied to EMC.

#### Large Scale Modeling for Signal and Power Integrity

This special session is targeting methodology, algorithms, and tools that can advance our modeling capability to meet the demands of industry and academia. The conventional PI and SI simulations are carried out in SPICE, and the models are generally partitioned between the vertical transitions and horizontal routings with simplifying assumptions, such as number of aggressors, ideal reference, etc. Such simulations are more geared towards pre-layout analysis to determine the solution space. In an actual design, these assumptions may not always be applicable, and the SI/PI issues often come out of those non-idealities. Furthermore, the application of innovative PCB techniques, such as crosstalk mitigation, are very design dependent and may need to be tuned for a given design. Finding and fixing SI/PI problems on a design and improving performance before fabrication is a big challenge for SI and PI engineers, which requires EM solvers and simulation tools that can handle problems at a large scale and at the post-layout stage.







# Lessons Learned Through Pre-certification Testing

BY ROBERT YDENS AND DR. BRETT D ROBINSON

Reading EMI test results from a test lab is very much like a radiologist reading a CT scan or MRI results. To the novice, it may seem very hard to decipher what is what, but to the trained eye, the test results provide a road map to not only the frequencies of the outages, but also an indication of what or where the outages more than likely are emanating from.

The engineering analysis process regarding the test scans or test results should be as follows:

- Evaluate the magnitude and nature of the problem. In this process we measure the frequency and the magnitude of each peak in the areas of the outages. It is important to realize that many of the outage peaks are not something you necessarily have to worry about as they could simply be harmonics of the key problem frequency. For instance, if you have noise peaks at 75 MHz, 150 MHz, 225 MHz, 300 MHz... these are obviously harmonics associated with the same problem frequency.
- Use hand held near field E and H field probes to perform sniff testing to determine the specific source or

sources of the issues. Specifically, we look for measured frequencies outages as documented above. A near field probe allows us to identify not only the frequency of the RFI noise, but also to identify the location where the noise is predominantly coming from.

- Analyze the design of the Unit Under Test (UUT) in conjunction with the initial scan and sniff test results. This helps to determine the next course of action. We look at the electrical design of the UUT to establish if the frequencies of concern used. For example, is there a clock or other frequency source that aligns with the measured outages?
- EMI Failures or out of limit conditions are typically attributed to grounding issues, lack of adequate

shielding, need for proper EMI filtering or poor PCB layout and design practices.

To help illustrate how to read these testing results, here are a couple of real world examples that will help you understand how to go about analyzing what the test data is actually telling you.

## CASE STUDY #1

### Test Results: Failed CE102

We measured and verified the Test House initial results. (Figure 1, page 34)

The EMI/EMC design change:  
A system had significant RF Noise that was primarily caused by poor grounding methods and switching power supplies which are typically noisy devices. The noise was primarily



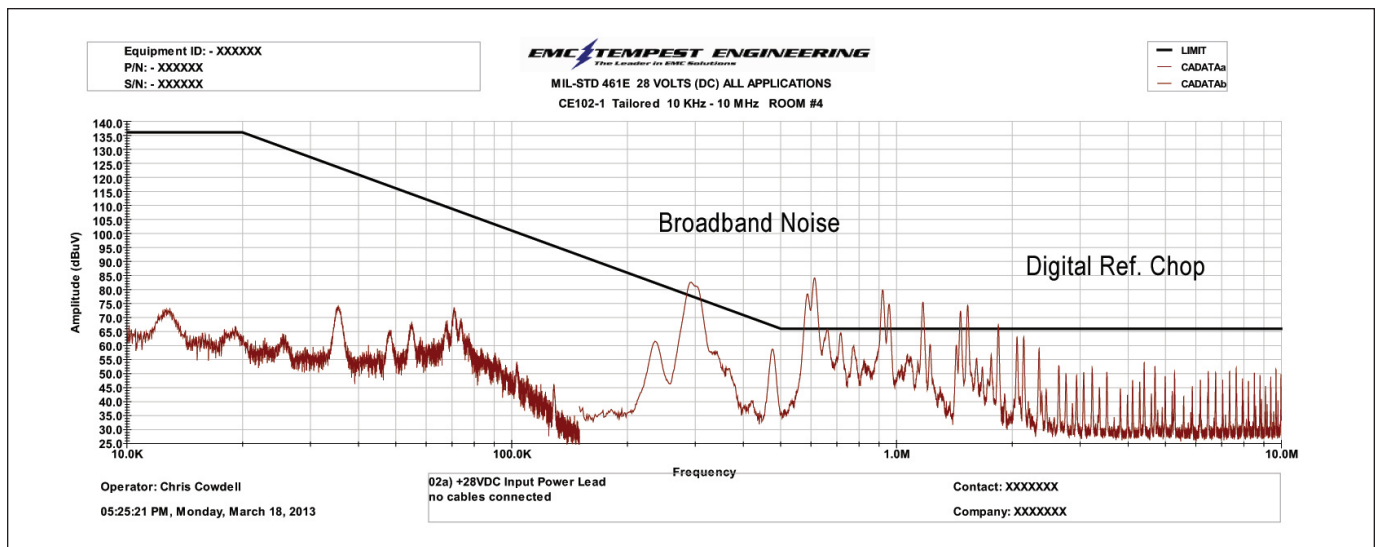


Figure 1

in the low frequency between 300 KHz and 3 MHz.

- We analyzed the grounding of the system and helped isolate the grounds so that the grounds did not re-inject noise into the electrical system. Based on the measured noise, we believed that the broadband noise and digital chop were a result of inadequate grounding as well as coupled noise from the switching power supply. Please note the harmonics in the measured data above, were at 300 KHz, 600 KHz, 900 KHz etc.
- Next, we separated the digital, signal and power grounds, and tied them together through an RF wire wound choke to provide the same ground reference, but not the  $\frac{1}{4}$  wave intrusion. This allowed for isolation of the RF noise source while reducing the cross contamination of the grounds. As we like to say, "A ground is not a ground, even if it is labeled so!"
- We then reviewed the system's interface requirements and found the simplest solution was to add filtering to the

existing connector. It was decided that we would add ferrite materials to help reduce the low frequency noise components as well as using capacitive filtering to reduce the noise. These were built into the existing connector harness. Type 43 material ferrites were introduced on each pin and a type 31 material core was added to the harness in addition to adding 47,000 pF caps to each pin (The most we could build into the tightly spaced connector in a short period of time.) Type 43 ferrites are

made of NiZn and are mostly used for suppression of conducted EMI from 20 MHz to 250 MHz, while type 31 ferrites are made of MnZn and are specifically used for EMI suppression applications from as low as 1 MHz up to 500 MHz.

- The System was then retested with the modified grounding scheme and with the custom filtered connector utilizing chip capacitor filtering in conjunction with a large inductive choke. (Figure 2)



Figure 2



- These fixes solved the system's EMI issues and allowed it to pass EMI/ EMC compliance testing as in Figure 3.

## Final Test results (PASS)

## CASE STUDY #2

### Test Results: Test Unit, Passed CE101, Failed CE102 (+9dB exception), Passed RE101, and Passed RE102

After performing the CE102 test as well as using a near field probe to identify the source of the EMI outages, we concluded that the following critical factors were contributing to the CE102 Failure:

1. The design utilized a noisy switching power supply
2. The positioning of the power supply directly underneath the PCB's digital section
3. Improper AC neutral terminations to the chassis

The noise from the switching supply was radiating directly to the signal lines on the PCB.

AC neutral was directly tied to the chassis which was also tied to -VDC. This caused noise to be re-injected back into the digital circuits from the AC power system. Note the noise on the AC neutral and how this noise followed the noise on the hot lead but extended into the higher frequency range.

4. Lack of proper EMI filtering on the input AC power lines, and the lack of EMI (LC) filtering on the output lines of the power supply to the PCB lead to the conducted emissions failures.

As a result of this analysis, we made the following fixes:

- Modified location of electronic items within the unit and provided some shielding where we could not relocate items. By relocating the source of the noise to further away from the data cables to the PCB, we reduced the effective coupling of the noise to the cables and thereby reduced the system noise.

- Changed the power supply used in this design from a switching supply to a linear supply.
- Modified system grounding and bonding to eliminate tying grounds together without some isolation of noise. We tied the AC neutral to the chassis through an RF choke to provide the logical ground connection, but protecting the digital ground from the noise inherent in the AC power.
- Added EMI filtering at the interface connectors to eliminate the noise. Filtering at the interface is the best location to eliminate incoming and outgoing noise.

**Results: Unit Passed CE102 testing**

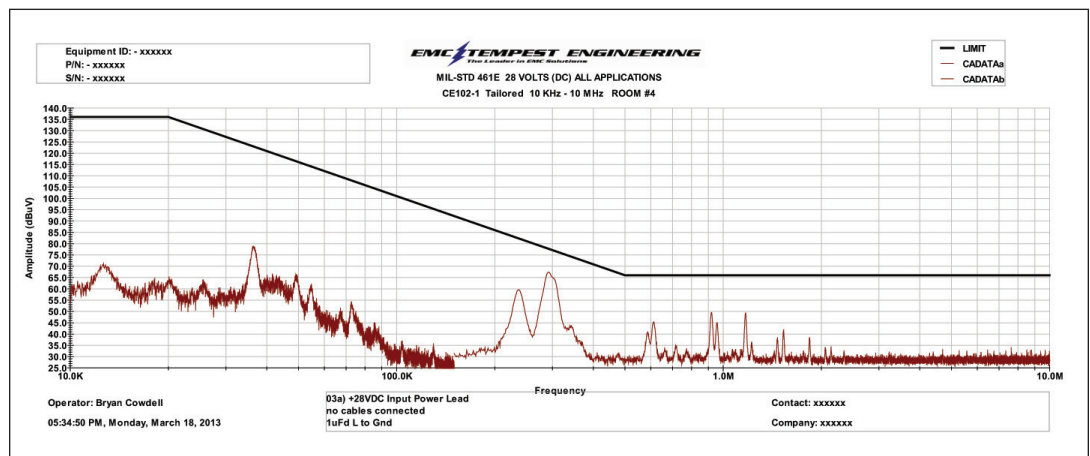


Figure 3

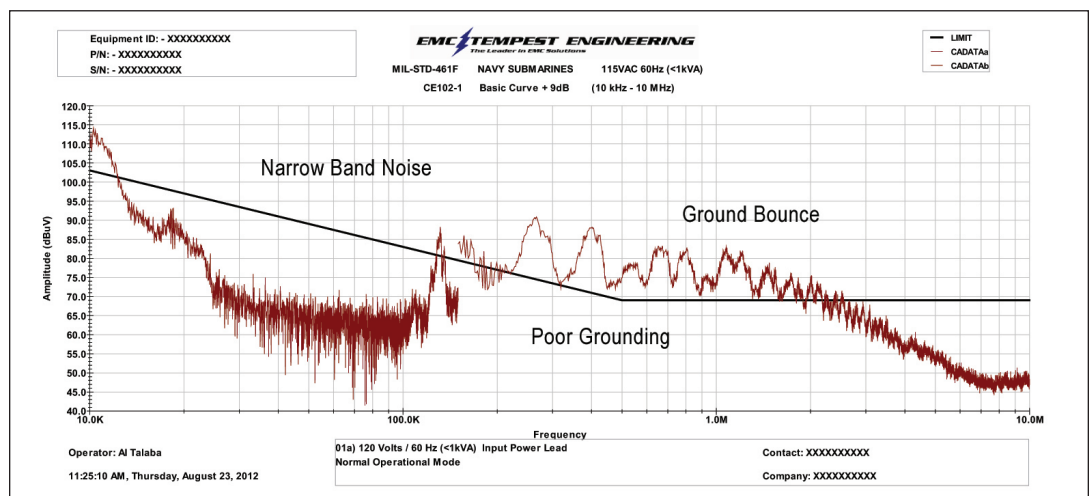


Figure 4: CE102-1 (+9dB) 115VAC Hot Lead 60 Hz

## SUMMARY

The majority of the failures are attributed to a few key items:

- Poor grounding design and implementation (combining analog, digital and “other grounds”)
- Poorly selected power supplies and modules
- Improper shielding methods
- Poor PCB layout and design techniques for EMI/EMC
- Insufficient filtering methods

## Poor Grounding Design and Implementation:

Many times we see poor grounding/ferrite usage techniques, which allow RF noise to bloom from one part of a system and be dumped into another through the interconnection of grounds such as mixing AC and DC (returns) grounds. Most PCB designs have ground bounce to some degree. When designs interconnect various grounds such as digital, analog and even AC neutral, this causes significant noise issues in the overall design, making each ground fight to take control<sup>1</sup> of the PCB.

## Poorly Selected Power Supplies and Modules

### Linear vs. Switched?

The other significant source of failures in EMI testing is the use of inexpensive and typically non-compliant switching power supplies. Switching supplies are widely used but are typically very noisy items. Linear supplies are better with regards to EMI but more expensive. Many power supplies come with filter modules, but they rarely provide sufficient filtering or adequate grounding to help resolve the EMI issues.

## Improper Shielding Methods

System shielding should be designed into the original product design. Ideally all designs would incorporate a Faraday Cage design approach which provides a circumferential shielding layer encapsulating the electronics. Shielding can easily be added in some areas after determining that noise is emanating from that specific area.

## Poor PCB Layout and Design Techniques for EMI/EMC

PCBs should always be designed with 4-8 layers or more. Two layer PCBs are not considered multi-layer and should be avoided in acceptable EMI designs. Do not mix or use common grounds within a PCB. Use whole ground planes and not segmented or islands of grounds within a plane in a PCB. Also avoid only using ground bus lines and not ground planes.

Basic PCB layering techniques must be adhered to including line

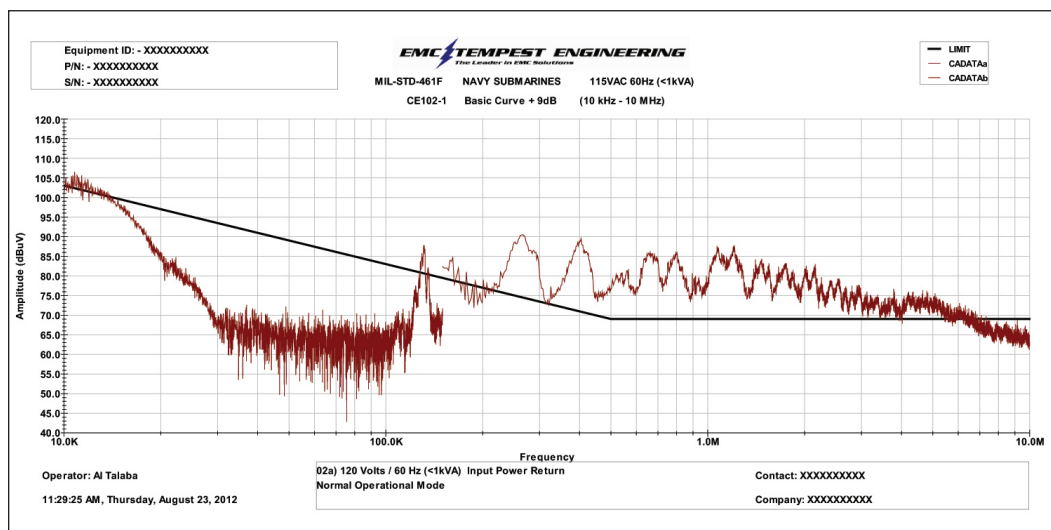


Figure 5: CE102 -2 (+9dB) 115VAC Neutral Lead 60 Hz

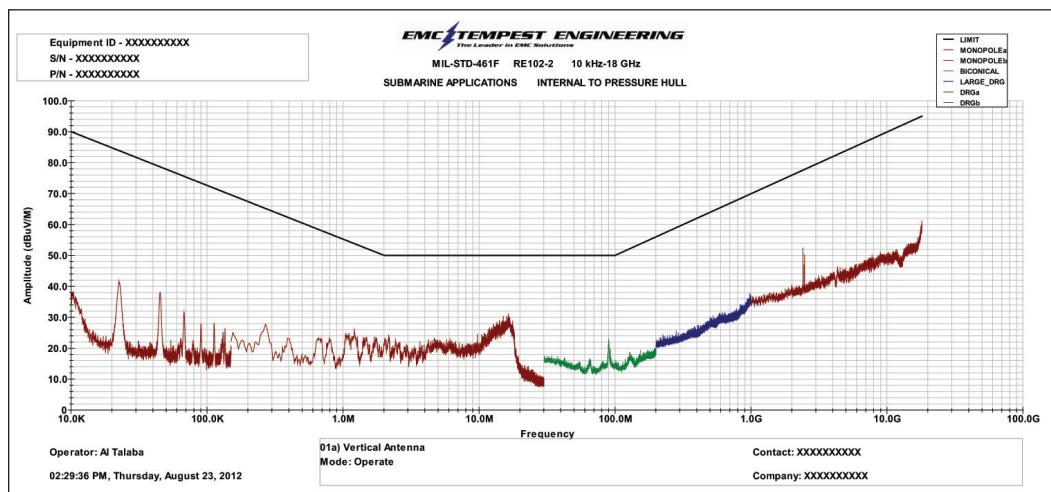


Figure 6: CE102-2 (all 4 Antennas combined)

spacing, awareness of adjacent signals for possible interference, right angle traces or knees. Additionally, designers must understand capacitance versus frequency to help solve your EMI compliance issues. All capacitors do not behave the same. Capacitors should be tuned to provide maximum filtering performance in the frequencies that are at issue. The lower the frequency at issue, the higher the required capacitance. Do not simply use 1 uF caps for all applications.

## Insufficient EMI Filtering Methods

Though sometimes expensive, it is wise to at least consider designing your system with the inclusion of filtered connectors to provide you with the additional insertion loss, EM mitigation needed at the interface to the system to allow you to pass your EMI testing requirements. There are many types of filtered connectors and these can be planned on as a fall back as needed. EMI filter Inserts can also be used during testing to evaluate the potential benefits of filtered connectors.


Filter inserts are a simple low cost options which can be quickly installed, adding capacitive filtering to a unit under test to evaluate the feasibility of improving the EMI design with added filtering. These filter inserts are chip capacitor filters which can be quickly pressed into a connector to provide 40+ dB of insertion loss in a fairly narrow frequency range. They can be tailored to allow for different capacitances on each pin to address the different data frequencies transmitted on each pin. This helps eliminate as much noise as possible with these filter inserts. Filter inserts do not provide the broad band filtering that some systems will require, however they can still be used to evaluate the potential improvement that can be achieved through the addition of filtering.

Once filtering has been proven to be effective, the system can be redesigned to incorporate on board filtering, or filtering can simply be added at the interface in the connectors. Filtered

connector solutions range from the chip capacitor level of filtering (40 dB) to Pi filtering (80 dB) which provides broader frequency performance and higher level filtering.

Additionally, ferrite materials can be added to help absorb system noise. Ferrite materials prevent interference from being transmitted in both directions; *from* a device or *to* a device (culprit vs. victim). Ferrite materials added to systems are used as inductors to form a passive low-pass filter. A pure inductor does not dissipate energy, but produces reactance that impedes the flow of higher frequency signals. A ferrite core or bead can be added to an inductor to improve its ability to block unwanted high frequency noise. The ferrite basically filters out the noise by absorbing the RF energy associated with the noise. This energy is dissipated out in the form of heat.

In summation, good EMI designs incorporate many basic concepts

to improve the probability that the developed system will meet EMI testing requirements. Pre-compliance or pre-certification testing is a great way to fine tune and modify designs to help insure success when performing Final EMI testing. Pre-certification testing also provides you with an opportunity to try various design fixes and solutions without the pressure of final test certification to play with and implement simple design modifications to help your system ultimately pass EMI testing requirements. 

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### (the author)

#### ROBERT YDENS

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# New Development Tools and EMC Strategies in Step with Practical Electronics

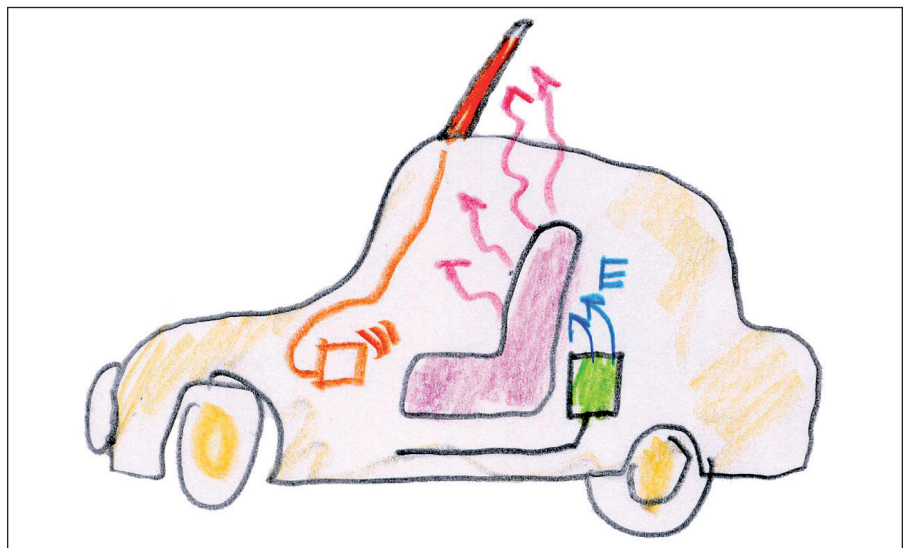
BY GUNTER LANGER

Imagine for a moment that you are trying out a brand new car: you slide into one of the ergonomic seats, start the engine and, to make things perfect, would like to listen to some music. However when you switch this on, you suddenly notice interesting side effects. The light comes on in the passenger compartment, for example. Or the radio starts whistling and whimpering.

These are relatively harmless phenomena. Much more serious problems could occur that may even jeopardize driving safety or impair the car's functions.

High-frequency interferences are very tricky in modern electric automobiles, hybrid vehicles or complex electronic systems for the driver's safety and comfort.

Usually, it is not an electronic component as a whole, but an individual device that is responsible for emissions. A device, such as a quartz crystal resonator or microcontroller, causes local electromagnetic fields that induce voltages in housings or structural parts. These parts are thus stimulated to oscillate and, as a result,



**Figure 1:** A component radiates into the driver seat's metallic structure via an electrical near field. The driver's seat that is excited in this way radiates emissions into the vehicle's antenna that interfere with radio reception.



The developer has to place individual protocols one beside the other and compare them step by step. This approach to EMC component development takes time, is complicated and unsatisfactory for the developer - it thus requires much effort and causes high costs.

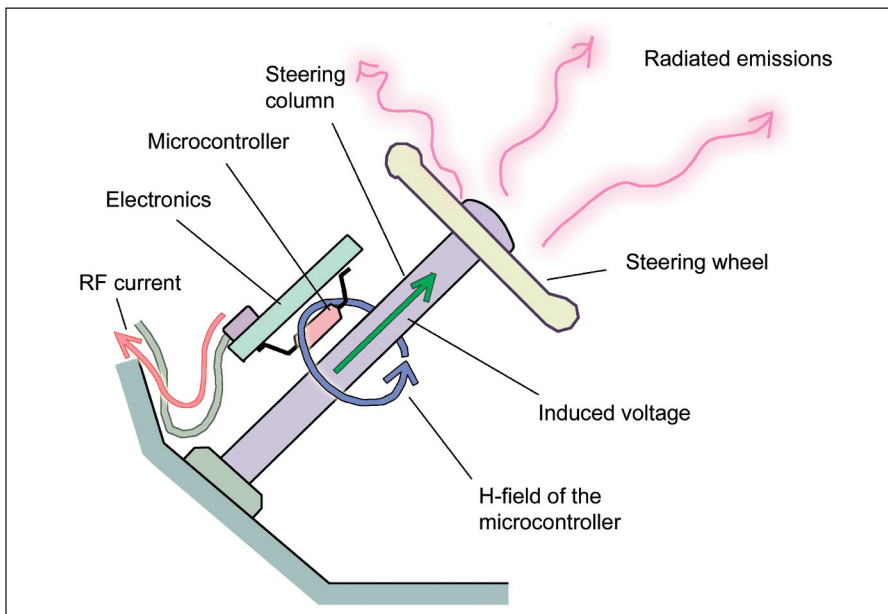
radiate emissions. The developer will certainly check his components for emissions by carrying out component measurements in an EMC test chamber during the development process. But these will measure emissions from the device under test in general. The measuring methods used in such tests are unable to sufficiently assess the near fields of a device under test. When performing measurements with conventional methods, the developer cannot intervene directly in the device under test, measure individual sections of the component more precisely or do anything to get to the bottom of the emissions source. He takes his device under test out of the EMC chamber, puts it in its package and takes it back to his workplace. Another problem in conjunction with these component measuring methods is that the component is tested outside its actual

vehicle environment, and emission frequencies may not be measured since the otherwise present neighboring structural parts are not stimulated to oscillate.

Back at his workplace, the developer can only compare the frequency images from the component test with those gained from experiences in other development processes and make assumptions about the reasons behind the problems. He will then modify the device under test on the basis of these assumptions. Only further test measurements in the EMC chamber will show him whether this was correct and successful. The measurement set-up has to be repeated for new component measurements. But in most cases the component, and especially the cable harness, cannot be returned to an absolutely identical

position. This results in measurement deviations. The frequency response characteristics measured at the different development stages of the device under test cannot be compared immediately and flexibly. The developer has to place individual protocols one beside the other and compare them step by step. This approach to EMC component development takes time, is complicated and unsatisfactory for the developer - it thus requires much effort and causes high costs.

What is needed here is a more effective search for emission sources in complex electronic systems during the development. The engineer must be able to measure as many disturbances as possible, systematically identify RF sources, carry out modifications and tests flexibly at his workplace in order to save time and costs.



**Figure 2: A microcontroller located on the component radiates a magnetic field. This encircles the steering column, where it induces a voltage. This voltage stimulates the steering column to radiate emissions that may interfere with sensitive components near the driver's seat.**

**Let us now take a look at how a component may become a source of emissions.** An electronic assembly or a printed conductor itself does not usually send out any emissions. However individual devices may generate RF near fields and these encircle connected cables, for example. They induce a voltage there and thus cause them to radiate emissions. Due to electric or magnetic coupling (i.e. in the near field), the entire metallic system, comprising the component and its connected cables as well as metallic parts such as housings, shielding plates, etc. in its immediate vicinity, is subject to self-excitation. (Figure 2)

The metallic system in its entirety acts as an antenna when excited by the electronics. The RF exciting current from the electronics to the antenna (cables and metal parts) can thus



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be assumed to be an approximate measure of the emissions from the device under test.

**We will now describe a measurement set-up that complies with our requirements for the efficient development of a component in terms of emissions.** Emissions are measured under conventional measurement conditions with an antenna, for example. The device under test must be modified if one or more frequencies of the development sample exceed the limit values defined in the respective standard. The values from this measurement are used as a reference for subsequent comparative measurements. (Figure 3)

When measuring emissions from electronic systems at a developer's workplace, it is important to define a measurement set-up that simulates the component's environment in the passenger compartment as closely as possible. A confined measurement set-up is arranged at the workplace to measure all reasonable RF currents of the device under test. Should the relevant frequencies be in a range that is subject to high external interference from the environment such as radio frequencies, a shielding tent is used to protect the measurement set-up against this interference. This shielding tent has a footprint of 50x90 cm and an attenuation of more than 40 dB in the frequency range from approximately 80 to 650 MHz. The front of the shielding tent can be folded up and down. The entire shielding tent can be opened wide to allow easier modification of the device under test. Supply lines such as power supply, cables for transmitting

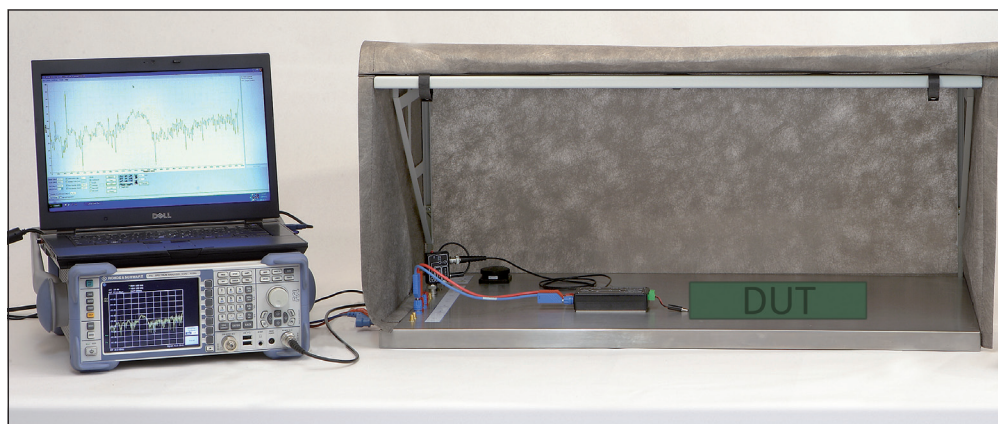
measurement signals are led to the outside through filtered bushings in the ground plane. This also establishes a fixed ground reference for the device under test and parts of the measuring equipment.

#### **How is the measurement carried out at the developer's workplace?**

A comparative measurement is carried out with the RF current transformers in the closed shielding tent and documented in a first step. These measurement results are compared with the results from the

component measurement to confirm the measurement set-up. Of course, the measurement results will not coincide. However it is important that the relevant frequencies from the component measurement are also found in the frequency image of the measurement set-up that has been chosen.

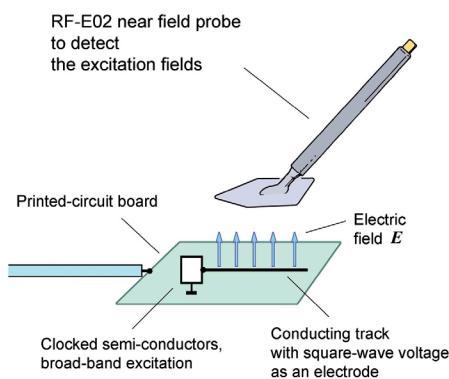
In the next step, magnetic field and electrical field probes are used to scan the ICs, line connections, plug-in connectors, etc. A precise analysis of the frequencies and the orientation



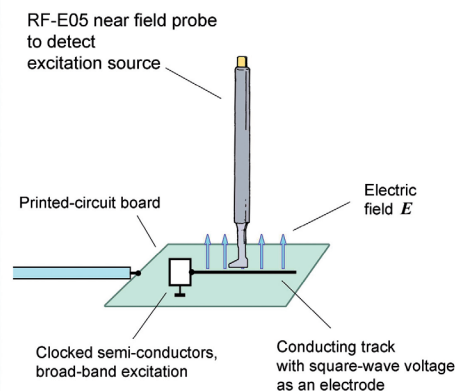
**Figure 3: ESA1 development system with ChipScan-ESA software and spectrum analyzer**

## **E/D Near field search**

**Determine if the module is excited via an E/D field**



**Determine the excitation source**



**Figure 4**



of the near fields often allows the developer to recognize the correlations between the fields and the exciting currents. The front of the shielding tent must be opened to measure the near fields with the probes. Of course, the shielding effect is then much lower than when the shielding tent is closed. The near fields of the device under test, however, are usually much stronger than the fields coupling in from the environment so that measurements can nevertheless be carried out successfully. The intensity of the field at a certain frequency and within a certain frequency range. (Figure 4 and Figure 5)

Possible RF sources are:

- electrical fields above devices such as processors
- electrical fields on switched lines and bus systems
- magnetic fields on switched data and clock lines
- magnetic fields at power supplies

As soon as the RF sources have been identified, the board can be modified on site by soldering components in place, taking shielding measures or rerouting lines. The results of a further measurement with the RF current transformer in the closed shielding tent will immediately show whether the measure that has just been taken is effective or not. RF current transformers and near-field probes can be used alternately for measurements in subsequent tests. The component can be constantly modified until a minimum exciting current from the RF current transformer flows in the supply line.

The frequency response characteristics that are measured can be documented with a PC and customized software. This software allows the developer to record, color, annotate, calculate and visualize any number of curves of a spectrum analyzer, and it enables a flexible, easy and fast comparison of

the different steps of the measurement process. The developer can simply export images and data from the software for documentation and statistical analysis. (Figure 6)

A closer look at EMC problems of components shows that plug-and-

socket connectors, and in particular connectors used in the HV systems of hybrid automobiles, are special. They are subject to high demands in terms of EMC. Testing such connectors in the component's prototype is, in fact, too late since the developer has no chance of improving the connector.

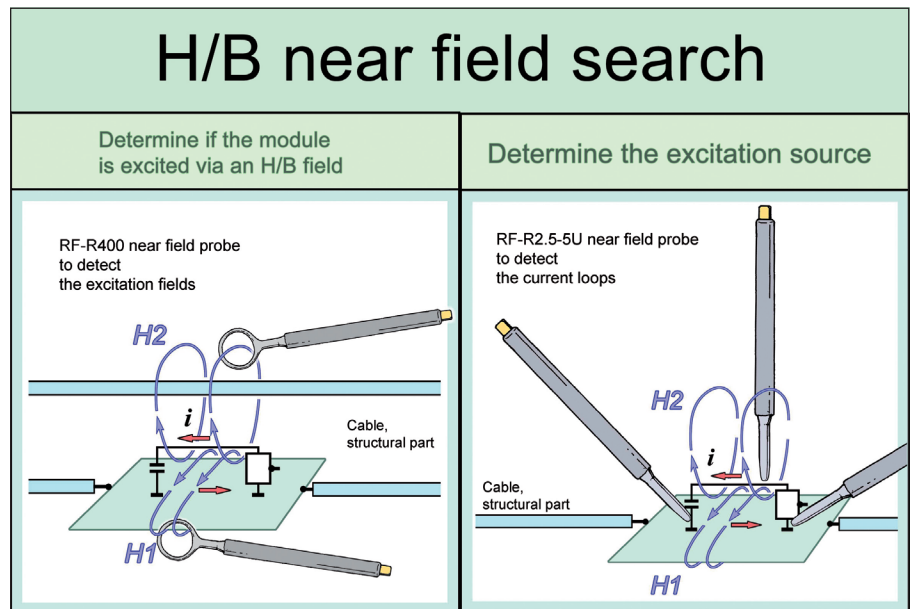


Figure 5: Use of electrical and magnetic field probes to measure near fields on components and their devices.

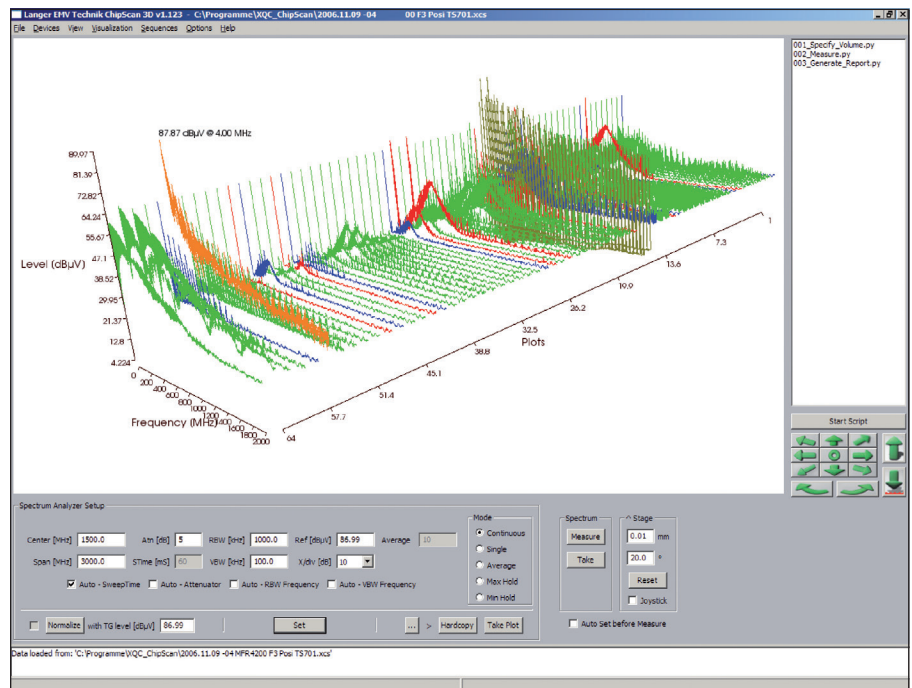
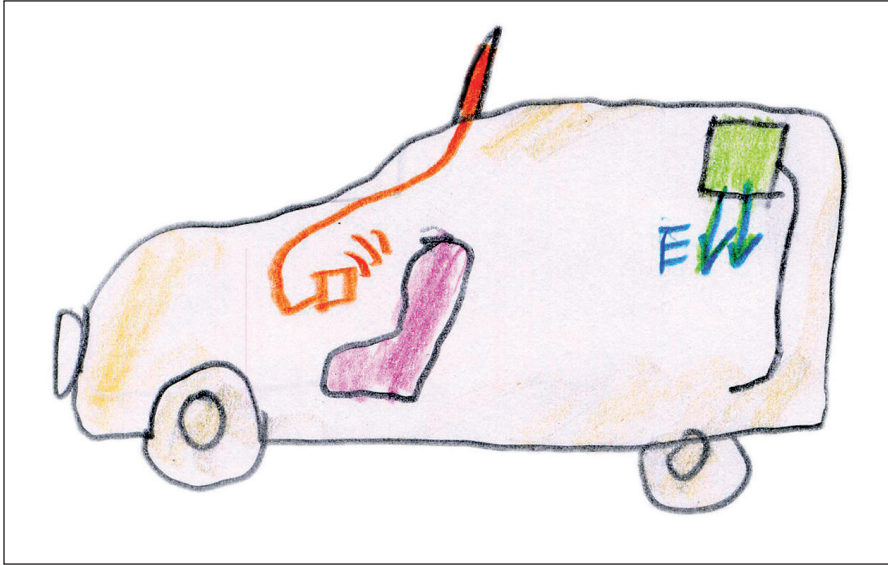


Figure 6: Large quantities of different data provided by a spectrum analyzer can be conveniently measured and compared using the ChipScan-ESA software.

The developer should thus test the individual connector in terms of its EMC characteristics at the beginning of the development process or rely on connectors with known EMC parameters that are deemed sufficient for the component.

Apart from devices with one or two cable connections, complex devices can be tested too. At the beginning of the test, different effects caused by different RF sources within the device under test will superimpose and lead to an amplification or partial cancellation of

RF fields at individual frequencies. It is, therefore, important for an efficient analysis of the causes, especially in complex devices under test consisting of several printed circuit boards, that the device be dismantled to manageable parts and the individual printed circuit boards be investigated separately.



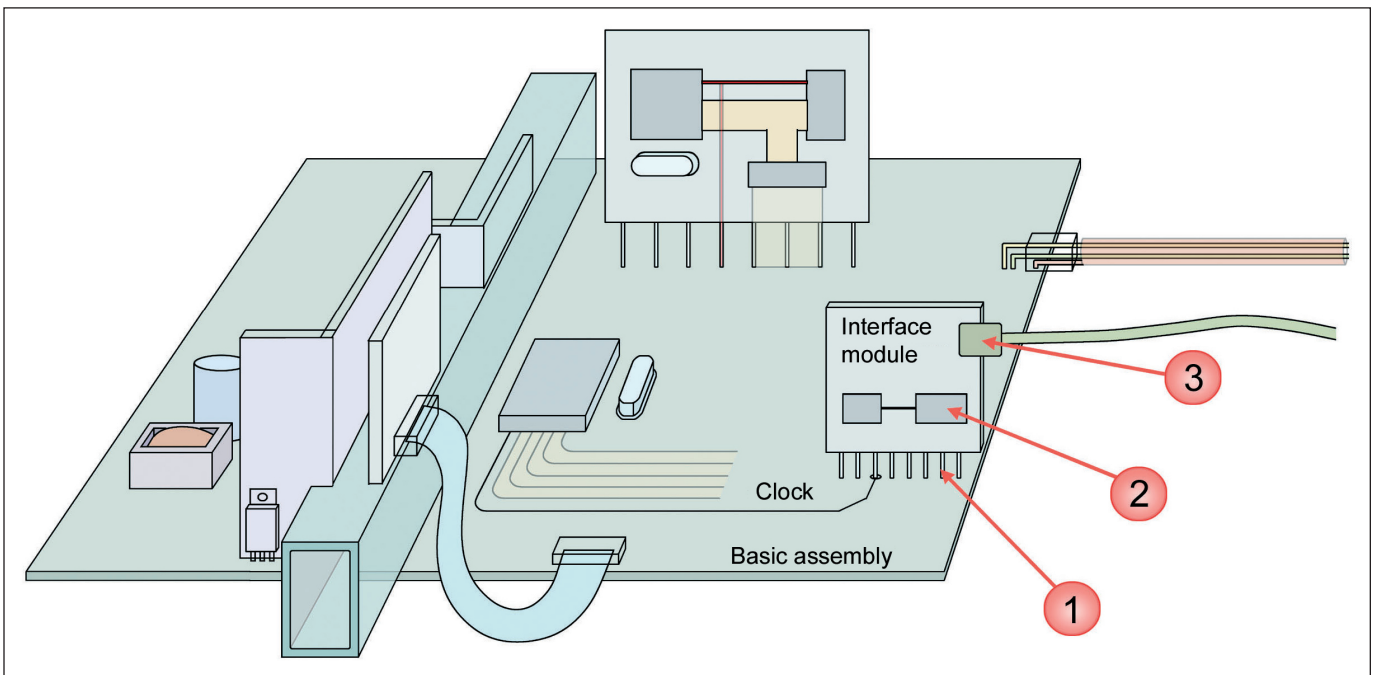
**Figure 7: The developer could identify the source of the emissions in Figure 1 by detecting the near fields. In this case, interference with the automobile radio could be prevented simply by relocating the component responsible for the emissions to a place in the automobile where no parts can be stimulated to oscillate in the vicinity.**

The device under test shown in Figure 8 has several potential emission sources. The investigation is limited to the interface module of the component in this example.

Three RF sources are conceivable:

1. the connector between the basic assembly and the interface module
2. the electronics (PHY with a microprocessor) on the interface module
3. the connector of the interface cable

These three RF sources will now be dealt in succession. This requires measurement set-ups that suppress the respective other RF sources and the RF sources of the basic assembly as far as possible.



**Figure 8: Possible emission sources of the interface module in a complex assembly**



## 1. Connector between the basic assembly and the interface module (Figure 9)

The basic assembly and interface module are connected to each other via data and control lines. These lines are well protected on the printed circuit board in the area of the basic assembly and the interface module since they are embedded into ground surfaces. But in the area of the connector they pass freely through an open space. The signal currents in the lines generate RF magnetic fields which propagate inside and around the connector. They generate induction voltages in the connector's ground pins. As a result, there is a voltage difference between the basic assembly and the interface module. This drives an RF current into the interface cable via the interface board which in turn causes an excitation of the cable and thus emissions from it.

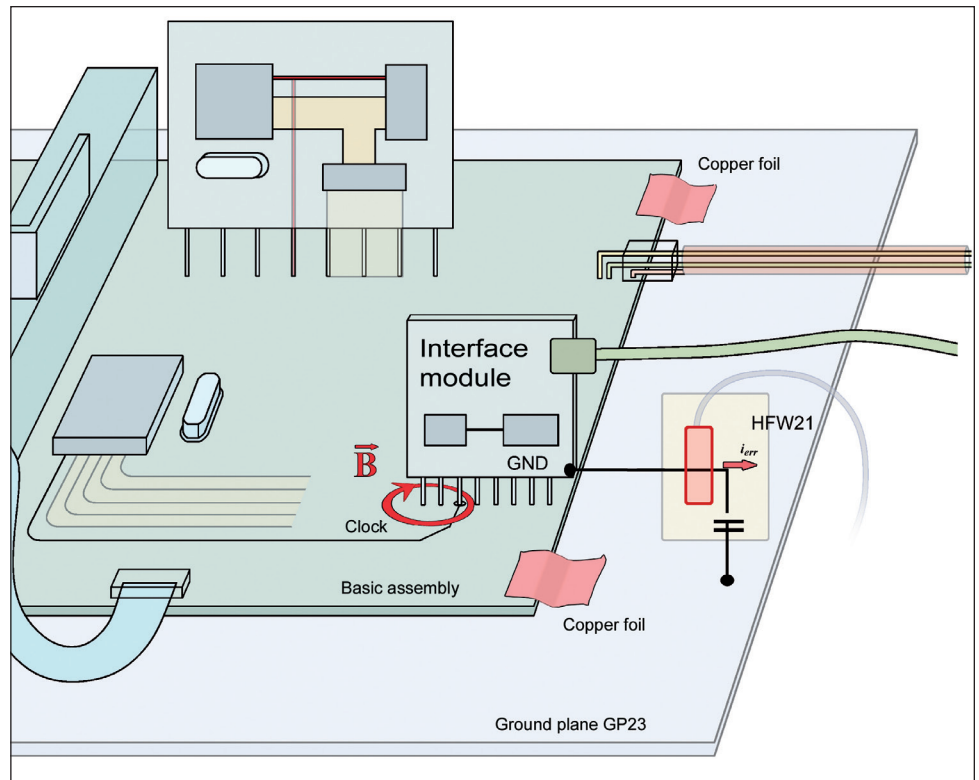


Figure 9: First measurement step with the ESA1 – Detect emission sources on the connector between the basic assembly and the interface module

A COM port of the current transformer is connected at a short distance to GND of the interface module to measure the current that is driven by the induction voltage. The current measured with a current transformer is a measure of the connector's share of the total emissions from the device under test. The effect of modifications such as filters on signal lines or changing the pin assignment can be measured directly.

## 2. Electronics (PHY with a microprocessor) on the interface module (Figure 10)

The ICs of the interface module generate currents that flow into the GND system where they induce a voltage. This voltage in turn drives a current from the basic assembly through to the connected interface cable which

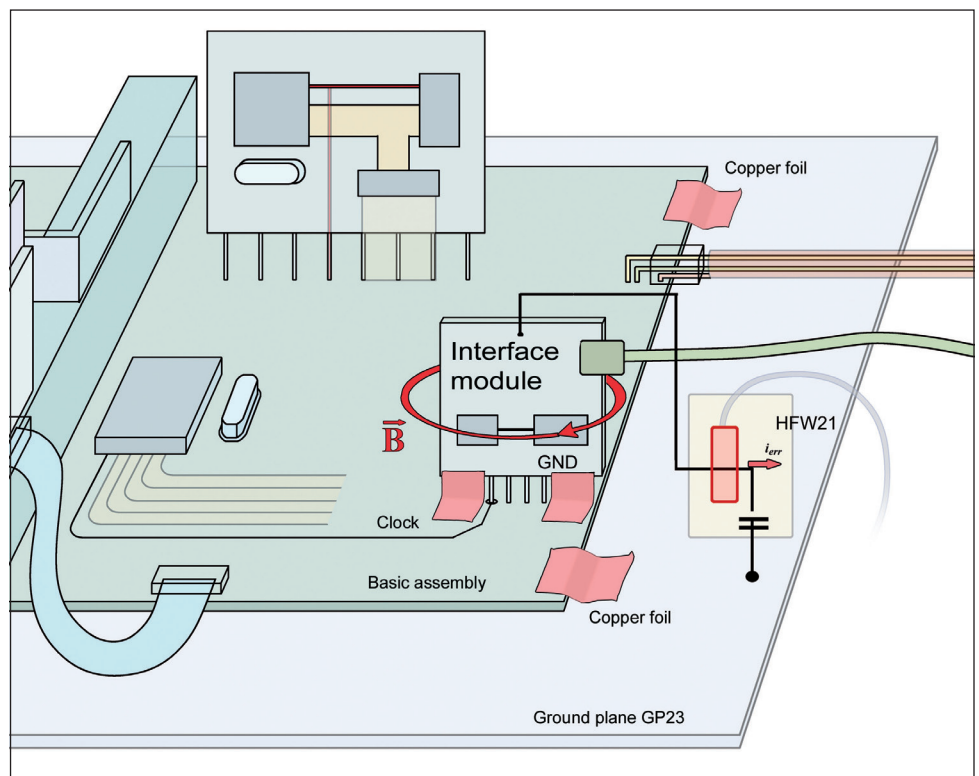


Figure 10: Second measurement step with the ESA1 – Detect emission sources in the electronics

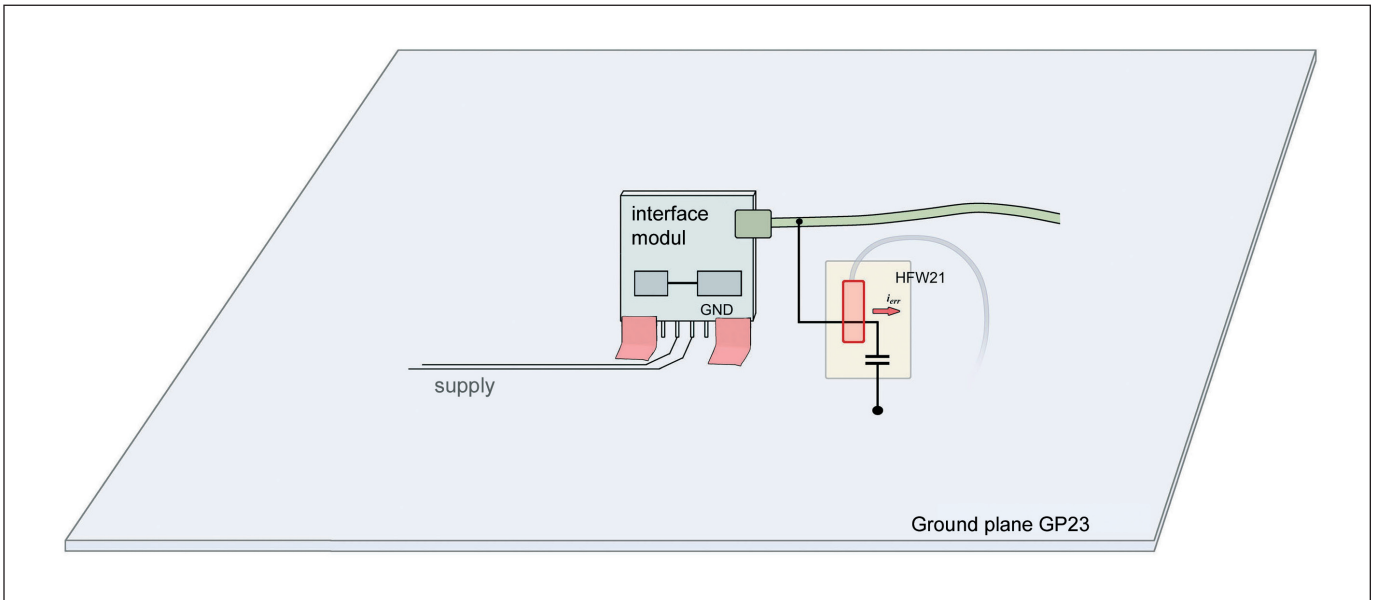


Figure 11: Third measurement step with the ESA1 – Detect emission sources on the connector of the interface cable

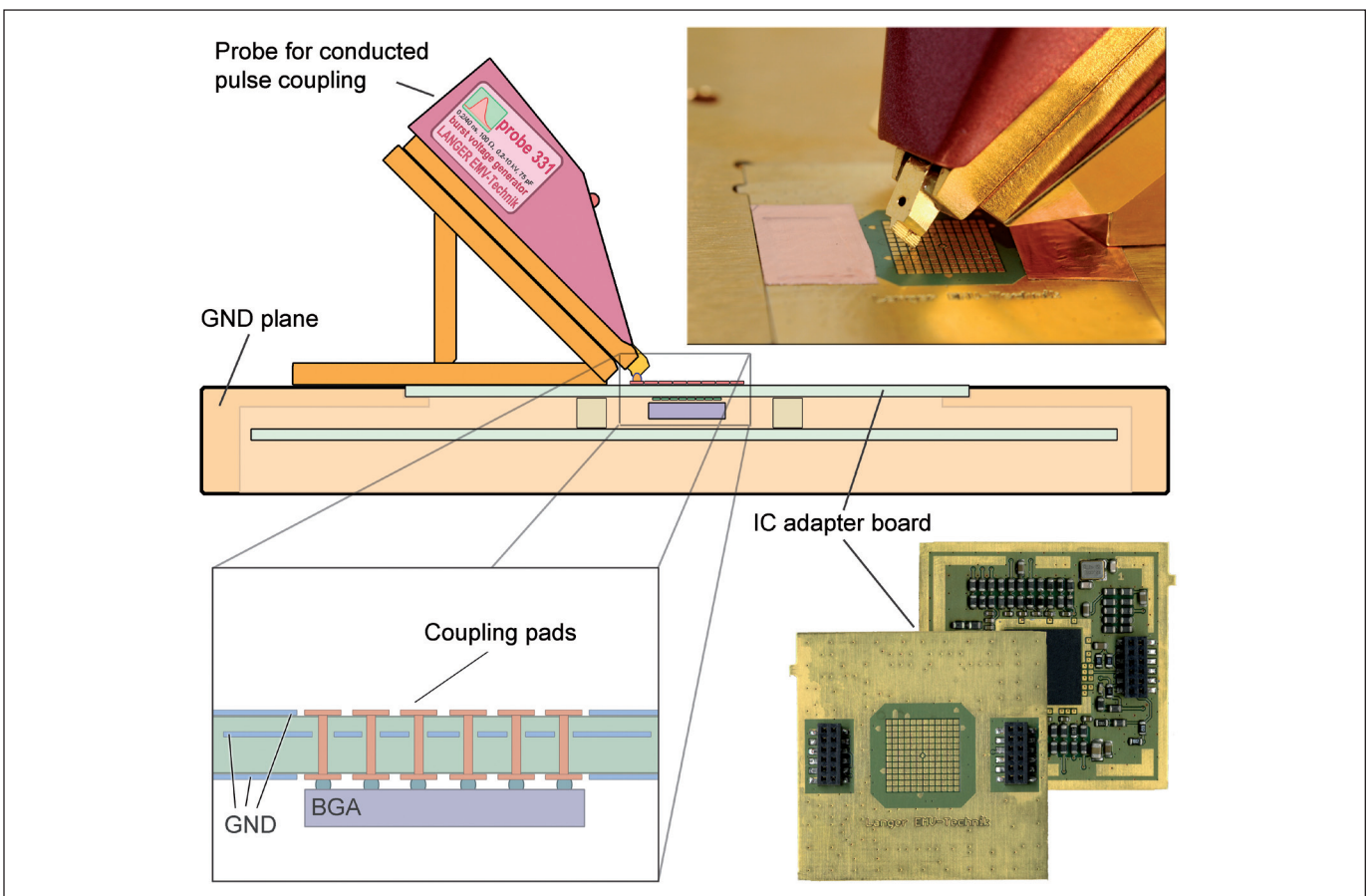


Figure 12: Shows the test set-up for direct disturbance coupling into an LFBGA package. The IC is mounted on a customised IC adapter board. Disturbances can be injected directly into the balls of the BGA with the probes from the P200/P300 series. The chip's external wiring is as specified by the manufacturer. In addition, filter elements are provided in supply and signal lines to prevent the disturbance pulse from draining and thus to establish defined conditions.



Procedures and information are available to the electronics developer that help him plan the EMC of a complex component in advance and to measure and modify this directly at his workplace during the development process.

excites the interface cable to send out emissions.

The basic assembly remains connected to the ground plane during the measurement. The connector's share in the emissions between the ground plane and the interface module is cancelled out by several large-area GND connections. The voltage that is induced by the IC currents can be picked up with the current transformer at the upper end of the assembly. The current transformer measures a proportional current. Modifications that are carried out directly on the interface module can thus be assessed.

### 3. Connector of the interface cable (Figure 11)

The interface connector is another RF source in this complex component. During data transfer, the interface driver drives a current through the connector. This current induces a direct-axis voltage in the connector housing that stimulates emissions from the interface cable.

The current transformer is connected to the interface cable for the measurement. It has to be noted that the voltage is superimposed according to number 2 above during this measurement. This voltage can be short-circuited by gluing a piece of copper foil to the interface circuit board.

The integrated circuit is another electronic element that is important for the developer of the component. The characteristics of the ICs used for the electronic system have a major


influence on the EMC characteristics of the entire component. The structures of microcontrollers and chipsets are becoming increasingly smaller. This is why the IC's sensitivity today can be up to ten times higher than that of their predecessor models. The behaviour of ICs and their package types in terms of immunity and emissions is a crucial aspect which the developer has to take into account when choosing devices for a component. It is thus important to select an appropriate IC and use it in compliance with the respective EMC requirements in the planning phase of a component's development process. Compliance measurements according to BISS/IEC should be carried out on ICs with respect to EMC parameters as a standard procedure. However, these measurements are not enough to ensure that an IC is successful in practice. In addition, ICs should be tested with practical and universal EMC parameters such as ESD.

The pulses that occur on ICs during ESD and burst tests for devices can be simulated for IC immunity tests. Special IC measuring and testing technology should allow the developer to carry out immunity tests independent of the device or component. (Figure 12)

The developer has to delve deep into a component's physical process during IC emissions analysis. If, for instance, a fast circuit with its high-frequency currents and voltages is placed in an unfavorable position on the device, this may interfere with the component itself or other components or devices through coupling paths via the component.

The test results help achieve three objectives:

1. Improvement of the IC to avoid problems in later use
2. Practical parameters and conditions for the interference-free use of the IC on components
3. Selection of an IC that is suitable for the IC user's application on the basis of the IC's EMC parameters

Procedures and information are thus available to the electronics developer that help him plan the EMC of a complex component in advance and to measure and modify this directly at his workplace during the development process. Development becomes more efficient and less time-consuming. Fewer component tests in an EMC chamber will be necessary. This reduces lengthy waiting times whenever an EMC chamber has to be used. This in turn speeds up component development so that resources, time, and costs can be saved. 

#### (the author) GUNTER LANGER

Dipl. Ing. Gunter Langer (\*1950) focuses on research, development, and production in the field of electromagnetic compatibility (EMC) since 1980. He founded the Gunter Langer engineering office in 1992 and Langer EMV-Technik Ltd. in 1998. His interference emission and interference immunity EMC measurement technology as well as the IC test system are used mainly in the development stage and are in worldwide demand.









# Fundamentals of Electrostatic Discharge

## Part Four: Training and Compliance Verification Auditing

BY THE ESD ASSOCIATION

**Y**our static control program is up and running. How do you determine whether it is effective? How do you make sure your employees follow it? In Part Three, we covered basic static control procedures and materials of your ESD control program. In *Part Four*, we will focus on two ESD control program plan requirements: training and compliance verification auditing. Per ANSI/ESD S20.20 and IEC 61340-5-1, the written ESD control plan is to include a training plan and a compliance verification plan.

### PERSONNEL TRAINING

The procedures are in place. The materials are in use. But, your ESD control program just does not seem to yield the expected results. Failures declined initially, but they have begun reversing direction. Or perhaps there was little improvement. The solutions might not be apparent in inspection reports of incoming ESD protective materials. Nor in the wrist strap log

of test results. In large companies or small, it is hard to overestimate the role of training in an ESD control program. ANSI/ESD S20.20 and IEC 61340-5-1 ESD Control Program standards cite training as a basic administrative requirement within an ESD control program.

There is significant evidence to support the contribution of training to the success of the program. We would not send employees to the factory floor without the proper soldering skills or the knowledge to operate the automated insertion equipment. We should provide them with the same skill level regarding ESD control procedures.

### ELEMENTS OF EFFECTIVE TRAINING PROGRAMS

Although individual requirements cause training programs to vary from company to company, there are several common threads that run through the successful programs.

### Successful training programs cover all affected employees

Obviously we train the line employees who handle ESD sensitive devices and typically test their wrist straps or place finished products in static protective packaging. But we also include department heads, upper management, and executive personnel in the process. Typically they are responsible for the day-to-day supervision and administration of the program or they provide leadership and support. Even subcontractors and suppliers should be considered for inclusion in the training program if they are directly involved in handling your ESD sensitive components, sub-assemblies or products.

Because ESD control programs cover such a variety of job disciplines and educational levels, it may be necessary to develop special training modules for each organizational entity. For example, the modules developed for management, engineering, assembly

technicians and field service could differ significantly from one another because their day-to-day concerns and responsibilities are much different. Also, the different education and skills should be considered.

### **Effective training is comprehensive and consistent**

Training not only covers specific procedures, but also the physics of the problem and the benefits of the program as well. Consistent content across various groups, facilities, and even countries (adjusted for cultural differences) reduces confusion and helps assure conformance. The training content should include topics such as the fundamentals of static electricity and electrostatic discharges, the details of the organization's ESD Control Program plan, and each person's role in the plan.

### **Use a variety of training tools and techniques**

Choose the methods that will work best for your organization. Combine live instruction with training videos or interactive computer-based programs. You may have in-house instructors available, or you may need to go outside the company to find instructors or training materials. You can also integrate industry symposia, tutorials, and workshops into your program. Consider using this "Fundamentals of ESD" series of articles.

Effective training involves employees in the process. Reinforce the message with demonstrations of ESD events and their impact. Bulletin boards, newsletters, and posters provide additional reminders and reinforcement.

Maintaining a central repository for educational ESD control materials will help your employees keep current or answer questions that may occur outside the formal training sessions.

Materials in such a repository might include

- Material from initial and recurring training sessions
- ESD Association or internal bulletins or newsletters
- DVDs or CDs
- Computer based training materials
- Technical papers, studies, standards (e.g. ESD Association, IEC, JEDEC), test methods and technical reports
- ESD control material and equipment product technical data sheets

In addition, a knowledgeable person in the organization should be available to answer trainee questions once they have begun working.

### **Test, certify and retrain**

Your training should assure comprehension, material retention and emphasize the importance of the effort. If properly implemented, testing and certification motivates and builds employee pride. Retraining or refresher training is an ongoing process that reinforces, reminds, and provides opportunities for implementing new or improved procedures. Establish a system to highlight when employees are due for retraining, retesting, or recertification.

### **Feedback, compliance verification, and measurement**

Motivate and provide the mechanism for program improvement. Sharing yield or productivity, quality, and reliability data with employees demonstrates the effectiveness of the program and their efforts. Tracking these same numbers can indicate that it is time for retraining or whether modifications are required in the training program.

Design and delivery of an effective ESD training program can be just as important as the procedures and

materials used in your ESD control program. Without an effective personnel training program, investments in ESD materials can be wasted. A training program that is built on identifiable and measurable performance goals helps assure employee understanding, implementation and success.

A key method of training effectiveness is observation of the operator in the EPA following ESD control procedures and precautions. Non-compliance with required ESD control program practices should be treated in the same manner of other impermissible actions that are handled through the company's disciplinary process. This includes verbal warnings, re-training, written warnings, and eventually re-assignment or termination.

## **COMPLIANCE VERIFICATION AUDITING**

Developing and implementing an ESD control program itself is obvious. What might not be so obvious is the need to continually review, verify, analyze, feedback and improve. You will be asked to continually identify the program's financial return on investment and to justify expenditures with the cost savings realized. Technological changes will dictate improvements and modifications. Feedback to employees and top management is essential. Management commitment will need continuous reinforcement.

Like training, regular program compliance verification and auditing becomes a key factor in the successful management of ESD control programs. The mere presence of the auditing process spurs compliance with program procedures. It helps strengthen management's commitment. Program compliance verification reports should trigger required corrective action and help foster continuous improvement.



The benefits to be gained from regular compliance verification of ESD control procedures are numerous.

- Prevent problems before they occur rather than always fighting fires.
- Identify problems and take corrective action.
- Identify areas in which programs may be weak and provide information required for continuous improvement.
- Leverage limited resources effectively.



The benefits to be gained from regular compliance verification of ESD control procedures are numerous.

- Prevent problems before they occur rather than always fighting fires.
- Identify problems and take corrective action.
- Identify areas in which our programs may be weak and provide us with information required for continuous improvement.
- Leverage limited resources effectively.
- Determine when our employees need to be retrained.
- Improve yields, productivity, and reliability.
- Bind our ESD program together into a successful effort.

An ESD control program compliance verification audit measures performance to the ESD Control Program Plan's required limits. Typically, we think of the ESD program compliance verification as a periodic review and inspection of the ESD protective area (EPA) verifying the correct use of packaging materials, wearing of wrist straps, following defined procedures, and similar items. Auditing can range from informal surveys of the processes and facilities to the more formal third-party audits for ISO 9000 or ANSI/ESD S20.20 certification.

## REQUIREMENTS FOR EFFECTIVE COMPLIANCE VERIFICATION

Regardless of the structure, effective compliance verification revolves around several factors. First, the *existence of a written and well-defined ESD Control Program Plan* with defined required limits for each EPA ESD control item. It is difficult to measure performance if you do not have anything to measure against. Yet, you quite frequently hear an auditor ask, "Some people say you should measure less than 500 volts in an EPA, but others say you should measure less than 100 volts. What's acceptable when I audit the factory floor?" Obviously, this question indicates a lack of a formal ESD Control Program Plan defined required limits and test procedures, and the audit will be relatively ineffective.

Second, the *taking of some measurements* – typically measuring resistance and detecting the presence of charge or fields. Therefore, you will need *test equipment* to conduct EPA compliance verification. As a minimum, you will need an *electrostatic field meter*, a *high range resistance meter*, a *ground AC outlet tester*, and appropriate electrodes and accessories.

Third, *include all areas in which ESD control is required* to protect electrostatic discharge sensitive (ESDS)

items. Typically included are receiving, inspection, stores and warehouses, assembly, test and inspection, research and development, packaging, field service repair, offices and laboratories, and cleanrooms. All of the areas listed in the ESD Control Program Plan are subject to compliance verification. Even the areas that are excluded from the plan need to be reviewed to ensure that unprotected ESDS devices are not handled in those areas. In the event that devices do enter those areas (e.g. Engineering and Design), mechanisms must be put in place to ensure that the devices are handled as non-conforming product. Similarly, we need to audit all of the various processes, materials, and procedures that are used in our ESD control programs – personnel, equipment, wrist straps, floors, clothing, worksurfaces, continuous monitors, seating, training, and grounding.

Fourth, we need to conduct compliance verification audits *frequently and regularly*. However, the user must determine the frequency (and if sampling is appropriate). Per Compliance Verification ESD TR53 ANNEX A Test Frequency "The objective of the periodic test procedures listed in this document is to identify if significant changes in ESD equipment and materials performance have occurred over time.

Test frequency limits are not listed in this document as each user will

need to develop their own set of test frequencies based on the critical nature of those ESD sensitive items handled and the risk of failure for the ESD protective equipment and materials.

Following are examples of how test frequencies are considered. Daily wrist strap checks are sufficient in some applications, where in other operations constant wrist strap monitoring may be used for added operator grounding reliability. Packaging checks may depend on the composition of the packaging and its use. Some packaging may have static control properties that deteriorate more quickly with time and use, and some packaging may be humidity dependent and may have limited shelf life.

Some materials, such as ESD floor finishes, may require more frequent monitoring because of their lack of permanency. Other materials, such as ESD vinyl floor covering, may require less monitoring. The testing of a floor should also be considered after maintenance on the floor has been performed.”

The actual frequency of compliance verification audits depends upon your facility and the ESD problems that you have. Following an ESD Control Program initial audit, some experts recommend auditing each department once a month if possible and probably a minimum of six times per year. If this seems like a high frequency level, remember that these regular verification audits are based upon a *sampling* of work areas in each department, not necessarily *every* workstation. Once you have gotten your program underway, your frequency of audit will be based on your experience. If your audits regularly show acceptable levels of conformance and performance, you can reduce the frequency and the sampling. If, on the other hand, your audits regularly uncover continuing problems, you will want to increase the frequency and the sampling.

Fifth, we need to *maintain trend charts and detailed records and prepare reports*. They help assure that specified procedures are followed on a regular basis. The records are essential for quality control purposes, corrective action and compliance with ISO-9000.

Finally, upon completion of the compliance verification audit, it is essential to *implement corrective action* if deficiencies are discovered. Trends need to be tracked and analyzed to help establish corrective action, which may include retraining of personnel, revision of requirement documents or processes, or modification of the existing facility.

## TYPES OF AUDITS

There are three types of ESD audits: *program management* audits, *quality process* checking, and *ESD Control Program compliance verification (work place)* audits. Each type is distinctively different and each is vitally important to the success of the ESD program

*Program management* audits measure how well a program is managed and the strength of the management commitment. The program management audit emphasizes factors such as the existence of an effective implementation plan, realistic program requirements, ESD training programs, regular compliance verification audits, and other critical factors of program management. The program management audit typically is conducted by a survey specifically tailored to the factors being reviewed. Because it is a survey, the audit could be conducted without visiting the site. The results of this audit indirectly measure workplace compliance and are particularly effective as a means of self-assessment for small companies as well as large global corporations.

*Quality process* checking applies statistical quality control techniques to the ESD process and is performed by operations personnel. This is not a

periodic verification audit, but rather tracking daily effectiveness of the program. Visual and electrical checks of the procedures and materials, wrist strap testing, for example, are used to monitor the quality of the ESD control process. Checking is done on a daily, weekly or monthly basis.

Trend charts and detailed records trigger process adjustments and corrective action. They help assure that specified procedures are followed on a regular basis. The records are essential for quality control purposes, corrective action and compliance with ISO-9000.

*ESD Control Program Compliance Verification* audits verify that program procedures are followed and that ESD control materials and equipment are within required limits or are functioning properly. Compliance Verification audits are performed on a regular basis, often monthly, and utilize sampling techniques and statistical analysis of the results. The use of detailed checklists and a single auditor assures that all items are covered and that the audits are performed consistently over time.

## BASIC AUDITING INSTRUMENTATION

Special test equipment will be required to conduct EPA compliance verification. The specific test equipment will depend on what you are trying to measure, the precision you require and the sophistication of your static control and material evaluation program. However, as a minimum, you will need an *electrostatic field meter*, a *high range resistance meter*, a *ground/AC outlet tester*, and appropriate electrodes and accessories. Additional test equipment might include a charged plate monitor, footwear and wrist strap testers, chart recorders/data acquisition systems and timing devices, discharge simulators, and ESD event detectors.



Although this equipment must be accurate and calibrated according to the vendor's recommendations, it needs not be as sophisticated as laboratory instruments. The compliance verification audit is intended to verify basic functions and not for product qualification of ESD control equipment or materials. The compliance verification audit is intended to verify basic functions and not as a product qualification of ESD control items or materials. You want the right tool for the job. Just as you would not buy a hammer if you are were planning to saw wood, you would not purchase an electrometer to measure static voltages on a production line. Remember, many of the test equipment you might choose for compliance verification are good indicators, but not suitable for precise evaluation of materials. However, be sure that you can correlate the measurements obtained on the factory floor with those obtained in the laboratory. If you are making measurements according to specific standards or test methods, be sure the instrumentation meets the requirements of those documents.

With a hand-held **electrostatic field meter**, you can measure the presence of electrostatic fields in your environment allowing you to identify problems and monitor your ESD control program. These instruments measure the electrostatic field associated with a charged object. Many electrostatic field meters simply measure the gross level of the electrostatic field and should be used as general indicators of the presence of a charge and the approximate level of electrical potential of the charge. Others will provide more precise measurement for material evaluation and comparison.

For greater precision in facility measurements or for laboratory evaluation, a **charged plate monitor** is a useful instrument that can be used in many different ways; for example to evaluate the performance of flooring

materials or measuring the offset voltage (balance) and discharge times of ionizers.

Because grounding is so important, resistance is one of the key factors in evaluating ESD control materials. A high range **resistance meter** becomes a crucial instrument. Most resistance measurements are made using a 100 volt or 10 volt test voltage. The resistance meter you choose should be capable of applying these voltages to the materials being tested. In addition, the meter should be capable of measuring resistance ranges of  $10^3$  to  $10^{12}$  ohms. With the proper electrodes and cables, you will be able to measure the resistance of flooring materials, worksurfaces, equipment, furniture, garments, and some packaging materials.

The final instrument is a **ground/AC outlet tester**. With this device, you can measure the continuity of your ESD grounds, check the impedance of the equipment grounding conductor (3<sup>rd</sup> wire AC ground) as well as verify that the wiring of power outlets in the EPA is correct.

## AREAS, PROCESSES, AND MATERIALS TO BE AUDITED

Previously we stated that ESD protection was required "wherever unprotected ESD sensitive devices are handled." Obviously, our audits need to include these same areas. Table 1 indicates some of the physical areas that may be part of the ESD Control Program Plan and, therefore, will be involved in Compliance Verification Audits. Remember, some areas may be excluded from the Plan depending on the Scope of the Plan.

Similarly, we need to conduct Compliance Verification audits of all the various requirements that are used in our ESD Control Program Plan. Some of these are shown in Table 2.

Receiving
Inspection
Stores and Warehouses
Assembly
Test and Inspection
Research and Development
Packaging
Field Service Repair
Offices and Laboratories
Cleanrooms

**Table 1: Typical Facility Areas Requiring ESD Protection**

Personnel
Wrist Straps
Floors, Floor Mats, Floor Finishes
Shoes, Foot Grounders, Casters
Garments
Mobile Equipment (Carts, trolleys, lift trucks)
Workstations
Worksurfaces
Packaging and Materials Handling
Ionization
Grounding
Continuous Monitors
Seating
Production Equipment
Tools and Equipment (Soldering irons, fixtures, etc.)
Marking
Purchasing Specifications and Requisitions
ESD Measurement and Test Equipment
Personnel Training

**Table 2: Typical Processes, Materials and Procedures**

## CHECKLISTS

Checklists can be helpful tools for conducting Compliance Verification audits. However, it is important that ESD control program requirements are well documented and accessible to avoid the tendency for checklists becoming *de facto* lists of requirements. Table 3 indicates the questions and information that might be included in an auditing checklist. Other checklists are in the ESD Handbook ESD TR20.20 section 4.3.3. Your own checklists, of course, will be based on your specific needs and program requirements. They should conform to your actual ESD control procedures and specifications, and they should be consistent with any ISO 9000 requirements you may have. For ANSI/ESD S20.20 based

ESD Control Programs, the recognized Certification Bodies (Registrars) use a formal checklist supplied by the ESD Association to aid in conducting the Certification Audit.

In addition to checklists, you will use various forms for recording the measurements you make: resistance, voltage generation, etc. Part of your compliance verification audit will also include the daily logs used on the factory floor such as those used for wrist strap checking.

## REPORTING AND CORRECTIVE ACTION

Upon completion of the compliance verification auditing process, Reports should be prepared and distributed

in a timely manner. Details of the audits need to be fully documented for ISO-9000 or ANSI/ESD S20.20 certification. As with all audits, it is essential to implement corrective action if deficiencies are discovered. Trends need to be tracked and analyzed to help establish corrective action, which may include retraining of personnel, revision of requirement documents or processes, or modification of the existing facility.

## CONCLUSION

Compliance verification and personnel ESD control training are key ANSI/ESD S20.20 and IEC 61340-5-1 requirements to maintain an effective ESD control program. They help assure that ESDS handling procedures are

Function/Area Audited: Facilities			
Date:			
By:			
Audit Questions	Y	N	Comments
1. Where ESD protective flooring is used for personnel grounding, are ESD footwear worn?			
2. Where ESD floors and footwear are used for personnel grounding, do personnel check and log continuity to ground upon entering the EPA?			
3. Are personnel wearing grounded wrist straps at the ESD protective workstations (if required)?			
4. Are personnel checking wrist straps for continuity or using a continuous monitor?			
5. Where continuous monitors are not used, are wrist straps checked and logged routinely and at frequent intervals?			
6. Are wrist strap checkers and continuous monitors checked and maintained periodically?			
7. Are wrist strap cords checked, on the person, at the workstation?			
8. Are disposable foot grounders limited to one time use?			
9. Are test records for wrist straps and foot grounders kept and maintained?			
10. When required, are ESD protective garments correctly worn?			
11. Are nonessential personal items kept out of the EPA?			
12. Are personnel working in the EPA currently certified or escorted?			
13. Are ESD Control requirements imposed on visitors to the EPA?			

Table 3: Partial Audit Checklist ESD Control Program



properly implemented and can provide a management tool to gauge program effectiveness and to make continuous improvement.

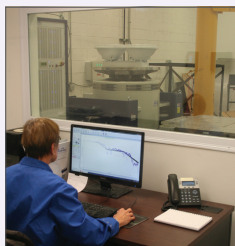
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## D.L.S. Environmental Testing Consolidates Under ACLASS 17025 Accreditation

D.L.S. Conformity Assessment announces the consolidation of their environmental testing services under the ACLASS 17025 accreditation program overseen by ANSI. This globally accepted program covers environmental testing under MIL-STD 810, MIL-STD 202, RTCA DO-160, ANSI, ASTM, IEC, ISTA, NEMA, and SAE standards and includes but is not limited to vibration, temperature extremes, humidity, shock, salt spray, acceleration, altitude, sand and dust, rain, chemical exposure, waterproofness, flammability, decompression, and icing. More information can be found at [www.dlsemc.com/environmental](http://www.dlsemc.com/environmental).



## EMC Test Design, LLC Announces New 40 GHz Probe

EMC Test Design, LLC has announced the introduction of a new 40 GHz isotropic ultra-broadband e-field probe. Model PI-05 covers 1MHz to 40 GHz and 2-1000 V/m. The probe extends the requirements of most EMC and RF safety standards for industrial, military and radar communication applications. For more information, visit [www.emctd.com](http://www.emctd.com).



## Fairview Microwave Debuts New Lines of Tunable RF Filters

Fairview Microwave, Inc. has announced their new lines of band pass and band reject tunable filters. The latest release includes 6 bandpass filters capable of octave-

band tuning from 125 MHz to 3 GHz depending on configuration, and a 5% pass band.

They employ a 5-section tunable design and have a mechanical dial accurate within 1%. Also offered by Fairview, are 5 new band-reject models with octave-band tuning ranges from 100 MHz to 2 GHz depending on configuration, and a 1% reject band. For additional details on the new bandreject and bandpass filters and the company, please visit [www.fairviewmicrowave.com/rf-products/band-pass-and-band-reject-tunable-filters.html](http://www.fairviewmicrowave.com/rf-products/band-pass-and-band-reject-tunable-filters.html).



## New Solvers in FEKO SUITE 7.0

FEKO reached a new milestone with the inclusion of the finite difference time domain (FDTD) solver to its comprehensive set of powerful computational methods. The solver is easily activated and it is simple to switch between the FDTD and other solvers. The addition of the FDTD solver will provide more efficient solutions to customers who are focused on simulation of wide-band antennas and inhomogeneous structures, e.g. anatomical models. For more information, visit [www.feko.info/download/releases/Suite\\_7\\_0/download\\_installation](http://www.feko.info/download/releases/Suite_7_0/download_installation).

## MITEQ Introduces New Coaxial and Compact Ultra-Wideband Linear Amplifier

Model AMF-5F-04001200-12-10P is a recent addition to MITEQ's family of low noise, wideband, and ultra-small coaxial LNAs in the 4 to 12 GHz band. This LNA has over 39 dB of gain in a housing that is only



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## Signal Hound BB60C Real-time Spectrum Analyzer Raises High Performance Bar

Signal Hound announced the Signal Hound BB60C, successor to the popular Signal Hound BB60A. The Signal Hound BB60C is a real-time spectrum analyzer and RF recorder. It has significantly enhanced performance compared to the BB60A. The BB60C has a frequency range of 9 kHz to 6 GHz, an instantaneous bandwidth (IBW) of 27 MHz, and the ability to sweep the RF spectrum at 24 GHz per second.

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## Society of Women Engineers Provides Free Tools to Retain Engineers

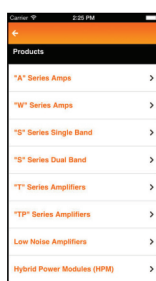
The Society of Women Engineers is proud to unveil the "Work & Life Integration Playbook." In its first eBook, SWE provides tools and case studies in policies, methods and tactics for encouraging employees to maintain a healthy relationship

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between home life and career pursuits. The playbook features stories from women engineers who have been there - struggling to achieve a happy medium between reaching professional goals and maintaining connections with friends and family outside the workplace. Download the free "Work & Life Integration Playbook" on SWE.org now and sign up for notification of future digital publications from SWE at [www.societyofwomenengineers.swe.org/e-book-download](http://www.societyofwomenengineers.swe.org/e-book-download).

### TDK Announces High-Performance EPCOS PFC Thyristor Module

TDK Corporation has extended its BR7000 series of EPCOS power

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The BR7000-I-TH/7485 features an additional RS-485 bus interface that allows up to another 32 EPCOS TSM-LC-S thyristor modules to be controlled. This bus interface also enables bidirectional communication with the thyristor modules. Additional information on the products can be found under [www.epcos.com/pfc](http://www.epcos.com/pfc).



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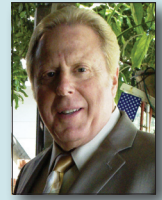
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