

OCTOBER 2011  
TM

# IN COMPLIANCE

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## Failure Analysis

### A Road Map



**PLUS**

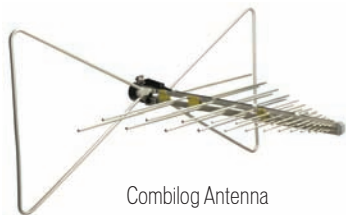
**Troubleshooting  
Radiated Emissions**  
Three Case Studies

**The “Core” of  
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# Letter from the editor

## Do Share!

Dear Readers,

This month, we set an initiative to connect with testing laboratories seeking their perspectives on the impact of the economy on manufacturers as well as where they see industry trends developing for the future. Two leading testing laboratories shared their insights, and on page 26 we publish our questions and their answers in our Who's Who in Testing Laboratories section beginning on page 26 of this issue.

We appreciate the participation of thought leaders within the compliance community and believe that by collecting and sharing this type of information we play an integral role in enriching connections and promoting compliance education. Over the next month, we'd like to get your perspective on the future of our industry and we invite you to participate in our online reader survey compiled to provoke thought, response and interaction. To share your opinions go to [www.incompliancemag.com/october\\_survey](http://www.incompliancemag.com/october_survey).

On another note, October brings some great compliance related educational opportunities. The Product Safety Engineering Society is hosting its annual Symposium in San Diego, CA, October 10-12. The website for this year's Symposium is: <http://ewh.ieee.org/soc/pse>. The Antenna Measurement Techniques Association (AMTA) is holding its 33rd Annual Symposium in Englewood, CO on October 16-21. You can read more about this event at [www.amta2011.org](http://www.amta2011.org). Coming up in Austin, TX, In Compliance is co-hosting a three-day seminar with Henry Ott, Electromagnetic Compatibility Engineering, October 25-27. Registration information for this event is available at [www.hottconsultants.com](http://www.hottconsultants.com). And finally, the Events Calendar on page 73 lists a plethora of compliance related educational opportunities being held throughout the country from mid-October to mid-November. We encourage you to take advantage of one in your area.

Until next time,  
 Lorie

**Lorie Nichols**  
**Editor**  
[editor@incompliancemag.com](mailto:editor@incompliancemag.com)





## 30 Failure Analysis: A Road Map

Although the foundation of a failure analysis is rooted in science, there is also an art to completing one, successfully. The path from problem discovery to problem solution has many bumps and twists along the way. This article will hopefully help guide you on that journey.

Keith Sellers



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Part 2  
Based on the methods in EN 55022 and EN 55011  
Keith Armstrong



# Electromagnetic Compatibility Engineering

Training for Noise and Interference Control in Electronic Systems  
presented by EMC expert

Henry Ott

October 25-27, 2011

Wyndham Garden Hotel  
Austin, Texas

Presented by Henry Ott Consultants  
in partnership with

**IN COMPLIANCE**  
Magazine

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

## COURSE CONTENT

### CABLING

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

### GROUNDING PRINCIPLES

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

### DIGITAL LAYOUT & GROUNDING

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

### HIGH SPEED DIGITAL DECOUPLING

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

### DIFFERENTIAL-MODE EMISSION

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

### COMMON-MODE FILTERING

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

### TRANSMISSION LINES

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

### MIXED SIGNAL PCBs

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

### RF & TRANSIENT IMMUNITY

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

### CONDUCTED EMISSION

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

### SHIELDING

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

## EMC EXHIBITS AND EVENING RECEPTION: WEDNESDAY, OCTOBER 26, 2011

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

## REGISTRATION

### COURSE DATES/TIME:

October 25-27, 2011

Tuesday and Thursday 8:30 a.m. to 4:30 p.m.

Wednesday 8:30 a.m. to 5:00 p.m.

**COURSE LOCATION:** Wyndham Garden Hotel, 3401 South IH-35, Austin, Texas 78741

**COURSE FEE:** \$1,495 (\$1,295 until 9/16/2011). 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 or mail the registration form.

**HOTEL RESERVATIONS:** Call the Wyndham Garden Hotel toll free at 877-999-3223 or 512-448-2444. Room rates are \$94 per night. You must mention In Compliance Magazine when making reservations to get this special rate. The hotel is holding a limited block of rooms. This rate is good until October 3, after that standard hotel rates apply.

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

## Who Should Attend

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

## Feedback from recent participants

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

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

*"Henry is the best in EMC."*

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

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

*"Really happy I flew all the way here."*

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

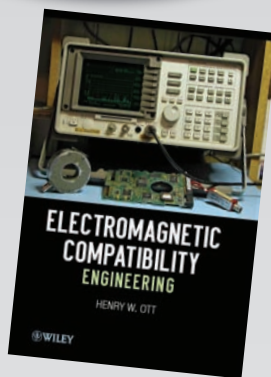
*"Should be required training for all engineers."*

*"This is the best practical course available."*

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

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

**Includes Henry Ott's latest book!**



**HENRY OTT**



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

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

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

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

## REGISTRATION FORM

### ELECTROMAGNETIC COMPATIBILITY ENGINEERING

October 25-27, 2011 Wyndham Garden Hotel, Austin, TX

Fee: \$1,495

Payment required prior to start of course.

**Register today!  
Attendance is limited.**

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Call 973-992-1793, fax to 973-533-1442 or mail registration form to: Henry Ott Consultants, 48 Baker Road, Livingston, NJ 07039-2502.  
Make checks payable to Henry Ott Consultants.

## FCC News

### Commission Unveils Broadband Performance Research

In an effort to increase consumer knowledge regarding the performance of their high-speed Internet services, the U.S. Federal Communications Commission (FCC) has released the first nationwide performance study of residential fixed broadband service.

Conducted in March 2011, the study examined service offerings from 13 of the largest broadband providers, which the Commission says account for about 86% of all wireline broadband connections in the United States. The study was based on direct measurements of broadband performance as delivered to the residences of several thousand volunteer broadband subscribers. Broadband services delivered by digital subscriber line (DSL), cable and fiber technologies were all evaluated.

The study's most interesting finding is that actual broadband speeds achieve 80-90% of the speeds advertised by broadband service providers, even during peak usage periods. According to the FCC, that's significantly better than a 2009 study of broadband performance in the U.S., which estimated that actual broadband speeds were about 50% of those advertised. The Commission's study also affirms that the highest available speeds are beneficial for high-demand applications, such as videoconferencing, high-definition video streaming or gaming, but that speeds of up to 10 Mbps are sufficient for most basic web browsing.

A complete copy of the FCC's research report on broadband performance is available at [http://transition.fcc.gov/Daily\\_Releases/Daily\\_Business/2011/db0802/DOC-308828A1.pdf](http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db0802/DOC-308828A1.pdf).

In a related action, the Commission has also released a beta version of a

broadband test for consumers that measures upload and download speeds, service latency and jitter. In order to run the test, consumers are required to provide address information, and the Commission says that it may use the data to analyze broadband quality on a more specific geographic basis. The broadband test is available at <http://www.broadband.gov/qualitytest>.

### Genachowski Predicts Creation of 100k New Broadband-enabled Jobs

Julius Genachowski, chairman of the U.S. Federal Communications Commission (FCC), predicts that expanded broadband Internet access will enable the creation of 100,000 new jobs over the next two years.

Speaking with a group of executives from Jobs4America (a coalition of call center companies) in Jefferson, IN in August 2011, Genachowski heralded the role that advanced communication technologies can play in job creation in the United States. "Bringing broadband to your town and home in the 21<sup>st</sup> century is like bringing in electricity in the 20<sup>th</sup>," said Genachowski, "connecting you and your community to the larger economy and opening up new worlds of commerce and opportunity."

The FCC says that an estimated 4000 broadband-enabled call center jobs are now being created each month in the United States. According to the Commission, many of these jobs were formerly handled at call centers outside of the United States, and can now be effectively performed by American workers either at new call centers or at home through enhanced connectivity.

The large-scale deployment and adoption of broadband Internet services has been a key focus of the FCC under Genachowski.

Additional information about the impact of the Commission's broadband initiatives on job creation is available at [http://transition.fcc.gov/Daily\\_Releases/Daily\\_Business/2011/db0804/DOC-308896A1.pdf](http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db0804/DOC-308896A1.pdf).

### Commission Issues Advisory on Cable Card Rules

The U.S. Federal Communications Commission (FCC) has issued an Enforcement Advisory for cable operators regarding their obligations to consumers under the Commission's new cable card rules.

Cable card technology now makes it possible for consumers with digital cable-ready televisions to avoid renting a set-top box from cable operators, and even to purchase their own set-top box and avoid operator rental charges. However, the Commission has received numerous complaints from consumers about the process of obtaining cable cards from cable operators, and about inaccurate or misleading information presented by some cable operators about cable card technology.

As of August 8, 2011, cable operators must comply with a number of new rules regarding cable cards, including the following requirements:

- Provide consumers with accurate information about the capability of retail cable card-compatible devices.
- Offer discounted package services for subscribers who do not rent set-top boxes from the operator.
- Offer uniform pricing for cable cards, and prominently disclose cable card fees.
- Permit consumer installation of cable cards.

The Commission's Enforcement Advisory provides additional details on



## FCC News

all of the new requirements applicable to cable operators, and is available at [http://transition.fcc.gov/Daily\\_Releases/Daily\\_Business/2011/db0812/DA-11-1373A1.pdf](http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db0812/DA-11-1373A1.pdf).

### FCC Adopts Spectrum Reforms to Accelerate Wireless Broadband Deployment

To help speed the deployment of wireless broadband services, the U.S. Federal Communications Commission (FCC) has modified certain provisions of its microwave spectrum allocation to provide greater backhaul capacity for wireless broadband service providers.

In a Report and Further Order issued by the Commission in August 2011, the Commission modified its rules to permit fixed microwave operations in several spectrum bands previously reserved for specialized microwave services. The change will allow the broader use of microwave facilities in mobile wireless networks to transmit data between cell sites, or between cell sites and network backbones. Microwave links represent a cost-effective alternative to traditional copper circuits and fiber optic links, and their use has increased by 50% in recent years, according to the FCC.

The Commission says that the newly available spectrum will speed the rollout from so-called fourth-generation (4G) broadband networks, bring new broadband services to rural areas, and foster job creation.

The complete text of the Commission's Report and Further Order is available at [http://transition.fcc.gov/Daily\\_Releases/Daily\\_Business/2011/db0809/FCC-11-120A1.pdf](http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db0809/FCC-11-120A1.pdf).

### Commission Releases Consumer Complaint Report

The Federal Communications Commission (FCC) has released its quarterly report on inquiries and complaints made by consumers to the agency's Consumer & Government Affairs Bureau during the last quarter of calendar year 2010.

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

the subscriber's permission). The Commission also tracks violations of the Federal Telephone Consumer Protection Act (TCPA), which includes regulations covering both the "Do Not Call" registry and unsolicited fax advertisements.

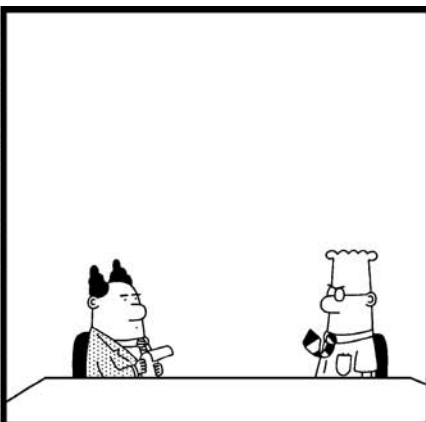
During the period from October through December 2010, the Bureau received a total of 22,553 complaints regarding wireline telecommunication services, with 19,478 complaints (86.4% of the total) in the area of TCPA issues alone, and more than 4339 complaints in connection with unsolicited fax advertisements. This compares with 25,925 total complaints during the October-December 2009 period, with 22,156 (85.5% of the total) involving TCPA issues.

In the area of inquiries, the Bureau also received 7878 inquiries in connection with wireline telecommunications, including 6730 inquiries dealing with TCPA issues, during the period from October through December 2010. This compares with 10,979 total inquiries during the last quarter of calendar year 2009, of which 9207 were related to TCPA issues.

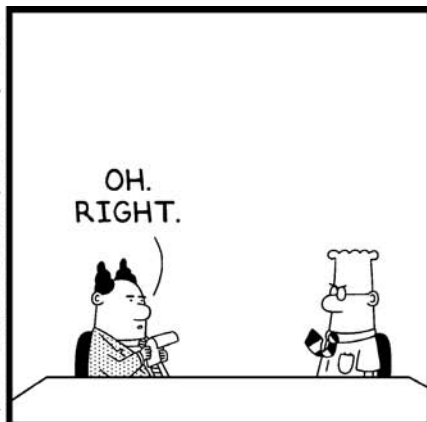
The complete text of the Commission's most recent quarterly report is available at [http://transition.fcc.gov/Daily\\_Releases/Daily\\_Business/2011/db0815/DOC-309057A1.pdf](http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db0815/DOC-309057A1.pdf).



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## European Union News

### EU Commission Releases Statistics on Unsafe Products

The Commission of the European Union (EU) has released statistics on notices of unsafe consumer products that have been processed through the EU's rapid information system (RAPEX) during July 2011.

According to the Commission's report, 136 notifications of products posing a serious risk to health and safety were processed through the RAPEX system during the month. This compares with 145 notifications of unsafe products

The complete text of the Commission's July 2011 report on RAPEX statistics is available at [http://ec.europa.eu/consumers/safety/rapex/docs/stat\\_07-2011.pdf](http://ec.europa.eu/consumers/safety/rapex/docs/stat_07-2011.pdf).

### 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 revised list of standards for the EU's Medical Device Directive is available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2011:242:0008:0038:EN:PDF>.

### Updated Standards List for Active Implantable Medical Devices Issued by EU Commission

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the

136 notifications of products posing a serious risk to health and safety were processed through the RAPEX system during July 2011. This compares with 145 notifications of unsafe products reported in July 2010, a 3% decrease year over year.

reported in July 2010, a 3% decrease year over year. Of the notifications of products presenting a serious risk to consumers received during the month, 55 (40%) were related to clothing, textiles and fashion items, with an additional 25 (18%) related to toys and 12 (9%) related to electrical appliances. There were also 15 notifications related to motor vehicles (11%).

Regarding the country of origin identified in connection with products posing a serious safety risk, more than half of all notifications (77, or 57%) were once again related to products originating from China, including Hong Kong. Another 19 notifications (14%) of unsafe products originated in EU Member States. Seven notifications (5%) failed to identify any country of origin.

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 replaces all previously published standards lists for the Directive, and was published in August 2011 in the *Official Journal of the European Union*.

essential requirements of its Directive 90/385/EEC, relating to active implantable medical devices.

According to the EU's Directive, "an 'active medical device' means any medical device relying for its functioning on a source of electrical energy or any source of power other than that directly generated by the human body or gravity."

Further, "an 'active implantable medical device' means any active medical device which is intended to be totally or partially introduced, surgically or medically, into the human body or by medical intervention into a natural orifice, and which is intended to remain after the procedure."

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- Single source for support & service
- More Compact & Portable – everything can be on one platform.

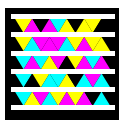
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## European Union News

The updated list of CEN and CENELEC standards that can be used to support compliance with the Directive was published in the *Official Journal of the European Union* in August 2011, and replaces all previously published standards lists for the Directive.

The list can be viewed at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2011:242:0001:0007:EN:PDF>.

According to the EU's Directive, an in-vitro diagnostic medical device is "any medical device which is a reagent, reagent product, calibrator, control material, kit, instrument, apparatus, equipment, or system, whether used alone or in combination, intended by the manufacturer to be used in-vitro for the examination of specimens, including blood and tissue donations, derived from the human body."

The list is available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2011:242:0039:0043:EN:PDF>.

### Toy Directive Standards List Updated by EU Commission

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the

The EU Commission has updated the standards lists for the Medical Device Directive, the Active Implantable Medical Devices Directive and the In Vitro Diagnostic Medical Devices Directive, as well as the Toy Directive.

### EU Commission Issues New Standards List for In Vitro Diagnostic Medical Devices Directive

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate compliance with the essential requirements of its Directive 98/79/EC, dealing with in-vitro diagnostic medical devices.

Under the Directive's definition, specimen receptacles are considered to be in-vitro diagnostic medical devices, while products for general laboratory use are not, unless such products are intended to be used for in vitro-diagnostic examination.

The updated list of CEN and CENELEC standards that can be used to support compliance with the Directive was published in August 2011 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

essential requirements of its directive relating to the safety of toys (88/378/EEC).

According to the Directive, a toy is defined as "any product or material designed or clearly intended for use in play by children of less than 14 years of age." The scope of the Directive includes electric toys that are powered by a nominal voltage up to and including 24 V, and requires sufficient protections for such devices to prevent the risk of electric shock and/or burns.

The most recently updated list of CEN standards for the Directive was published in August 2011 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive.

The revised list of standards can be viewed at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2011:235:0007:0008:EN:PDF>.

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

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## CPSC News

## Convictions Handed Down in Testing Fraud Case

Four people have been convicted in a U.S. District Court for falsifying test data submitted to the U.S. Consumer Product Safety Commission (CPSC), and for destroying documents in connection with a federal grand jury investigation into the matter.

According to the CPSC, Joyce Serventi, the president of a New Jersey company contracted by Tampa, FL-based Youth Research, Inc. was convicted in August of conspiracy to falsify data in connection with the child resistance testing of cigarette and multi-purpose

lighters. Serventi was sentenced to two years of probation by the U.S. District Court for the District of New Jersey, and ordered to pay a \$3000 fine.

Serventi's conviction follows that of Youth Research's president, Karen Forcade, who was sentenced in September 2010 to eight months in prison followed by eight months of home confinement, and a \$10,000 fine, for her role in the conspiracy. Also convicted in September 2010 for conspiring to falsify data was Stephanie Van Treuran, a contractor for Youth Research, who received two years probation, three months of home detention, and a \$3000 fine.

Nancy Buhrmann, another contractor for Youth Research, was sentenced in February 2011 to 21 months in prison, followed by two years of supervised release, for destroying paper and electronic documents in connection with the federal grand jury investigation into the fraudulent testing. Buhrmann has filed an appeal in connection with her conviction.

The conspiracy to falsify test data was uncovered by a CPSC health scientist while examining routine test reports submitted by Youth Research to the CPSC. The scientist determined that the same children were used in repeated tests, with changes to birth dates,

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## CPSC News

genders and the names of schools attended by the children. The discovery resulted in further investigation by CPSC officials, and was ultimately referred to the U.S. Department of Justice's Office of Consumer Protection Litigation in January 2007.

### Video File Sharing Device Linked to Overheating

Cloud Engines Inc. of San Francisco, CA has recalled about 9500 units of its Pogoplug-brand video file sharing device manufactured in China.

According to the company, the video sharing device can overheat or catch fire,

The recalled video sharing devices were sold through Adorama, B&H, Best Buy, Buy.com, J&R, Pogoplug.com, New Egg, and Sony Style from March 2011 through June 2011 for about \$200.

For more information about this recall, go to <http://www.cpsc.gov/cpscpub/prerel/prhtml11/11294.html>.

### Company Recalls Flashlight Batteries Due to Fire Hazard

NexTorch, Inc. of Mukiteo, WA has announced the recall of about 16,000 of its NexTorch brand flashlight batteries manufactured in China.

### Black & Decker Pays Penalty for Failing to Report Defective Products

The U.S. Consumer Product Safety Commission (CPSC) has announced a financial settlement with a company that failed to notify the CPSC that certain models of its weed trimmer/edgers were unsafe, even after it received reports of consumer injuries.

Black & Decker of Towson, MD has agreed to pay a civil penalty in the amount of \$960,000 in connection with CPSC charges that the company failed to report the product safety defect immediately, as required under federal law. According to the CPSC, the

**Black & Decker has agreed to pay a civil penalty in the amount of \$960,000 in connection with CPSC charges that the company failed to report a product safety defect immediately.**

emitting excessive heat, sparks, smoke or flames. Cloud Engines says that it has received three reports of the recalled units overheating, including one device that caught fire, one device that emitted smoke, and one device that melted, damaging the supporting desk. However, there have been no reports of consumer injuries.

NexTorch reports that the batteries can overheat and rupture, posing a fire and burn hazard to consumers. The company says that it has received one report of the flashlight batteries rupturing and catching fire, causing burns to the body, clothes and vehicle of a consumer.

The recalled flashlight batteries were typically packaged with NexTorch flashlights and sold through firearms dealers and law enforcement supply stores, as well as on the web, from July 2007 through July 2011 for about \$2 per battery.

More information about this recall is available at <http://www.cpsc.gov/cpscpub/prerel/prhtml11/11296.html>.

company knew for at least a year before notifying the agency that its electric Grasshog Model XP trimmer/edger was defective and could cause harm to consumers.

Further, the CPSC alleges that Black & Decker failed to provide full information about the defective product when requested to do so by the CPSC in May 2006. As a result of information received from the company, the CPSC closed their investigation, only to reopen it in October 2006 when Black & Decker informed them of a growing number of incidents and consumer injuries.

Ultimately, Black & Decker announced a recall of more than 200,000 trimmer/edgers in July 2007, following reports that the product's spool, spool cap and

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## CPSC News

pieces of trimmer string could come loose during use. The company received more than 700 reports of incidents related to the product defect, including 58 injuries to consumers. The trimmer/edgers were sold from November 2005 through the spring of 2007 for about \$70.

Federal law requires that manufacturers, distributors and retailers immediately (i.e., within 24 hours) report to the CPSC information that a product contains a defect which could create a substantial product hazard, or pose a risk of injury or death to consumers.

In agreeing to the civil penalty, Black & Decker has denied CPSC allegations that it knowingly violated the law.

### Philips Recalls Compact Fluorescent Bulbs

Philips Lighting Company of Somerset, NJ has recalled about 1.86 million compact fluorescent dimmable reflector lamps manufactured in Mexico and Poland.

According to the company, the glue that attaches the glass outer envelope or globe to the body of the lamp can fail, allowing the glass outer envelope to fall and strike people and objects below, posing a laceration hazard to consumers.

Philips has received 700 separate reports of lamps where the glue failed and the

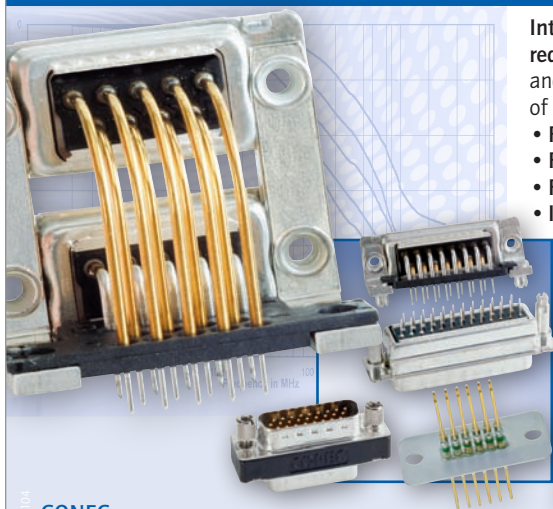
glass outer envelope fell, including two reports of minor injuries and three reports of minor property damage.

The recalled compact fluorescent lamps were sold at grocery stores and home centers nationwide, through online retailers and professional electrical distributors from March 2007 through July 2011 for between \$11 and \$24.

Additional details about this recall are available at <http://www.cpsc.gov/cpsc/pub/prerel/prhtml11/11302.html>.

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## UL Standards Updates

Underwriters Laboratories has announced the availability of these standards and revisions. For additional information, please visit their website at [www.ul.com](http://www.ul.com).

Underwriters Laboratories has announced the availability of the following standards and revisions. For additional information regarding the standards listed below, please visit their website at [www.ul.com](http://www.ul.com).

### STANDARDS AND OUTLINES

**UL 82: Standard for Electric Gardening Appliances**

New Edition dated August 12, 2011

**UL 867: Standard for Electrostatic Air Cleaners**

New Edition dated August 4, 2011

**UL 1447: Standard for Electric Lawn Mowers**

New Edition dated August 1, 2011

**UL 1709: Standard for Rapid Rise Fire Tests of Protection Materials for Structural Steel**

New Edition dated August 3, 2011

**UL 363: Standard for Knife Switches**

New Edition dated August 12, 2011

**UL 412: Standard for Refrigeration Unit Coolers**

New Edition dated August 22, 2011

**UL 779: Standard for Electrically Conductive Floorings**

New Edition dated August 12, 2011

**UL 943B: Standard for Appliance Leakage-Current Interrupters**

New Edition dated August 17, 2011

**UL 1310: Standard for Class 2 Power Units**

New Edition dated August 26, 2011

**UL 2756: Specification for UL Advantage Program for Class III Products**

New Edition dated August 24, 2011

### REVISIONS

**UL 246: Standard for Hydrants for Fire-Protection Service**

Revision dated August 11, 2011

**UL 1431: Standard for Personal Hygiene and Health Care Appliances**

Revision dated August 3, 2011

**UL 2438: Standard for Outdoor Seasonal-Use Cord-Connected Wiring Devices**

Revision dated August 2, 2011

**UL 60335-2-24: Safety Requirements for Household and Similar Electrical Appliances, Part 2: Particular Requirements for Refrigerating Appliances, Ice-Cream Appliances and Ice-Makers**

Revision dated August 1, 2011

**UL 248-1: Low-Voltage Fuses - Part 1: General Requirements**

Revision dated August 22, 2011

**UL 330: Standard for Hose and Hose Assemblies for Dispensing Flammable Liquids**

Revision dated August 26, 2011

**UL 355: Standard for Cord Reels**

Revision dated August 30, 2011

**UL 778: Standard for Motor-Operated Water Pumps**

Revision dated August 25, 2011

**UL 1072: Standard for Medium-Voltage Power Cables**

Revision dated August 15, 2011

**UL 1123: Standard for Marine Buoyant Devices**

Revision dated August 22, 2011

**UL 1191: Standard for Components for Personal Flotation Devices**

Revision dated August 24, 2011

**UL 1241: Standard for Junction Boxes for Swimming Pool Luminaires**

Revision dated August 23, 2011

**UL 1563: Standard for Electric Spas, Equipment Assemblies, and Associated Equipment**

Revision dated August 25, 2011

**UL 1795: Standard for Hydromassage Bathtubs**

Revision dated August 23, 2011

**UL 1917: Standard for Solid-State Fan Speed Controls**

Revision dated August 16, 2011



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## Thoughts on the IEEE EMCS 2011

The 2011 Long Beach Symposium was one of the better EMCS events in recent years. The organization was done well, the venue was attractive and all the attendees we spoke with were enjoying the week. Our congratulations go to the symposium committee and their team of tireless volunteers.

Most exhibitors reported good booth traffic and seemed generally upbeat about the activity in the EMC/EMI markets. It did seem however those companies with a diversity of products were doing better than the narrowly focused organizations.

This year iNARTE offered our traditional EMC Certification examinations as well as our new EMC Design Engineer examination and our MIL STD EMC Specialist examination. The new programs did attract a lot of interest and all our

literature was snapped up, but only one applicant stepped up to be examined in the new MIL STD discipline, and no one was ready yet for the Design Engineer certification examination.

We are in the middle of our Grandfather period for the Master EMC Design Engineer certification, and there were a lot of applicants taking up this offer and gathering their references from the other EMCS attendees. So the iNARTE booth was a pretty busy place.

### EMC DESIGN ENGINEER CERTIFICATION

Examination papers are now ready for this new program. Don't wait for the next EMC Symposium to get this valuable new credential. You can sign up for examination at any of our almost 200 Authorized Test Centers by registering at the iNARTE web site, [www.narte.org](http://www.narte.org).

This Engineer level certificate is designed for the graduate or the relatively new design engineer that is planning to build a career in EMC Design

As an independent credentialing agency, operating within the guidelines of ISO 17024, iNARTE has to maintain separation between training and certification determination. However, we do recognize how important it could be for many Engineers to be exposed to tutorials and workshops on the certification subject matter prior to examination. Consequently we are always eager to work with training institutes offering relevant courses and who are willing to include our examinations as a part of their program.

Washington Laboratories Academy is just such an organization, and the iNARTE MIL STD EMC Specialist examination is offered as an option to all attending their



iNARTE mingles with the rich and famous on the Queen Mary



Laminating luggage tags during a slack moment

MIL-STD 461F courses. It has also been agreed that our new EMC Design Engineer examinations will be available to attendees at their upcoming High-Speed Digital Design Series, presented by Robert Hanson. For more information on these combination training/certification opportunities, please visit <http://www.wll.com/academy.html>.

## SOMETHING NEW FOR ESDA CERTIFIED PROGRAM MANAGERS

Working closely with the ESD Association, iNARTE has created a new short form examination that is now available to ESDA Certified Program Managers. The questions in the short form exam relate to subject matter that is not well represented in the regular ESDA certification examinations for Program Managers. Because iNARTE recognizes the value of the ESDA credential, successful candidates taking the short form exam will be awarded full iNARTE certification and the certificates issued will feature a special endorsement in ESDC Program Management.

## RABQSA

Four months have now passed since iNARTE and RABQSA signed a formal affiliation Agreement. The intent of the affiliation is to merge the iNARTE operations into RABQSA within twelve months of that signing date, and this process is well underway, but without either party taking any actions that cannot be rescinded in the unlikely event that either Board of Directors decide that this merger is not in the best interests of their organization.

After the merger, iNARTE will continue with its certification programs and the iNARTE name, together with the RABQSA name, will continue as brands of the new organization.

At this time, one of the first actions of the affiliation has been to give RABQSA access to the iNARTE Authorized Test Centers so that any of our proctors may be asked to host a RABQSA certification examination in their region.


At the same time, iNARTE is reviewing several RABQSA initiatives that could be developed into classic iNARTE programs targeting the individual practitioners, while RABQSA continues to offer certification to auditors, inspectors and assessors.

iNARTE and RABQSA together make up the world's largest personnel credentialing organization with approximately 15,000 certificate holders

## REGISTER FOR CERTIFICATION EXAMS

The following event offers candidates a chance to take the iNARTE certification examinations without incurring proctoring fees.

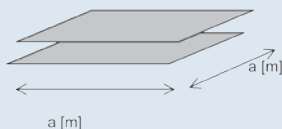
**IEEE PSes 2011** – San Diego, CA. iNARTE examinations on October 13<sup>th</sup>

Candidates can register in advance at the iNARTE web site ([www.narte.org](http://www.narte.org)) to examine at this event for any of the programs that we offer. At the event, candidates can register until the day before the exam, but only for the discipline related to the event. 

## QUESTION OF THE MONTH

### Last month we asked:

The following figure shows closely arranged square parallel plates having  $a(m)$  in length on all sides. When the space between the plates has a relative dielectric constant of 4, and a separation distance of 2mm, what is the lowest resonance frequency between these plates?



- (A)  $300/a$  (MHz)
- (B)  $150/a$  (MHz)
- (C)  $75/a$  (MHz)
- (D)  $37.5/a$  (H)

The correct answer is: (C)  $75/a$  (MHz)

### This month's question is:

A discrete inductor mounted on a printed-circuit board is modeled at low frequencies as a pure inductance. At higher frequencies, the lumped-element model is?

- (A) A parallel resistance, inductance, and capacitance circuit
- (B) Still a pure inductance
- (C) A series resistance, inductance and capacitance circuit
- (D) A pure resistance

### (the author)

#### BRIAN LAWRENCE

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







## Static Hocus Pocus

BY NIELS JONASSEN, sponsored by the ESD Association

When you read an ad extolling the virtues of some device and promising fantastic results, you often wonder, “Can this be true?” If you’re not familiar with the device, you may let it go, or maybe even believe the hype a little bit—*nid moy*, as they say here in Bangkok. It’s a completely different story, though, when somebody makes outrageous claims in an area that you know well.

### 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 republishing this series as the articles offer timeless insight into the field of electrostatics.

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

~ The ESD Association

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Mr. Static Column  
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Over the years that I have been employed at the Technical University of Denmark, I have experienced this scenario over and over again, generally in one of two forms. In the first, someone who knows very little physics skims a textbook, semidigests it, mixes that scant understanding with a little alternative medicine, and comes up with a gadget that he or she swears will be a boon to mankind. In the second, a company or other producer of devices that already work to a certain degree adds some completely useless component, such as a black box, that is said to boost efficiency by a zillion percent. Needless to say, the new component also boosts the price.

In the static arena, for instance, there’s always the cordless wrist strap. I haven’t seen any of those for a couple of years now, but I expect they’ll come back one of these days. And in the real world, not that long ago, you could have had your house checked for radon at a price that seemed too good to be true—and it was.

And in Europe we have seen, and to some extent still see, widespread concern about something called ground rays, which are said to be a causal agent in a number of

serious illnesses, including cancer. No one has actually been able to define what ground rays are, and these ground rays can’t be measured by any physical instrument. But some gifted people claim they can detect—or measure, another misuse—so-called veins of them, using pairs of bent knitting needles. Naturally, these same beneficent people will help you screen your house for this evil phenomenon—at considerable expense to you, of course.

Now, I don’t wish to imply that such activities are necessarily fraudulent; indeed, I suppose some such claims are made in good faith. Nonetheless, these inventions are still just a lot of hocus-pocus, as the following examples attest. In each case, the gadget described met with considerable commercial success or aroused a good deal of public interest. Since some of these devices are still in production, I have refrained from using their trade names here.

### Antistatic Acupuncture

One day in 1980 or thereabouts, I received a call at the laboratory from a Mr. PN, who asked if I would be interested in an apparatus that could eliminate static electricity.

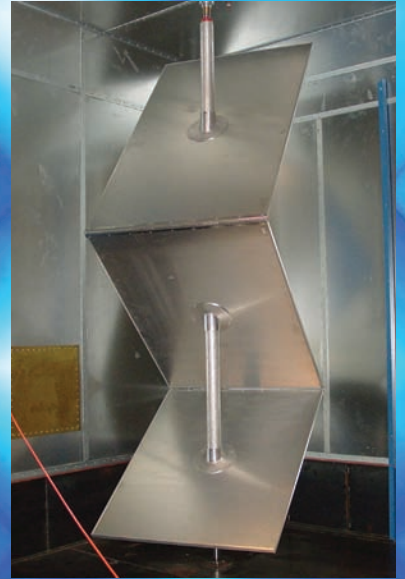
Of course I would be. I asked what kind of static electricity it eliminated, but PN didn’t quite understand my question. As far as he was concerned, there was only one kind: human static electricity. So I invited him to come over and demonstrate his device for me.

It consisted of two shoe-sole-shaped copper cutouts, nicely chrome plated, about size 9. The two plates were connected by an ordinary insulated wire about 150 cm long. The insulated wire was attached to a common wire 2 to 3 m long that ended in a ground connector, which was designed to hook onto a heating radiator or water pipe.

There was also a nice pair of socks that went with the setup.

PN boasted that by wearing these soles inside shoes, the user would be drained of static electricity. (I tried to object that someone who was grounded surely couldn’t get charged anyway, but evidently I was missing the point.) And the claims didn’t

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stop there: according to PN, the soles would keep working even after the user took them off!

Not wishing to insult him, I merely said, mildly, "Let's do an experiment." I demonstrated that just walking across our asphalt floor caused me to become charged to about 3 kV. I then mounted the soles (hoping, as I did so, that nobody else was watching): no charging. I removed the soles and, once again, got charged to 3 kV.

Oh, but I hadn't worn the soles long enough, PN said; they hadn't had time to drain the static from my body. I explained that the charging of a person is a business between the underside of his or her shoes and the floor covering. But no. By PN's reckoning, human static electricity flowed in the body along the acupuncture channels.

He had it all worked out. If you slept with these acupuncture soles on, you slept much better, he said. If you were suffering from one or another of various illnesses, there was a schedule for you to follow that told you what hours of the night you should wear the soles for best effect.

What PN wanted from me was an official statement to use in his patent application. I told him there was nothing there to patent—nothing new—and besides, I said, his soles could be downright dangerous if someone happened to touch a live wire while wearing them.

PN later modified his invention, severing the ground connection and wrapping the two loose ends around a copper core. Thus altered, it gave a reasonable decay resistance, thanks to the semidirty surfaces of the wires' insulation. But what was the point of the copper core? No explanation was forthcoming.

Over the next couple of years, I had the dubious pleasure of dealing with PN on other occasions. He managed to attract a certain amount of public attention to his acupuncture soles, which were written up in several newspapers and even got some sort of endorsement from the secretary of the interior. (I cannot help remarking that this same secretary always carried a couple of chestnuts in his pocket, believing they were good for his rheumatism. They apparently

worked—he never had rheumatism in his whole life.

In any event, PN kept sending me copies of his correspondence with all of the various authorities and the institutions at which he talked people into using his device. Of course, he made sure to forward documentation of all the glowing praise heaped on him when his soles won a silver medal as runner-up for best invention of the year at a big exhibition in Brussels! But it was a source of constant irritation to him that he couldn't secure an official approval, and he even went so far as to complain to the president of our university about me, charging that I had hindered people from learning about his brainstorm.

The president answered that I was the expert (thank you).

By sheer chance, I learned that PN had applied for a Danish patent and was on the verge of getting it, due mostly to the fact that none of the patent authorities knew

to think of it, I've often had the same experience with physicians.)

My last encounter with PN ended on a somewhat tragicomic note. PN had succeeded in getting the Institute of Technology of Denmark, an institution for technical applications, to look at his gadget, and the institute staff pleaded with me to come to a demonstration and put this business to rest once and for all. I agreed to be present.

PN brought his father along to the meeting. At one point during his demonstration (in which there was absolutely nothing new), PN made some outrageous statement, and I could stand it no more. "If that were the case, it would violate Ohm's law!" I cried.

The father then interjected, "The parliament issues new laws all the time. Couldn't it also change this Ohm's law you're talking about?"

And now for a more suspicious story.

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## Now, it would be wonderful if the examples cited were unwittingly or deliberately misused. But in fact, such abuse

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any more about static electricity than did PN himself. I protested, and eventually the patent application was denied. Naturally, PN went to court with a civil case against our laboratory for preventing him from winning the patent he so rightly deserved.

When asked if I wanted to appear in court, I said most emphatically that I did not. The lawyers and judge could read my protest, and besides, they had the wrong plaintiff. PN should have been bringing suit not against our laboratory, but against the laws of physics. Happily, the case was dismissed.

I don't think PN was deliberately trying to con people. He probably honestly believed his own theories and saw himself as the little man standing up to the men in white coats. I spent many hours trying to teach him a little physics, but to no avail. (Come

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## Static Field Remover

Over the last couple of decades there has been, at least in Europe, a great deal of concern voiced over the static electric field generated by monitors and television screens. It is this field that makes dust and other particles plate out on the screen, due to simple static attraction as well as polarization forces.

If a person is sitting close to the screen, the field will be distorted and will converge toward the person's face, and the particles will then plate out on his or her nose, forehead, and cheeks. Studies have shown that any static field on a person's face will dramatically increase the plate-out rate of particles, and scientists have speculated that this may result in an increase in the occurrence of rashes and more-serious skin



diseases such as eczema, given the presence of allergens or other unsavory substances in the air.

As far as I know, this connection has not yet been established definitively, but many years ago we demonstrated at our laboratory that it was possible to drastically reduce the field put out by a monitor by applying a topical antistat to the screen. (The antistatic layer forms a primitive but fairly effective Faraday screen.) Later, several types of transparent, conductive filters designed to be mounted in front of the screen appeared on the market. Most worked reasonably well, though they were rather expensive.

In the late 1980s, a Danish company that had been selling such filters for some years got the opportunity to market a new American invention—let's call it the Field Remover. Someone very high-up in the corporation had already signed the necessary papers, and the gadget came with a pretty positive report from a Scottish laboratory. But the marketing people

to ground. The Scottish laboratory had followed these directions and found that the field in front of the monitor was reduced by a factor of about 50 to 100.

Performing only the first step of the prescribed procedure, I applied the liquid to the screen and measured the field. With no suction cups, no magic box, and no ground wire, the field was reduced by a factor of 50 to 100. I then went through the remaining steps—mounting the cups and all the rest—but nothing further happened, and there was no additional reduction in the field.

I called the staff at the Danish importer and asked them to come and witness my measurements. When they did, we looked at each other and I suggested, "Let's break open that magic box and see what's inside."

The box contained a cube of carbon-black-saturated aerated plastic. When the suction-cup plugs were inserted, they just touched the carbon-black plastic. The diode had only one wire attached, which terminated


back to me and asked if I would write up a full report on the test, which I did.

In the end, the company decided not to go ahead with the Field Remover, and I got a grateful letter thanking me for saving the marketers' jobs. I still wondered why the Scottish laboratory had done such a sloppy job.

I also got a phone call from the device's "inventor." He had learned of my report and was furious. I obviously didn't know what I was talking about, he fumed before demanding to know what my background was. I told him I had about 30 years of university training in the field. Where, I inquired, had he acquired his own expertise in static electricity? At first he was rather vague, but when pressed he finally admitted that his formal training consisted of one three-day tutorial given in Chicago.

That was the last I heard of him, but not of his invention. A couple of years later, I saw the Field Remover advertised in a Swedish magazine.

## Conclusion

Now, it would be wonderful if the examples cited were the only times the laws of physics have ever been either unwittingly or deliberately misused. But in fact, such abuse is all too common, in electrostatics as in other fields. In sum, there will always be people who try to sell other people a lot of nonsense, and there will always be people who are willing to buy it. 

## the only times the laws of physics have ever been either is all too common, in electrostatics as in other fields.

wanted an opinion from our university, so I agreed to test the device.

The Field Remover kit consisted of the following:

- A small plastic bottle containing a clear liquid.
- Two (conductive) suction cups with wires ending in small plugs.
- A plastic box (carrying the trade name) measuring about 6 cm<sup>3</sup>, equipped with a light diode labeled static event detector and a ground wire.

The manufacturer's instructions advised the user to apply the liquid to the monitor screen and, if I remember correctly, to the keyboard; mount the suction cups on the screen and keyboard; connect the suction cups to the box; and, connect the box

randomly in the plastic like the ground wire. Obviously, neither the box nor the wiring had any real technical or scientific purpose.

I advised the marketing people, "Buy the liquid; it's a good antistatic. You can probably sell it for \$1.50 a bottle and make a good profit." They had been planning to sell the whole device for somewhere between \$150 and \$200.

As might be expected, my findings caused some problems within the company. Management wasn't happy about the fact that marketing had consulted an independent expert. It wasn't necessary, the higher-ups insisted; they had been told in the United States that this was a fantastic product, and besides, there was always that Scottish report. The marketing people came

### (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.



## Smoking or Non-smoking?

BY DAVE LORUSSO

In the Summer of 2000 I booked some burn time at a small environmental lab in south Dallas. The facility was not exactly state-of-the-art, but the price was right: \$300 a burn. It sure beat paying about \$4,000 a burn at an NRTL at the time. For 300 bucks, you got the chamber, a methane line burner connected by a hose to a big tank of methane gas, and a technician who would manually operate the whole thing from an adjoining isolated room. A fire extinguisher was always ready “just in case”.

The test setup consisted of a huge (somewhat) fireproof chamber and a not very efficient vent hood that tended to spew smoke throughout the industrial park. Texas is hot enough in the summer - so naturally, neighbors in the industrial park complained about the smoke during business hours. To placate his neighbors, the lab manager agreed not to operate the fireproof chamber until after the industrial park cleared out each day.

Unfortunately, he neglected to tell us about the new lab hours. So I drove up to Dallas early one morning from Austin with two colleagues, raring to go at 9 a.m. “Um... could y’all come back at ten - tonight?”

We adjusted. We called our wives, found a cheap hotel, and fired up our laptops. We spent our time wisely and productively - and with that smoking vent hood in mind - we made a quick trip to Home Depot. There we found some cheap respirators - the kind used for painting projects. We would wish for better gear later, but for the moment, we breathed easily, looking forward to the destructive testing to come.

Finally, 10 p.m. and time to burn. I asked the technician if we could video tape (no solid-state camcorders in those days) the line burner in front of the chassis to show how high the flame reaches at 1 minute 30 seconds, the peak of the flame profile. He agreed. “That’s not

going to set me back 300 bucks, is it?” I asked. After making us wait twelve hours to get into the lab, he gave us two free minutes of burn time. We set up our video equipment and got our masks ready.

Flame height at 1 minute 30 seconds was about 11 inches. We were glad we were videotaping: the video came in handy later on during redesign.

Showtime!! We had our first chassis prototype with dead line cards and a working fan module ready. The test order was to burn the line cards without a metal back and top plate. We figured if it passed without the metal covers, we’d be saving money.





Time to burn the chassis. We triple-checked everything keeping in mind that when you play with fire, you're gonna get burned. Well, we didn't get burned, but our chassis looked like a supernova at the magic 1.5 minute mark.

Decision time: Do we use the handy fire extinguisher or do we let the chassis burn? I really hadn't thought that far ahead about what to do if there was a MASSIVE failure - another valuable lesson learned. Let it burn. In for a penny. My stomach turned with each passing second - not from the vast billowing smoke entering my puny respirator, but from the thought that our chassis was turning into a flaming piece of junk before my very stinging eyes.

Four minutes. I couldn't take it anymore. The line burner profile is 5 and a half minutes, but I knew that in another minute and a half there'd be nothing left to analyze. We packed our stuff with a better understanding of how fire flowed in our product. Lesson learned: Better to fail a pre-test than to go blindly into an expensive final test. We spent 300 bucks, learned a lot, and re-designed our product.

It had been a long, hot, stressful day: a 3-hour one way trip to Dallas, a 12-hour wait to do a 4-minute test that ended badly. Ahead of us: a lonely night in a cheap hotel and the long drive back to Austin in the next day's rush hour traffic. Comfort food was desperately needed.

Going on instinct alone (no Smartphones in those days!) we found a 24-hour restaurant and staggered in. We were covered in soot. Like pigs in a poke, we didn't notice how badly we smelled...

(the author)


DAVE LORUSSO

Dave is a regulatory consultant based in Austin, Texas, where he lives with his wife Kathy and their Boston Terrier, Abilene. Dave is an expert in NEBS, Product Safety and EMC. He has published numerous articles on compliance engineering. He can be reached at [dave@lorusso.com](mailto:dave@lorusso.com) or 512-695-5871.



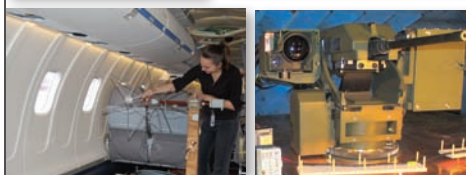
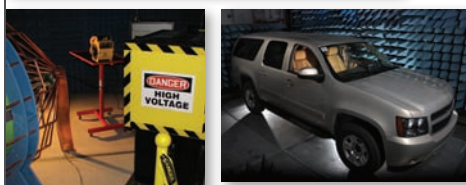
That is, until the greeter wrinkled her nose and took a few steps back as we approached. She recovered her professional attitude quickly and gave us a smile. She asked us - three guys who had never touched tobacco

"Smoking or Non-smoking?"

We looked at one another, shrugged, and I made the first easy decision of the day: "Smoking's fine". 

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# Who's Who in Testing Laboratories

## Thought Leaders Share Their Points of View

Testing laboratories, by the nature of their business, have the opportunity to observe trends in the electronics industry that many of us probably don't have a chance to glimpse. We decided to tap into the wealth of knowledge held there and ask these industry leaders to share, from their point of view, just

how the industry is being impacted by the dips in the economy, what manufacturers can do to be as efficient as possible in the testing process, and where the opportunities are developing in manufacturing. Grant Schmidbauer, Senior Vice President - Region North America of Nemko and Derek Coppinger, Senior Vice

President - Corporate Development of NTS answered our call to action and here they provide their insights to our questions, reassuring us that there are positive outcomes that come from economic downturns and new developments continue to emerge.



### Nemko

Provides Insights to In Compliance Readers

#### Nemko

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#### Laboratory Profile

Nemko contributes to a safer world by sharing knowledge and safeguarding products, environment, people and systems. Nemko creates value for the customer by providing fast and reliable global market access.

**ICM:** How has the economic landscape impacted the innovation of the products you see pass through your laboratory?

#### Thought Leader Answer:

There are far fewer products being developed due to cost reduced R&D budgets. We are seeing many more "re: and re:" products where the manufacturer makes minor changes/updates, and then can market the product as a new. This reduces cost, both internally and externally, and allows manufacturer's to stay current in the market and battle the economic downturn. We also see the continuing trend where more and more development of consumer IT products (PC, laptop, tablets, smartphones) is done overseas, which also includes the testing and certification activities.



Grant Schmidbauer  
SVP Region North American  
Nemko USA, Inc.

As a result the local engineering staff is transforming from product based work to project based work, including performing regulatory research for different country markets.

**ICM:** Is there a particular product sector that you see thriving through the slower economy?

**Thought Leader Answer:**

With the addition of radios to so many products, there continues to be a demand for Wireless/Radio (Telecom) testing. In addition, with the local downturn in the USA, manufacturers are looking to market existing products in many different International markets, thus market access services remain strong. There is also a thriving business in the area of energy efficiency with many countries implementing mandatory requirements.

**ICM:** From your perspective, what is the most significant investment a manufacturer can make in the development of its product to assure it will pass compliance testing?

**Thought Leader Answer:**

To ensure a smooth process at the test house, a key service offering is pre-compliance. Pre-compliance can be in

the form of product pre-testing and pre-evaluation, where it can give the manufacturer an early indication of product compliance issues according to the standard, and allows time, where time is still available, to make product changes. Pre-compliance can also be in the form of market access research, such that all markets of interest can be considered, not just the US and EU, so that the best project plan can be assembled to give the manufacturer the best chance to get to market on time; this is especially important for radio approvals.

**ICM:** Would you share a word of advice for readers on how to best prepare for testing their product at your laboratory?

**Thought Leader Answer:**

To make a small investment in time, up front at the start of the project, to take a meeting, or schedule a conference call, with the key people at the test house, to discuss the salient points of the project, including familiarization with the product set-up and operational

condition during test. Simple things like EUT operation cycles, cable lengths and/or providing proper support equipment can cause significant delays in the project if not taken into consideration.

**ICM:** What trends do you see developing in the electronics industry that you believe may make a significant impact on the prosperity of the industry throughout the upcoming year?

**Thought Leader Answer:**

On the contrary, many of today's trends, while may prove challenging for industry, will present many new opportunities. The main areas that we see trends affecting industry are:

- Use of radios in many different kinds of products
- Global market access services
- Energy efficiency requirements
- Consumer IT products (PC, laptop, tablets, smartphones) developed overseas
- LED innovation as a light source

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# Who's Who in Testing Laboratories



## National Technical Systems

Provides Insights to In Compliance Readers

**ICM:** How has the economic landscape impacted the innovation of the products you see pass through your laboratory?

**NTS Answer:**

The process of technical innovation continues to evolve regardless of what is happening in the economic environment. NTS serves customers in a wide range of different industries and I can tell you that there are emerging technologies everywhere. Limited access to capital and reductions to R&D budgets may slow the pace of innovation during difficult economic times, but great ideas don't wait around.

**ICM:** Is there a particular product sector that you see thriving through the slower economy?

**NTS Answer:**

Obviously I think we all see the tremendous level of focus and investment going into

the Power & Energy sector these days. The development of new technologies and applications related to alternative forms of energy is a very hot business space right now and the stakes are very high so this is driving technical innovation in the areas of power generation, storage and transmission. Smart Grid technologies, which are becoming increasingly prevalent throughout North America and Europe, are an excellent example of this type of innovation.

**ICM:** From your perspective, what is the most significant investment a manufacturer can make in the development of its product to assure it will pass compliance testing?

**NTS Answer:**

Too many product manufacturers start thinking about compliance-related considerations only after they have developed a product prototype that meets all of their functionality requirements. We have seen many customers come to us at the 11th hour with a new product shipment deadline looming over them, only to realize that their product is unable to meet its regulatory requirements. Naturally, when this happens our design experts step in and help address the source of the problem as quickly as possible. But as the old saying goes "An ounce of prevention is worth a pound of cure". Customers who consult with us during the design engineering phase of their product development process rarely encounter these problems when it comes time for testing and certification.

**ICM:** Would you share a word of advice for readers on how to best prepare for testing their product at your laboratory?

**NTS Answer:**

Every product is different and every customer's needs are different. At NTS we understand this so we place great importance on having a properly trained and highly responsive project management team to help each customer fully scope out and formally define their objectives and test

plans. The best way that customers can prepare for this process is by coming to us with well organized product documentation (diagrams, schematics, product manuals, etc), finished product samples/prototypes, and a clear definition of where and how they intend to market their products.

**ICM:** What trends do you see developing in the electronics industry that you believe may make a significant impact on the prosperity of the industry throughout the upcoming year?

**NTS Answer:**

Competitive pricing pressure in the consumer electronics industry continues to push manufacturers to seek out lower cost suppliers. This in turn results in quality control issues, as faulty, low-grade components make their way into the production line, leading to compliance testing failures, increased warranty and customer service costs and negatively impacting brand reputations. This is one of the reasons why NTS has invested in a new Supply Chain Management division, to offer solutions to our customers who are struggling to manage quality concerns as a result of these and various other sourcing challenges. We also see a lot of crossover in consumer electronics technologies these days. For example, almost every handheld digital device on the market has some form of wireless communications capability now. Technologies that were relatively new and unproven just a few years ago are becoming truly pervasive, providing a wide range of new opportunities for product manufacturers.



Derek Coppinger  
Senior VP  
Corporate Development  
NTS

### National Technical Systems

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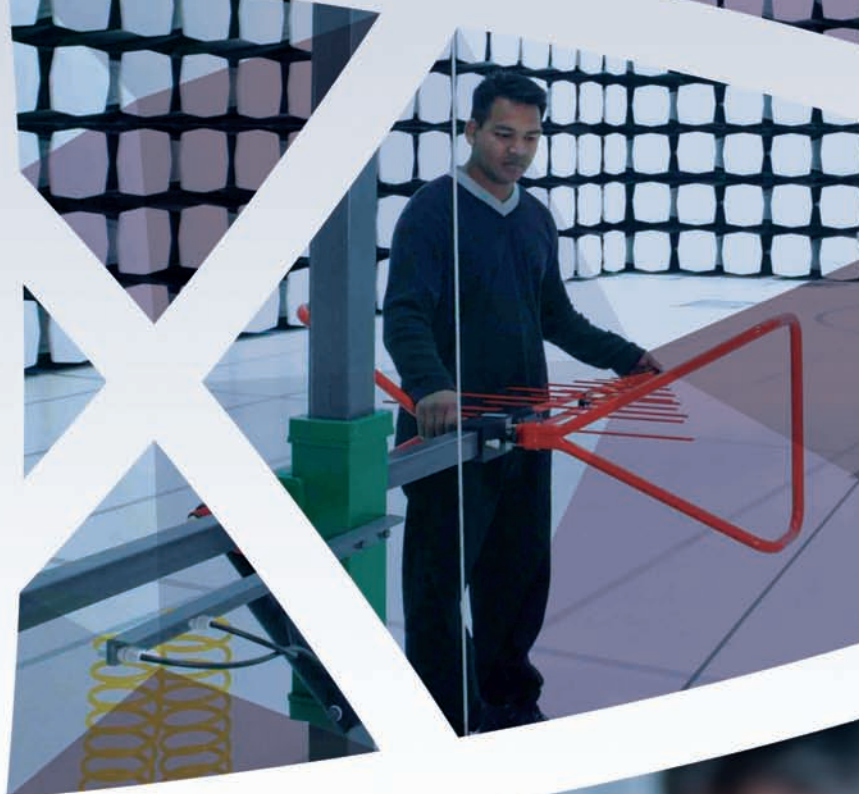
### Laboratory Profile

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



Engineering the most comprehensive network of commercial test laboratories in North America.

That's just one way that NTS works for your success.



At NTS, our heritage lies in the testing and certifications business.

Over the last 50 years, through a combination of acquisitions, innovations and organic growth we have become the largest commercial test laboratory network in North America. Our testing capabilities span a very wide spectrum, covering Environmental, Dynamics, EMC, Wireless, Product Safety, Reliability, Quality Assurance, Ballistics and more. Our nationwide network of test laboratories is tied together through our LabInsight customer portal, which enables real-time witnessing and participation in testing programs taking place simultaneously at multiple NTS locations. Simply put, no other commercial test lab in North America can match our capacity and capabilities, which means we get you from test lab to market in the shortest possible time and with the least amount of effort, because helping you achieve your goals is how we achieve ours.



**NTS**

ENGINEERING SUCCESS

# Failure Analysis: A Road Map

Although the foundation of a failure analysis is rooted in science, there is also an art to completing one, successfully. The path from problem discovery to problem solution has many bumps and twists along the way. This article will hopefully help guide you on that journey.

BY KEITH SELLERS

**I**nvestigative and analytical skills are a must and need to be implemented effectively in order to reach a useful end. Further, time is typically of utmost importance when performing a failure analysis. Knowing how to interpret your results quickly and efficiently will allow you to continue on a forward path. Dead ends will be reached, as well as paths in which the test results offer no apparently useful information; however, one must always bear in mind that a result is truly a result not matter how insignificant it might appear at the time. Being able to eliminate a possible failure mode from the discussion is just as important as identifying the ultimate root cause.

Holistically speaking, an analyst must realize that every failure is unique to the product being investigated; however, experience in performing failure analyses is critical as failure symptoms are very common and your knowledge

about them is priceless when trying to diagnose a new failure. Additionally, the gathering of background/historical information about the specimen being investigated is crucial in determining which steps should be taken along your failure analysis path. Knowing the types of questions to ask and what information you should try to obtain is a useful tool.

Within this article we will discuss how to attack printed circuit board (PCB)/printed circuit assembly (PCA) specimens when performing a failure analysis. Specific test methodologies will be discussed with descriptions of the associated test equipment and what an analyst may expect to glean from the results. With the analysis portion complete, we will then discuss report writing and what to do the next time a failed specimen ends up in your hands for analysis!





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Here is a list of some simple questions that you might try to answer with your initial visual examination:

- Is there visual confirmation of the failure issue?
- Are there other similar or adjacent areas affected by the failure issue?
- Do all or some of the specimens exhibit the same failure condition?
- How many areas are or how much of the area is affected by the failure?
- In layman's terms, what does the failure look like (be simple – color, shape, size, etc.)?
- Is there an industry wide name for the failure issue/condition that you are observing?
- Do you see anomalies other than those mentioned/described by your source?

## GETTING BACKGROUND INFORMATION

From the “source” of the failure (the person(s), department, division, company, etc., that has given you the task of analyzing the failed specimen), you should first obtain the exact goals that are expected from the analysis you are about to perform. Specifically, you should determine if the source has specific questions that need to be answered in order to satisfy the original query. Be sure to document these goals/questions and refer back to them often as you move forward in your failure analysis.

Additionally, you should try and secure as many of the following items as possible:

- representative failed specimens
- representative non-failed specimens
- representative components/materials that comprise the failed specimens
- representative process chemicals that may have been used in the construction, cleaning, handling, etc. of the failed specimens, and most importantly....

You, as the analyst, need to gather as much information as possible

concerning the manufacturing of the product, the exact nature of the failure, the way in which the failure was detected, and the environment in which the failure occurred/was detected.

For the analysis you are about to perform, time will almost always be in short supply. Failures typically result in some kind of “down” condition for your source, and they will be anxious to receive information as soon as you have it. That being said, you must make quick and sound decisions along your path. Do not rush; simply use the information you have at that time to make a scientific decision about where to go next. Sometimes an allotment of failed and non-failed specimens will allow you some leeway in making these decisions as incorrect decisions won't be costly; however, in most instances, failed specimens will be at a premium,

along with representative non-failed specimens of the same date code, lot number, etc., and you will have to make sure you conserve the samples you have and use them to gather as much information as possible. There will even be instances where only a single test can be performed due to its destructive nature. In a situation such as this, you must simply choose the test that will get you the most information and then try and supplement the results in other ways.

With the groundwork set, off we go...

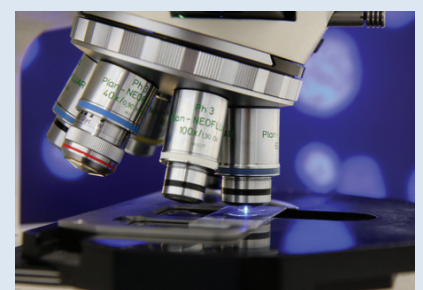
## THE INITIAL EXAMINATION

Before doing absolutely anything with the failed specimens, find a clean and clutter-free location in which you can spread out all of the supplied specimens and get yourself organized before beginning. At this point, be sure to inspect each test specimen for its proper identification/serialization and record this information for future use when preparing samples for test or for writing your test report.

When ready to begin, use various light sources (natural, fiber optic, IR, etc.), magnifications (via a standard bench microscope or stereomicroscope), and visual enhancement techniques (backlighting, diffused lighting, mirrors, etc.) to perform a detailed visual examination of each and every specimen you have received. Obviously you should concentrate on the specific failure area as identified by your source, but be sure to look around at other similar areas on the same or

### In the Initial Examination

Various light sources, magnifications, and visual enhancement techniques may be used to perform a detailed visual examination of specimens.





The use of x-ray allows you to see inside the “black box”, internal structures that are not visible under normal conditions are now visible.

different specimens depending on what you have received for review. Information in respect to both failed and non-failed areas will be useful later on, and of course, be sure to record and photograph your observations – remember that you will need overview and close-up images to illustrate the situation for your source in the test report.

To get you started, here is a list of questions that you might try to answer with your initial visual examination:

- Is there visual confirmation of the failure issue?
- Are there other similar or adjacent areas affected by the failure issue?
- Do all or some of the specimens exhibit the same failure condition?
- How many areas are or how much of the area is affected by the failure?
- In layman's terms, what does the failure look like (be simple – color, shape, size, etc.)?
- Is there an industry wide name for the failure issue/condition that you are observing?
- Do you see anomalies other than those mentioned/described by your source?

With the completion of your initial visual examination, the next step on your failure analysis journey must be determined. Barring in mind your identified failure issue, you must decide whether nondestructive or destructive testing is where you should be heading. In almost every case, you as the analyst should exhaust any and all nondestructive test techniques at your disposal before turning to destructive

test techniques. Why? The answer should be obvious; especially if you have yet to visually confirm the failure issue...performing a destructive test too early in the process could damage the true location of the failure and ultimately inhibit your ability to solve the problem at hand...thus, utilize all nondestructive test techniques!

## NONDESTRUCTIVE TEST TECHNIQUES

In addition to the traditional visual examination, various other visual techniques can be used to help see

your failed specimen in a different way. Two (2) common techniques are: x-ray examination and Scanning Acoustic Microscopy (SAM). Each of these techniques, in their own way, provide a visual means of understanding things associated with your specimen that you could not see with the naked eye or even a standard stereomicroscope.

The use of x-ray allows you to see inside the “black box”, internal structures that are not visible under normal conditions are now visible. Missing/broken wire bonds, misaligned components, and evidence of counterfeiting are some of the characteristics that can be seen



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One must always bear in mind that a result is truly a result not matter how insignificant it might appear at the time.

using x-ray. The technique does have inherent limitations however, as the image you see of your specimen is a “thru” shot in which anything in the path of the beam is visualized. With this, some anomalies (such as a BGA solder joint separation at the board interface) might not be seen, while some areas of the failed specimen might not be able to be seen if structures on the opposite side of the board are in the sight line of the region of interest.

As a complement to examination via x-ray, SAM can be used to inspect for anomalies not traditionally seen via x-ray. Of specific interest, SAM is typically used to look for internal anomalies such as delamination, voiding, and/or cracking within a component structure. The scattering of the acoustic signal when air is “struck” at one of these anomalies

causes a response in the imaging that allows you to see where and to what extent the internal problem is present. Area or volume calculations can also be performed to better quantify the anomaly.

For these additional examination techniques, the same simple questions that were mentioned above may give more complete answers this time around.

Moving from visual examination techniques to something a bit more quantitative, while assuming that the failure is electrical in nature, an electrical examination should be performed as the next step in the process. This evaluation is an extended qualification of the nature of the failure, as an open circuit will be approached much differently than a shorted circuit, not to mention the difference between

a high-resistance and a low-resistance short circuit.

For this examination, focus on the area of interest as specified by your source and obtain electrical characterization information on the failed specimen as well as on the non-failed specimens. In doing this comparison, attempts should also be made to isolate the anomalous conditions if at all possible. And, as always, record everything that you do regardless of whether you currently feel that the result is useless. One must always bear in mind that a result is truly a result not matter how insignificant it might appear at the time.

While performing the electrical examination, here is a list of questions that you might try to answer or obtain information about:

Destructive Test Technique	Property
Decapsulation	Die inspection
Differential Scanning Calorimetry (DSC)	Degree of cure ( $\Delta T_g$ ), glass transition temperature ( $T_g$ ), melting point (MP)
Dye-n-Pry Analysis	Solder Joint Fracture, Solder Joint Strength
Fourier Transform Infrared (FTIR) Spectroscopy	Contamination, organic-based
Ion Chromatography (IC)	Contamination, ionic-based
Microsection Analysis	Board integrity
Scanning Electron Microscopy/Energy Dispersive X-Ray Spectroscopy (SEM/EDS)	Contamination, inorganic-based
Solderability Analysis	Solderability
Thermal Stress Analysis	Board integrity
Thermomechanical Analysis (TMA)	Coefficient of thermal expansion (CTE), time to delamination

Table 1: The role of various destructive test techniques

An analyst should not put on blinders when heading towards a solution. Be aware that sometimes the most influential results are found when performing a test in a specific way.

- Is there an electrical confirmation of the failure issue?
- Based on your previous experiences, what type of issue would these electrical characteristics cause/create?
- Is it possible that other areas of the specimen are affected?
- How many areas are affected by the failure issue?
- Does the failure condition have a technical name?
- Do you see anomalies other than those mentioned by your source?

With the main nondestructive test techniques now exhausted and with your failure issue (hopefully) now located, identified, and characterized to the best of your “nondestructive” abilities, it’s time to move on to destructive techniques. Listed in the paragraphs below are various test techniques that inherently cause damage to your test specimen. That being said, you must make wise decisions about the sequence in which the testing will be performed in order to maximize the amount of information that can be gleaned while also minimizing the amount of peripheral damage to the specimen. After all, if you hit a dead end with your initially chosen analysis path, you will need to regroup. Having leftover specimen to test will be critical.

## DESTRUCTIVE TEST TECHNIQUES

With specific information about the failure issue in your back pocket and having had a primary view of the anomaly at hand, decisions must now be made in regard to the specimen’s disposition and exactly in what

direction your analysis should be headed. For most PCB/PCA based failure analyses, the path you choose is dependent on where the failure issue is occurring. By that we mean, at what step in the process of the PCA’s construction does the failure issue appear to be manifesting itself. From the evaluations performed above, you should be able to categorize your failure analysis as one of the following – board level or assembly level.

Based on this classification, your first path decision can now be made. The level you have selected will point you towards properties that should

be investigated. Table 1 is a list of destructive test techniques and the associated properties that can be found as a result – note that this list is not meant to be all-inclusive but simply a punch list of tests that are typically performed on PCB/PCA type specimens. Choose test techniques that will give results pertinent to the failure issue you are investigating, but don’t forget about any other pieces that could be part of the puzzle you are trying to solve. An analyst should not put on blinders when heading towards a solution. Be aware that sometimes the most influential results are found when performing a test in a specific way.



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Be creative! The “art” of failure analysis is that it is an ever evolving idea, and a little creativity in selecting your test methodology never hurts.

That being said – be creative! The “art” of failure analysis is that it is an ever evolving idea, and a little creativity in selecting your test methodology never hurts.

The paragraphs below provide insight and guidance on each destructive test technique listed in Table 1. The purpose of the specific testing is given along with some questions you might answer or obtain information about.

### Decapsulation

This test is more of a sample preparation technique and would be used if the failure issue under investigation is related to the assembly level or, more specifically,

the component level. Decapsulation allows for the removal of component encapsulant material such that an internal die structure can be primarily viewed using normal visual techniques or SEM. This inspection can be used as a check of the internal bond wire structures, as well as before a detailed examination of the die’s surface.

When inspecting the internal structures of a decapsulated component, these questions might provide answers or information:

- Are bond wires present within the component and are they structurally sound?
- Does the internal die appear to be intact?

- Is there any evidence of electrostatic discharge (ESD) damage?
- Could the component and/or the die be a counterfeit?
- How does the failed component compare to a non-failed (exemplar) component?

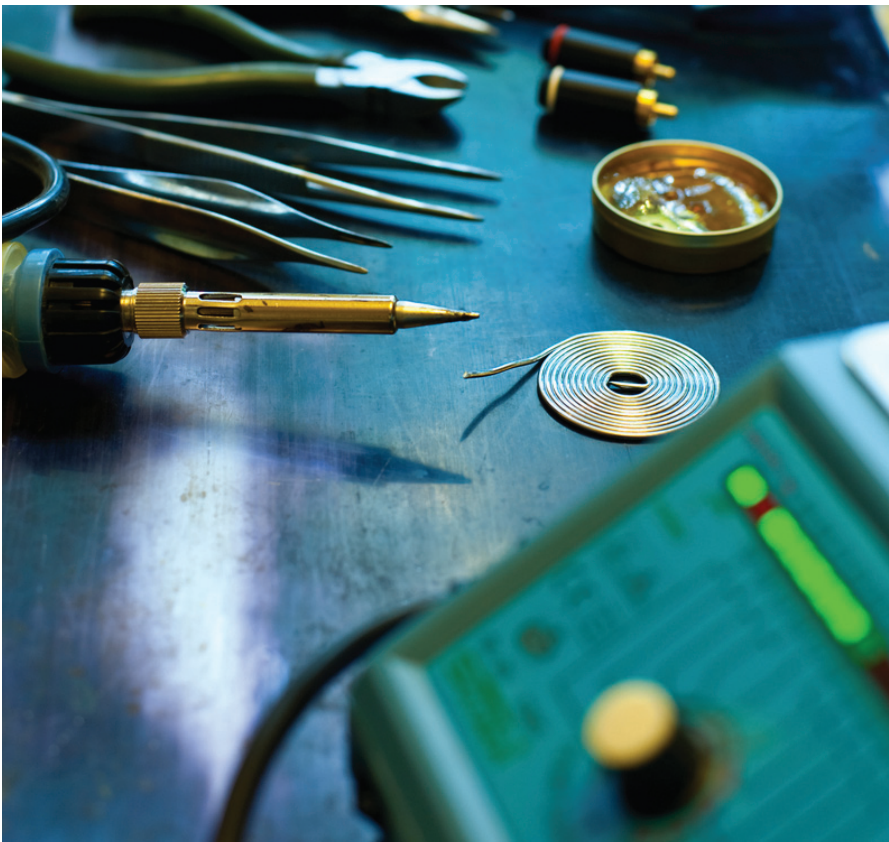
### Differential Scanning Calorimetry (DSC)

This specific test would typically be conducted for failure issues related to either the board level or the assembly level, given the fact that assembly level failure issues can at times be the result of poor board level construction. Gaining information about a board’s cure status can be extremely useful in determining exactly what has occurred. Specifically, this test method is of great interest if a lack of cure of the board could be contributing to the mode of failure by causing excess expansion of the board during the soldering process. Additionally, if Pb-containing versus Pb-free processing is involved, basic material information about the board’s glass transition temperature (T<sub>g</sub>) could be useful. Further, if possible, you should compare the failed sample board’s properties to those of a non-failed board to determine whether or not the specific property of interest is truly an issue.

While performing this DSC Analysis, these questions might provide answers or information:

- What is the glass transition temperature of the board sample?

**Dye-n-Pry analysis involves the removal of a BGA component in such a way that each individual solder joint can be evaluated for the possibility of an open circuit.**





To help determine the exact failure issue, comparing failed and non-failed locations is useful to assist in identifying what organic materials are supposed to be present in comparison to those that are not supposed to be present.

- What was the degree of cure of the board sample?
- Is it possible or probable that the degree of cure could be causing the failure issue?
- Given the degree of cure found, what types of problems could this cause/create?
- Do all of the samples, failed and non-failed, exhibit the same condition?

### Dye-n-Pry

This test is typically used for failure issues related to BGA components, although it can be used with some modification for other component types, and would thus be investigated in relation to an assembly level failure. Dye-n-Pry analysis involves the removal of a BGA component in such a way that each individual solder joint can be evaluated for the possibility of an open circuit. Dye penetrant is flowed beneath the component such that the fluid is allowed to “submerge” each individual solder joint ball. Then, once the dye is cured, the component is removed from the board with each of the solder joints is carefully observed. Ultimately, this post-component removal inspection can be used to determine if any open solder joints are indeed present. For solder joints that have some type of failure issue, the dye material will be visible “within” the joint.

When inspecting the Dye-n-Pry test location after component removal, these questions might provide answers or information:

- Are any fully or partially open solder joints present?
- For each open solder joint, at which interface – component/solder versus

solder/board – has the separation occurred?

- Is there any evidence of head-in-pillow defect – a defect in which the solder joint does not completely reflow resulting in the solder paste on the board and the solder ball not combining?
- Is there any evidence of pad cratering – a defect in which the board material has cracked beneath a given surface mount pad?
- Are there any apparent solder wetting issues?

### Fourier Transform Infrared (FTIR) Spectroscopy

This specific test would typically be conducted for failure issues related to the assembly level; specifically, when it is believed that an organic contaminant might be causing visible corrosion or might be contributing to some type of high resistance short. To help determine the exact failure issue, comparing failed and non-failed locations is useful to assist in identifying what organic materials are supposed to be present in comparison to those that are not supposed to be present.



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## EMC, RADIO, TELECOM ENVIRONMENT, SAFETY

When reviewing the FTIR test results, these questions might provide answers or information:

- Was an organic contamination/material detected by FTIR?
- Specifically, what organic material was detected?
- Is it possible that this organic contamination/material could be causing the failure issue?
- What type of issue would an organic contamination such as this cause?
- Is this an isolated issue or are there other areas affected?
- Do all of the supplied specimens exhibit the same condition?

## Ion Chromatography (IC)

This testing would typically be conducted for failure issues related to the assembly level or board level when utilizing no-clean assembly. An analysis via IC would be performed if it is believed that ionic material on the specimen's surface could be leading to a high resistance short. The testing itself can be performed on a board basis

through full extraction or on a localized basis through spot checks at various areas on the specimen's surface. If the "source" has known ionic cleanliness requirements, this information might be helpful in determining what is occurring in respect to the failure mode at hand. Pass/fail criteria for a test such as IC is not always a definitive way to determine if the specimen is truly clean. A localized concentration of ionic residues would be problematic regardless of the specimens' overall cleanliness level.

When reviewing the IC test results, these questions might provide answers or information:

- What types of ionic contamination were detected by IC?
- Is it possible that the ionic levels detected could be causing the failure issue?
- What type of issue would the ionic contamination levels detected cause?
- Do some of the individual ionic levels suggest a potential source for the contaminant?

- Do both failed and non-failed specimens exhibit the same or similar ionic levels?

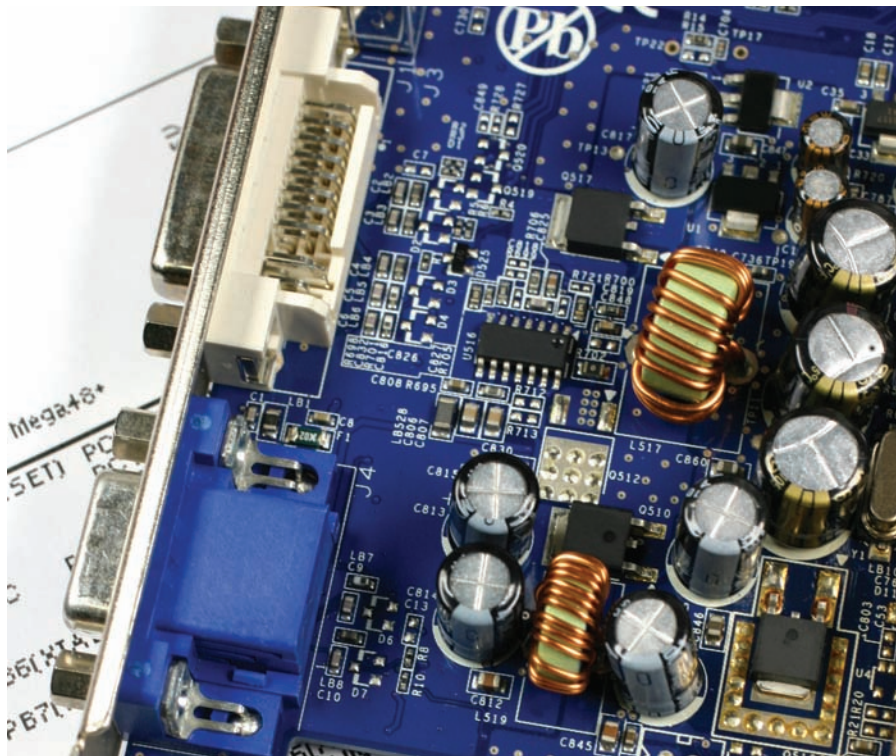
## Microsection Analysis

This evaluation would typically be conducted for failure issues related to either the board level or the assembly level for examination of internal board anomalies or solder joint related anomalies, respectively. For the analysis, the specimens of interest are diced and mounted in an epoxy resin to allow for cross-sectional examination via metallurgical scope of the board/solder joints in the vertical plane. Evaluation can be performed in a generic sense, simply commenting on what is "seen" or "not seen", or to an industry standard, such as IPC-A-600 and/or IPC-A-610. Once again, it is best to compare failed regions to non-failed regions while taking many photographs to tell the story of what is occurring – always keep in mind the report that you will need to write upon completion of your analysis!

When evaluating your prepared microsection samples, these questions might provide answers or information:

- Are there any internal board issues that could be causing the failure issue?
- Are there other areas of the specimen that are showing the same anomaly?
- Do all of the supplied specimens, both failed and non-failed, exhibit the same condition?
- In layman's terms, what does the failure look like (be simple – color, shape, size, etc.)?
- Is there an industry wide name for the failure issue/condition that you are observing?
- Do you see anomalies other than those mentioned by your source?

**Microsection analysis is recommended for failure issues related to either the board level or the assembly level for examination of internal board anomalies or solder joint related anomalies.**



## Scanning Electron Microscopy/ Energy Dispersive X-Ray Spectroscopy (SEM/EDS)

This testing is typically performed for failure issues related to the assembly level but can also be used to help further evaluate possible board level anomalies. SEM/EDS provides both visual and elemental information

- Are there other areas of the specimen that are showing the same anomaly?
- Do all of the supplied specimens exhibit the same condition, both failed and non-failed?
- Do you see anomalies other than those mentioned by your source?

either the board level or the assembly level. Confirming whether or not a board can withstand repetitive solder reflow cycles is worth a look. After performing the test, microsection specimens are typically prepared and then evaluated to look for anomalies that might be similar to that which has been observed in the failed specimen.

Comparing failed and non-failed (or contaminated and non-contaminated) locations is best for determining what elements should be present and which ones should not be present.

about the selected area(s) of interest. SEM provides an additional way to visually inspect a sample. The magnifications reached by SEM will be much higher than that which can be obtained by stereomicroscope or metallurgical scope – and don't forget to take photographs! At the same time, EDS provides elemental information about an observed contaminant or a corrosion product. Typically, these types of materials could be causing a high resistance short and thus need to be evaluated, elementally, in order to determine their composition, and then possibly their origin. Comparing failed and non-failed (or contaminated and non-contaminated) locations is best for determining what elements should be present and which ones should not be present.

When reviewing the SEM/EDS test results, these questions might provide answers or information:

- Via SEM, did inspection at a higher magnification provide any additional detail to that which was already observed using a stereomicroscope and/or a metallurgical scope?
- Via EDS, did the identification and quantification of the elemental species present provide any significant information about the observed contaminant/corrosion material?

## Solderability Analysis

This testing would typically be conducted for failure issues related to either the board level or the assembly level. Confirming whether or not a board can pass IPC-J-STD solderability testing is a crucial piece of information when trying to evaluate the cause of a failure, specifically a solder joint failure. When possible, you should attempt to perform this analysis or as many representative samples as possible, bearing in mind that surface mount pads may not solder the same as ones plated through hole.

When performing the solderability test, these questions might provide answers or information:

- How well did the specimen solder?
- Did the specimen meet its IPC-J-STD solderability requirement?
- Could the solderability test result explain or be related to the failure issue?
- What type of issue would a solderability issue such as this cause?
- Do all of the supplied specimens exhibit the same condition?

## Thermal Stress Analysis

This specific type of testing could be conducted for failure issues related to

When evaluating the specimens after Thermal Stress Analysis, these questions might provide answers or information:

- After completion of the Thermal Stress Analysis, were any visual anomalies detected?
- Were the anomalies found similar to the failure issue observed?
- Is there an industry wide name for the failure issue/condition that you are observing?
- Do all of the supplied specimens exhibit the same condition?

## Thermomechanical Analysis (TMA)

This specific test would typically be conducted for failure issues related to either the board level or the assembly level. Obtaining information about a board's expansion properties is a useful piece of information when trying to diagnose the failure issue at hand. Using TMA, thermal expansion properties can be evaluated both in terms of the board's coefficient of thermal expansion (CTE) and through observation of the board's behavior when it is held at elevated temperature for an extended period of time, as during solder reflow. For example, if a board delaminates during the reflow process, it would result in a solder joint





## Failure Analysis Report

issue that is being experienced on the assembly level with the cause actually being due to a board level problem.

While performing this TMA Analysis, these questions might provide answers or information:

- What are the pre- and post- glass transition temperature (Tg) CTE's for the board sample?
- What is the "overall" thermal expansion (TE) for the board sample?
- Are the CTE and TE values found typical given the board's construction?
- Can the board sample survive Time-to-Delamination testing?
- Is it possible/probable that the board's performance at elevated temperature is causing the failure issue?
- What types of problems could the thermal expansion properties cause?
- Do all of the specimens, failed and non-failed, exhibit the same properties?

## ENDING YOUR ANALYSIS

Knowing when to stop your analysis is almost as difficult as knowing where to start your analysis. The big difference on this end of the path is that you will know that you have gone far enough when you can answer these questions:

- Do I have enough information to explain to my source what has happened to the failed sample?
- Do I have enough information to explain to my source why this has happened to the failed sample?
- Do I have enough information to answer all of the questions that my source had?
- Do I have enough information to explain to my source how they can avoid this issue in the future?

The common theme in these questions is "information". Each and every failure analysis should focus on information – the more the better. This starts from the very beginning, as mentioned above, when you as analyst gather all the appropriate background information so that you can start your failure analysis oriented in the correct direction. From there, you make decisions on how to progress based on the information gathered from each test you select along your path. The various sets of questions listed above for each of the described test methodologies are given to help you gather this information. You must then use the path to collect more and more information until enough is gathered for you to easily and successfully write a test report that your source can understand and use to understand and solve the failure issue at hand.

## WRITING THE REPORT

Most failure analysis reports are quite detailed and become lengthy due to the many pages of photographs and instrument scans. These items are interesting to look at and do indeed tell a part of the story; however, for most people reading the report, the results given in these items are not understood in the context of simple presentation. That being said, the verbiage that you use as analyst and author is the glue that will bring all of your hard work together. And you truly will be an

author at this point, as you need to tell the "story" of your analysis. You need to establish the failure issue at hand and then explain how you went about attacking that problem. The report has to have structure and should flow from section to section. The following is a description of a typical failure analysis report layout:

**Section I – The Abstract:** When writing a failure analysis report, it is always a good idea to include a statement of work (SOW) to get things started. This SOW can usually be taken directly from your source's initial contact with you. The SOW will state exactly what the source needs you to determine; for example, "John Smith is experiencing an intermittent open at BGA component location U1 on PCA S/N 12345678." This type of statement gets the ball rolling in the report and allows you to then follow up with the background information that you have gathered. By including the background information obtained, as discussed earlier in this article, you can paint a picture of how the failure issue at hand has come about. This section will give the history of the specimen as well as any troubleshooting that may have been done on the specimen prior to you coming into possession of it. In the end, the Abstract should be a summary of the information that you were given or obtained prior to the commencement of any testing, nondestructive or destructive.

**Section II – The Body:** After clearly establishing the failure issue at hand and after presenting the information surrounding the failure itself, it is time to jump right into the testing that you've performed. Section II will make up most of your test report and should include sub-sections for each of the test methodologies that you implemented in your analysis, no matter what the result! Within these individual sections, you should describe the samples selected for analysis, the methodology performed, and the results. These



results should include any visual observations or numerical values that you've come upon that help show the work that you've performed. At the same time, unless you feel compelled, there is no real need at this level of the report to describe how a particular single result is related to the failure issue at hand, but you can make some commentary if you'd like – it is, after all,

Given that your audience will include your source and probably your source's manager or director, you might as well get to the good stuff right away in your report as "some people" aren't going to want to read all the way to the end! I have found it very useful to put the Analytical Summary right up at the front of the report. This summary should be no more than

performed and your findings; avoid the words "possibly", "probably", "maybe", etc.

## SUMMARY

In this article, a road map for successful failure analysis has been laid out. As you can see, there are many twists and turns that need to be managed, and the

**It is entirely possible that no single test result will mean anything standing alone, and only when all of the results are put together will a true root cause be found.**

your report. Ultimately, the root cause of the failure issue will likely be drawn from the results of multiple analyses performed. That is why it is ok to simply state results in this section of the report and nothing more – in essence, conclusions are for the Conclusions section! That being said, it is entirely possible that no single test result will mean anything standing alone, and only when all of the results are put together will a true root cause be found.

**Section III – Appendix:** With all of your hard work described in words, photographs, tables, and figures in Section II of the report, don't forget to include any other information that you've gathered. Spectra, scans, and the like should all be included in your test report as support for the information that you have provided in the individual test sections. Most of this information might never be looked at by your audience, but it most definitely needs to be there in some form. Provide a list of what you are including and then simply attach everything for reference as needed.

With these three report sections written, the final section ends up becoming the first one in the organization and the most important one to boot! We'll call it Section "0"...  
**Section "0" – The Analytical Summary:**

one to two pages and should highlight the SOW, the Abstract information, the results that you have found throughout your testing and then, most importantly, your conclusions and recommendations. This latter part is clearly and rightfully the most difficult part of your job on this failure analysis. As the analyst, you are responsible for tying everything together and interpreting the results in a way that everyone involved can understand. At times, it is not an easy job; but given experience and knowledge, the path you have taken will lead you directly to the "answer". For your conclusions and recommendations in this section, here is some helpful advice:

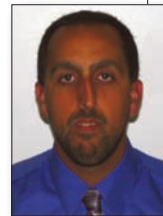
- Limit your conclusions for the root cause of the failure issue to one or two possible causes.
- Recommend any possible corrective actions, preventative actions, or repairs that might allow your source to avoid this failure issue/mode in the future.
- Be sure to specifically answer as many of the questions in the source's SOW as possible.
- Depending on the failure issue/mode, compile supporting literature that might be useful to your source.
- Be as definitive as possible in your statements about the testing you

amount of information and types of specimens you are given by your source will have a profound effect on what exactly it is you are able to accomplish as well as how well you are able to accomplish it. Sometimes a failure mode will not be found, sometimes the evidence of the failure will not be found in a lab setting, and sometimes all of the evidence of the failure is gone at the time of the analysis. Even in situations such as these, useful information can still be found if searched for in the appropriate manner, and conclusions can be drawn based on results obtained from "similar" specimens. Like a police investigation, PCB/PCA failure analysis can be done "by the book" and when that happens, good things usually result. **IN**

### (the author)

#### KEITH SELLERS

the Managing Scientist at Trace Laboratories, Inc.'s facility in Hunt Valley, MD (ksellers@tracelabs.com), has been with Trace since 1999 and holds a bachelor's degree in Chemical Engineering from the University of Delaware. Keith's primary work is in the areas of contamination and root cause failure analysis with recent work focused on Pb-free alternatives, tin whiskers, ionic cleanliness, counterfeit components, and related reliability issues.





# Troubleshooting Radiated Emissions: Three Case Studies

Radiated emissions (RE) are often the number-one cause of compliance failures for most electronic products. This article describes simple troubleshooting steps and tools to isolate most RE issues. Three case studies are described showing how low-cost probes and instruments may be used to help the EMC or product development engineer troubleshoot a product right in the R&D lab. By characterizing and resolving the RE prior to compliance testing, the chances are much greater for a successful compliance outcome.

BY KENNETH WYATT

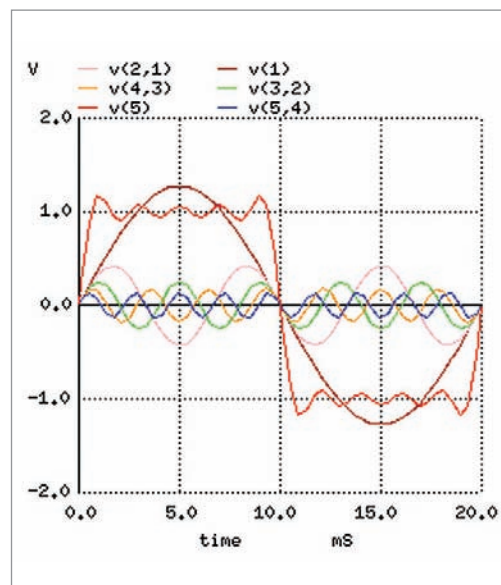
Radiated emissions (RE) are typically the toughest compliance issue for most electronic products. Because emissions limits are established worldwide, products that don't meet the limits may not be placed on the market. The best way to achieve compliance is through proper product design, but often these design techniques are not taught in universities, nor are these techniques fully understood by many experienced engineers. The result is that, many products lack the proper EMC design and therefore are unlikely to meet limits for RE. In this article, I'll describe the basic troubleshooting steps involved and show a few of the tools and probes I use. Then, I'll take you through three case studies that demonstrate

the troubleshooting philosophy and specialized probes and instruments used to reduce RE to meet compliance limits.

## BACKGROUND THEORY

In order to better understand RE and how to troubleshoot your product, let's review how harmonics are created, and then describe differential-mode (DM) and common-mode (CM) currents and how they get generated. General design techniques are mentioned, but specific design practices are a subject for another paper.

A periodic square wave (Figure 1) may actually be represented as a series of more basic signals called "basis functions". Assuming the



**Figure 1: An infinite number of harmonically-related basis functions (sine waves) will create an ideal square wave.**

The solution to most EMC problems is to *control the path of current!* Namely, both power and signal return currents must be well defined.

rise and fall times of the square wave are straight up and down (zero rise/fall time), an infinite number of harmonically related basis functions, or sine waves, are required. Digital circuitry today uses rise and fall times of sub-nanoseconds, which can generate harmonics of several hundreds to thousands of MHz.

DM currents and their associated radiation are caused by digital signals (and their harmonics) traveling through circuit loops. The larger the loop, the stronger the fundamental and harmonic emissions will be. We want to minimize the area of any circuit loops through use of signal or power return planes, typically by use of multi-layer circuit boards. For low-cost products, multi-layer boards may not be feasible, so other design techniques must be used to minimize these loops.

To reduce emissions, the area of the loop may be decreased. This is an

important point to keep in mind during circuit layout. Placing a crystal oscillator (one common source of harmonics and resulting emissions) close to the circuitry that requires its signal is a good design practice. Likewise, the use of multi-layer boards with full signal or power return planes serves to reduce the loop area substantially.

Now let's consider CM currents and how they are generated. How current may travel the same direction through both the signal and signal-return wires in a system is not necessarily intuitive. Referring to Figure 3, note that due to finite impedance in any grounding system (including circuit board signal/power return planes), there will be a voltage difference between any two points within that return plane. This is denoted by  $V_{GND1}$  and  $V_{GND2}$  in the figure. This difference in potential will drive CM currents through common cabling or circuit traces between circuits or sub-systems. These CM currents may be generated on circuit

boards or within sub-systems inside product enclosures. In addition, unbalanced geometries - for example, different lengths or path routings for high-speed differential pairs - can create CM voltage sources that drive associated CM currents. Because the current phasors are additive, the resulting radiated phasor may be quite large compared to those generated by DM currents, which are opposite in direction. Therefore, CM emissions tend to be more of an issue than DM emissions.

So, how do these large DM loop areas and CM sources get generated? One major issue I run into constantly is that the return plane (power or signal) often contains gaps or slots, forcing the return DM signal out around the lowest-impedance path, thus creating a large radiating loop; this and the fact that unbalanced geometries or common-impedance couplings can create CM voltage sources. It's no

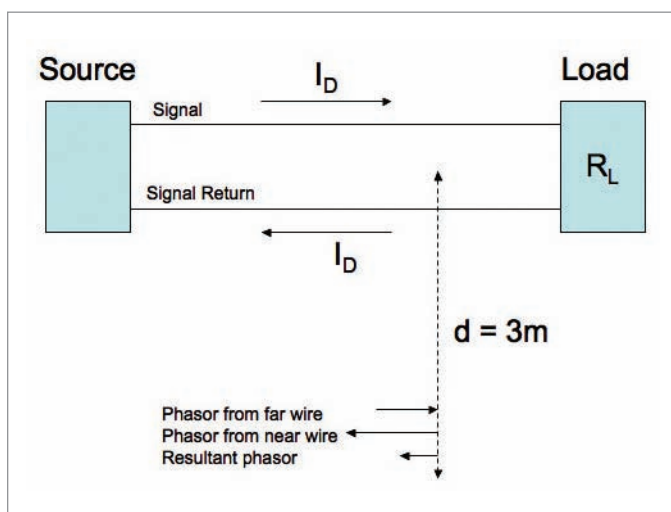


Figure 2: General model for DM current generation. Note that the resulting phasors from the wires are *subtractive*.

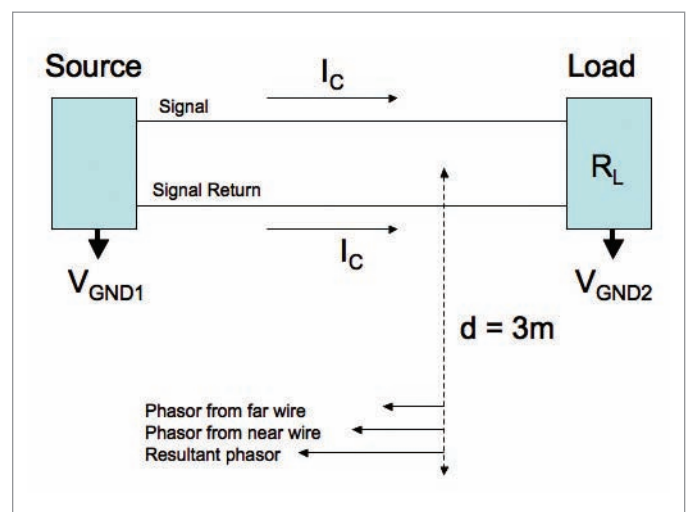


Figure 3: General model for CM current generation. Note that the resulting phasors from the wires are *additive*.



During troubleshooting, it's more important to know whether the fix is "better", "worse" or "no change"; as long as the test setup doesn't change, the results should be believable.

wonder PC boards can generate a lot of harmonic emissions. The solution to most EMC problems is to *control the path of current!* Namely, both power and signal return currents must be well defined.

So, how do you tackle a product with high radiated emissions?

## USEFUL TROUBLESHOOTING TOOLS

### Troubleshooting Kit

Several years ago, I assembled an EMC troubleshooting kit in a portable Pelican model 1510 roller-case that can be wheeled right to an engineer's workbench or into your client's facility. Contents include a handheld spectrum analyzer<sup>1</sup>, a broadband preamplifier, small DIY antennas, various probes and other accessories. Other useful items for your troubleshooting kit include

the usual ferrite chokes, aluminum foil, copper tape, power line filters, signal filters and various values of resistors and capacitors. Figure 4 shows the contents of the case.

### Antennas

The antenna you select is not really that critical for troubleshooting purposes. As long as its fixed in length and fixed in place on the bench, you'll receive consistent results. During troubleshooting, it's more important to know whether the fix is "better", "worse" or "no change"; as long as the test setup doesn't change, the results should be believable.

I use a couple inexpensive television antennas available through most electronics parts suppliers. These include a pair of television "rabbit ears" and a UHF "bowtie" with TV balun to match 50-ohm coax (Figure 5). If the troubleshooting workbench is

non-metallic, I'll extend the antenna to approximate resonance (if possible) and tape it down to the bench with duct tape. If the bench is metallic, I support and position it some distance above the bench. Try using a test distance of about a meter from the EUT – closer if the emissions are too low to see clearly. Sometimes I find a low-noise, wide-band preamp between antenna and analyzer helps.

If ambient signals from broadcast radio, television, mobile phones and two-way radio services interfere with observing the product harmonics, you may need to bring the antenna closer or set up the troubleshooting measurement in a basement or building interior away from outside windows.

### Probes

Useful probes include E-field, H-field and current probes. All are easily constructed or are available from



Figure 4: Contents of the EMC troubleshooting kit. I can probe for various RE problems, as well as test for ESD and radiated immunity. This is based on a Pelican 1510 roller-case.

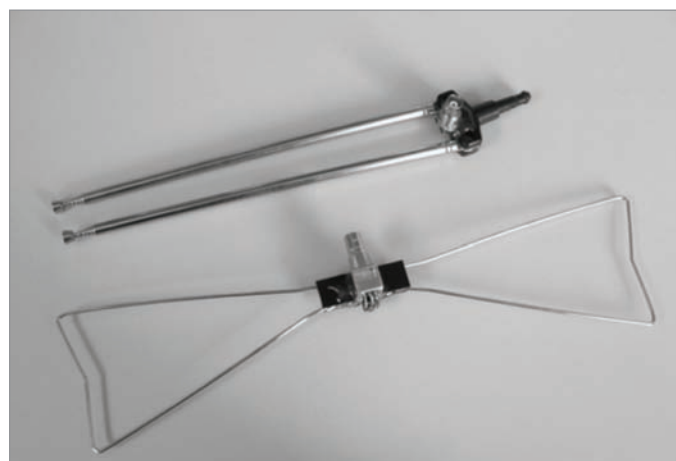


Figure 5: Examples of DIY antennas for radiated emissions troubleshooting. The television "rabbit ears" is resonant from 65 to 200 MHz depending on how the elements are extended, while the bowtie resonates well from 300 to 800 MHz. I installed an inexpensive 300 to 75-ohm television-style balun to better match the 50-ohm coax to the bowtie.

I've found that most cable emissions are very likely due to poor grounding to the enclosure at the I/O connector.

several manufacturers<sup>2</sup>. A simple E-field probe may be made by extending the center conductor about 0.5 cm from a section of semi-rigid coax or high-quality flexible coax and then attaching a coax connector to the other end. H-field probes may be fashioned by looping the center conductor of a coax cable around and soldering it to the shield to form a small loop of 0.5 to 5 cm in diameter - the larger the loop, the more sensitivity. A more sturdy H-field probe design uses semi-rigid coax to form the loop. Be sure to add a small ferrite choke on the probe input coax to reduce CM currents due to the unbalanced geometry. Beehive Electronics makes a low-cost set of E- and H-field probes and, because the H-field probe design is balanced, it does not require the ferrite choke. Depending on the diameter of your H-field probe, you may need to

use a broadband preamplifier between the probe and analyzer.<sup>3</sup>

## GENERAL TROUBLESHOOTING STEPS

### Locating Internal Sources

Using an E-field or H-field probe, identify the high-harmonic sources and circuit traces, and determine potential coupling paths to slots, seams or cables (Figure 6).

Once the potential sources are mapped, you're ready to start applying fixes. You should generally start with the lower harmonics and work upwards. Often, lower-frequency sources will cause significant high-frequency harmonics, depending upon the rise time. Sometimes adding a simple low-pass filter to power or signal traces can reduce emissions dramatically.

### Cables

Check your cables next, as CM currents often couple into them resulting in radiation. Try unplugging all the cables and then plug each in one at a time to find any that are radiating. Remember that there may be more than one bad cable! Snapping a ferrite choke around the base of the cable near its chassis connector may help as an interim fix. I've found that most cable emissions are very likely due to poor grounding to the enclosure at the I/O connector.

These CM currents on cables may also be measured with a current probe. Clamp the probe around the cable in question and move it back and forth to maximize the readings, then tape it in place while you apply potential fixes. I made my own current probes (Figure 7), but the advantage of commercial probes is that they can open up and snap around a cable, rather than having to be threaded on.

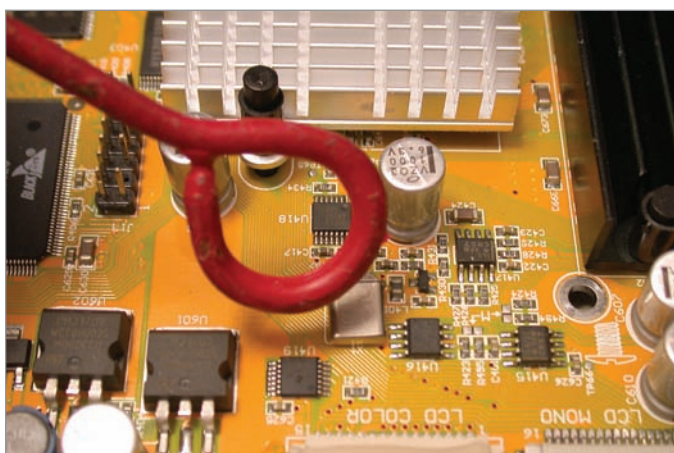


Figure 6: Use of simple H-field probes to locate emission sources.



Figure 7: Examples of DIY current probes. These photos were taken prior to installing the E-field shield by wrapping a layer of copper tape over the windings, leaving a small gap around the inside of the probe. Fourteen (14) turns of Teflon-insulated wire wound around a Würth Elektronik #74270097 ferrite core (4W620 material) was used, which is useful from 10 to 1000 MHz.



# CASE STUDIES

## #1 Industrial Alarm System

This first project consisted of an extensive alarm and access control system for large industrial or government buildings. There were several different control units with associated highly secure, door-access keypads and remote switches and sensors. It was all to be interconnected with RS-485 control cabling – up to several hundred feet apart. It also had to comply with FCC Class B limits.

Taking a look at the major system components quickly revealed the major issue – the RS-485 and LAN cables were penetrating the shielded enclosures and were radiating badly. The other issue turned out to be splits in the power and signal return planes with signal traces crossing over these splits, which created CM current sources. I've found both issues to be fairly common.

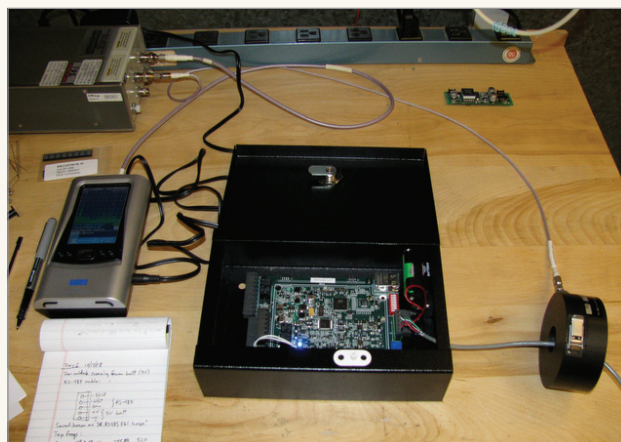
Fortunately, the client had a screen room available, so ambient signals were not as much an issue. Because cable emissions were the dominant source, I ended up using a current probe around the cable under test for most of the board-level troubleshooting.

As previously mentioned, the other very common issue with many products I evaluate is high-speed circuit traces crossing over splits in signal return or power return planes. In the case of the alarm system, many of the circuit boards included RJ-45 LAN connectors and the associated 20 MHz PHY oscillator trace crossed several of these splits. This forced the return signal out into a large loop area, which caused radiated emissions and coupled CM currents onto both the RS-485 and LAN cables.

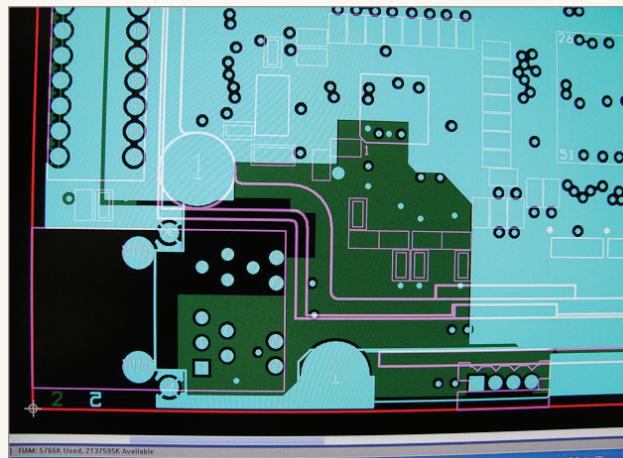
Ultimately, I designed a simple, low-pass L-C filter (ferrite choke and capacitor) for each RS-485 wire. Low-pass filters were installed on all the on-board dc-dc power supplies and large ferrite chokes were added to the penetrating cables. Once the circuit boards were re-laid out to eliminate the splits, the client was able to achieve its FCC-Class B emissions goal. This was a case where some simple EMC and system design in the front end of the design would have done wonders.

## #2 Torque Measurement System

This case study was of a self-contained, computer-controlled torque measurement system used for determining the force required to remove soft drink bottle caps. In this case, the embedded OEM Windows PC controller with touch-screen LCD display was radiating at several frequencies from 90 to 200 MHz.



**Figure 8: General configuration of the major sub-assemblies showing the RS-485 cable penetrating the shielded enclosure. Also shown is the current probe and portable spectrum analyzer used to probe potential sources.**



**Figure 9: Section of the circuit board showing several splits or gaps in the signal and power return planes.**



**Figure 10: Copper tape was added to bond the front bezel and rear panel on the LCD module.**



Since most of the radiation appeared to be coming out the front of the controller through the LCD display, we disassembled and found several issues. Because this was an OEM component, there was little that could be done internally except to install retrofit bonding and gasketing. It also turned out the controller/LCD display assembly was “floating” as mounted to the shielded enclosure. Finally, when the video display cable was probed, a very high CM current was observed at the dominant radiated frequency of 95 MHz.

Here’s where copper tape comes in handy. Most LCD displays I’ve seen are comprised of two metal case halves – a front bezel and rear shield cover. For whatever reason, these are rarely connected. In addition, this LCD assembly was isolated from the sub-chassis of the controller. During the troubleshooting phase, I added copper tape to bond the LCD case halves together and copper tape (later replaced with finger-stock) between the LCD module and sub-chassis. We then copper-taped the sub-chassis to the main shielded enclosure. “Floating” metal is bad news, as it can act like an antenna and re-radiate internal noise currents.

Finally, a small ferrite choke was added to the internal video cable and that, plus the extra bonding, was enough to get the emission level down so it would pass the CISPR 11-A limit.

### #3 Digitizing Oscilloscope

One of the most common sources of radiated emissions is due to poorly bonded connectors mounted on shielded product enclosures. This occurs especially if

the connectors are circuit board mounted and penetrate loosely through the shielded enclosure. Poorly bonded connectors allow internally generated CM currents to leak out and flow on the outside of I/O, mouse or keyboard cables. This also allows ESD discharges inside the product – more bad news. If these currents are allowed out of the enclosure, the attached cables will act as radiating antennas, often resonating around 300 MHz due to the typical 1m length.

This was the case for a new digitizing oscilloscope prototype. The I/O connectors were all soldered onto the PC board and the board was fastened to the rear half of the enclosure. The connectors simply poked up through cutouts in the front metal shield.

Notice the gap around the bonding fingers of the connectors (Figure 13)? While measuring the CM current flowing on the outside of the USB cable under test, and simply jamming the screwdriver blade of my Swiss Army knife between the connector bonding fingers and metal chassis enclosure, I was able to drop the overall cable currents by 10 to 15 dB.

The solution was to fabricate a custom shim with spring-fingers that would slip over all the connectors and bond firmly between the connector ground shell and enclosure. More and more low-cost products are relying on PC board mounted I/O connectors as a cost-cutting measure. Any time you see this, be prepared to carefully examine the bonding between the connector ground shell and the shielded enclosure.

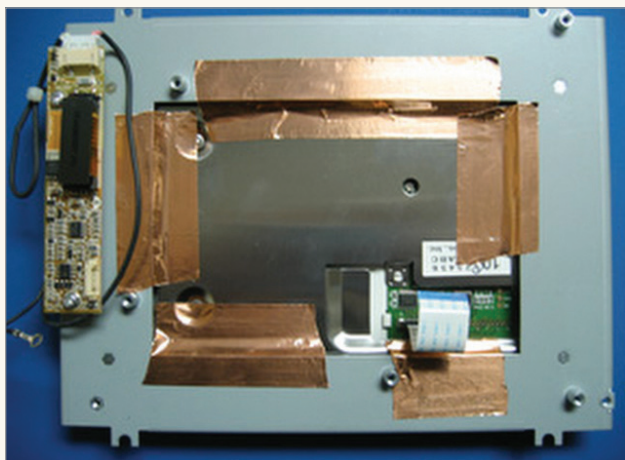


Figure 11: The LCD module was bonded to the sub-chassis. This was later replaced with strips of finger-stock.




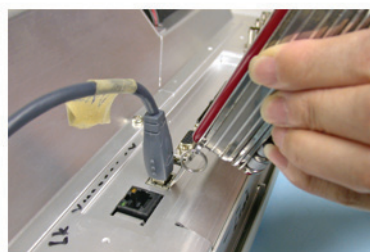
Figure 12: A flat ferrite choke was added to the video cable as a final solution.

## Slots and Seams

Once any cables issues are addressed, its time to probe for leakage through slots or seams in the chassis. The length of the slot or seam is important. The worst-case is when the slot/seam is 1/4-wavelength long at the harmonic in question. I use a permanent marking pen to record the areas of leakage and frequencies of concern from every seam/slot on the enclosure. Once these are marked, I'll cover them with copper tape and re-measure the RE levels. Keeping an eye on the levels, I'll start removing the tape piece-by-piece to determine which slots or seams are actually causing problems.

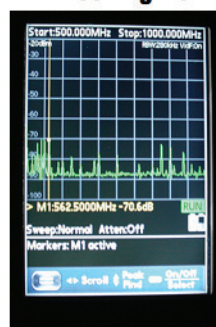
## SUMMARY

In order to pass required EMC tests for radiated emissions, it is necessary to understand the basic concepts of current flow through loops, as well as differential- and common-mode currents and how they are generated. Troubleshooting an existing design is simply a process of identifying the likely sources, determining the coupling paths via probing, and applying temporary fixes. Once these fixes have been applied and the product passes emission limits, the electronic and mechanical engineers may determine the most cost-effective solutions. Obviously, troubleshooting or characterizing products early in the design cycle is preferred in order to reduce overall implementation costs. 

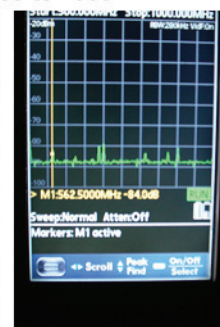


**Test setup:**  
**Current probe on USB cable.**  
**Connection between connector**  
**ground shell and chassis**  
**enclosure made with**  
**screwdriver blade.**

### Looking from 500 to 1000 MHz



Before



After

**Some harmonics dropped by 10-15 dB!**

Figure 13: Cables should be tested individually. Here I have a current probe clamped around the cable under test and am monitoring the harmonics with a simple hand-held spectrum analyzer. As I ground the connector shell to the chassis with the Swiss Army screwdriver blade, the harmonics were reduced considerably!

## NOTES

1. The handheld spectrum analyzer being used is made by Thurlby Thander Instruments ([www.tti-test.com](http://www.tti-test.com)). It sells for approximately \$1,995 (USD) and covers 1 MHz to 2.7 GHz. A complete review of the low-cost Thurlby Thander PSA2701T may be found on the author's Web site, [www.emc-seminars.com](http://www.emc-seminars.com).
2. Probe manufacturers include Fischer Custom Communications ([www.fischercc.com](http://www.fischercc.com)),

Beehive Electronics ([www.beehive-electronics.com](http://www.beehive-electronics.com)), Teseq ([www.teseq.com](http://www.teseq.com)) and many others.

3. I made my own broadband preamp using a MiniCircuits model ZX60-3018G-S, which covers 20 to 3000 MHz at 18-23 dB gain and 2.7 dB noise figure. It sells for \$50. Beehive Electronics also makes a low-cost (\$525) broadband preamplifier that covers 150 kHz to 6 GHz at 30 dB gain and around 5-6 dB noise figure.

### (the author)

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Kenneth Wyatt, Sr. EMC Engineer, Wyatt Technical Services LLC, holds degrees in biology and electronic engineering and has worked as a senior EMC engineer for Hewlett-Packard and Agilent Technologies for 21 years. He also worked as a product development engineer for 10 years at various aerospace firms on projects ranging from DC-DC power converters to RF and microwave systems for shipboard and space systems. A prolific author and presenter, he has written or presented topics including RF amplifier design, RF network analysis software, EMC design of products and use of harmonic comb generators for predicting shielding effectiveness. He has been published in magazines such as, RF Design, Test & Measurement World, Electronic Design, Microwave Journal, Interference Technology, HP Journal and several others.

Kenneth is a senior member of the IEEE and a long time member of the EMC Society where he serves as their official photographer. He is also a member of the dB Society and is a licensed amateur radio operator.

His comprehensive yet practical EMC design, measurement and troubleshooting seminars have been presented across the U.S., Europe and Asia. He currently resides in Colorado and may be contacted at [ken@emc-seminars.com](mailto:ken@emc-seminars.com). His Web site is: [www.emc-seminars.com](http://www.emc-seminars.com).









# The “Core” of Designing for NEBS Compliance

BY DAVE LORUSSO

Most of you know NEBS has something to do with telecommunications. It's true; NEBS has a lot to do with telecommunications. NEBS is the premiere set of documents used to ensure telecommunications equipment perform at their highest level possible.

NEBS stands for “Network Equipment – Building System”. Breaking this down: “Network Equipment” is the hardware (and software?) that constitutes a telecommunications carrier's network. The network could be in a Central Office (CO) or part of an Outside Plant infrastructure. “Building System” emphasizes organization and structure, mainly around a Central Office. NEBS is primarily a series of tests meant to ensure that telecommunications equipment meets a vast array of safety, electromagnetic compatibility, and environmental requirements. NEBS indirectly describes the environment of a typical CO.

So, what is a Central Office environment like?

Typically, a CO is a large unobtrusive, windowless, secure building. There are approximately 35,000 COs in the

United States. There might even be one in your neighborhood. Since the U.S. telecommunications system is more than 100 years old, COs often occupy prime real estate. There are many older COs throughout the country with harsh environments inside. This is why you'll see tough requirements around temperature, humidity, vibration, illumination, fire resistance, and contaminants. Your product must conform to this environment.

Copper pairs from your home or business eventually find their way to a local Central Office building. They enter the CO underground via a cable vault and terminate in a distribution frame. There is a demarcation between Outside Plant (OSP), where the wires come from, and the central office pairs. Since OSP is exposed to many transient events (both destructive and non-destructive), protection must be provided. Typically, this is in the form

of a 5-pin Protector Module. This protection is taken into consideration when lightning and power cross criteria is presented to the copper pairs. Protected central office pairs then find their way to a CO switch that can switch calls locally or to long distance carrier phone offices.

For online virtual and pictorial tours of a CO, go to [www.nebs-faq.com](http://www.nebs-faq.com).

The core NEBS documents are available as a set from Telcordia: FD-NEBS-01, NEBS™ *Physical and Electrical Protection*, and include:

- GR-63-CORE, *NEBS™ Requirements: Physical Protection*
- GR-1089-CORE, *Electromagnetic Compatibility and Electrical Safety – Generic Criteria for Network Telecommunications Equipment*
- SR-3580, *NEBS Criteria Levels*

The above documents will set you back about \$2,500.00... expensive, but worth the investment. You need to understand what service providers require for their networks. But this is just the beginning. There are many more Telcordia documents you need to purchase to get a complete understanding of NEBS.

## GR-63-CORE

According to Telcordia's ROADMAP-TO-NEBS-1, Telcordia GR-63-CORE, *NEBS™ Requirements: Physical Protection*, is considered the "backbone" of the NEBS program and identifies the minimum spatial and environmental criteria for all new

*telecommunications equipment systems used in a telecommunications network. Topics covered include temperature and humidity, fire resistance, spatial and vibration criteria, airborne contaminants, acoustic noise, and illumination.*

Let's look at the spatial criteria. Equipment and cabling must be compatible with the vertical and horizontal space allocations in a Central Office. Floor loading limits must also be taken into consideration since equipment can be mounted on a second floor or above. Section 2 "Spatial Requirements" provides a broad overview of criteria

applicable to frames, distribution and interconnecting frames, dc power plant equipment, and cable distribution systems. Criteria is given right down to the hole pattern used to anchor a frame to the building floor (Figure 1).

An important area to understand is how frames are distributed in a typical Central Office (Figure 2). There is a Maintenance Aisle and a Wiring Aisle. This arrangement allows personnel to operate, maintain, and repair equipment from the front. Cables are in the back running upward to the overhead cable distribution tray. DC power is brought down to the equipment. Equipment is powered by -48 Vdc.

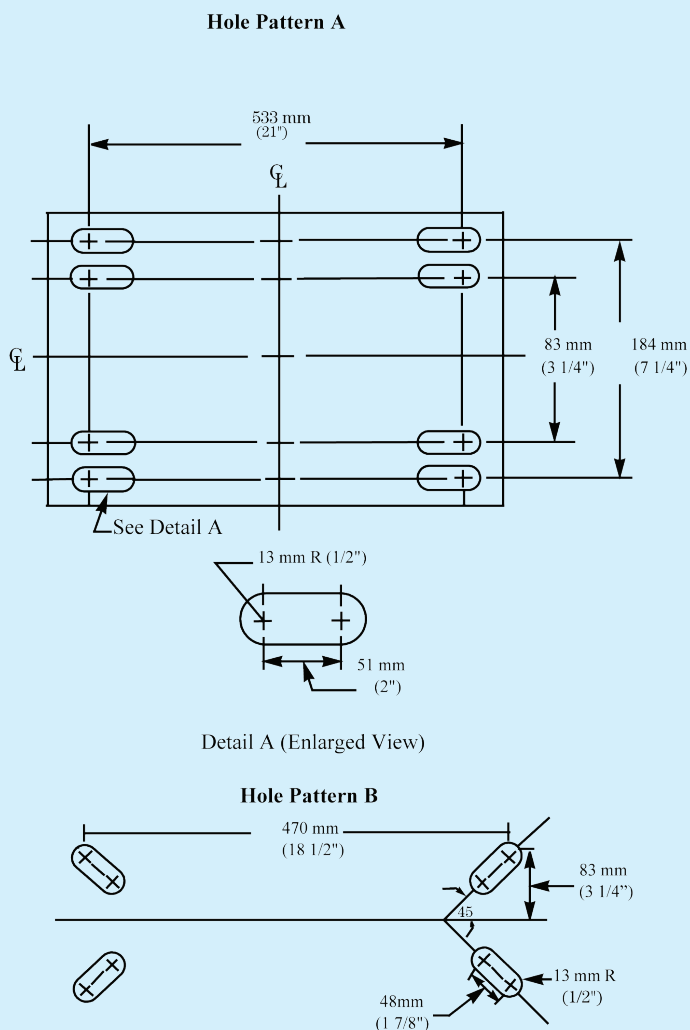
It's also important to understand how a typical central office is cooled. A typical cooling system is all-air usually using central fan rooms, overhead ducts, and diffusers to distribute air. The preferred cooling method for Network Equipment is for air to enter from the lower front and exit through the top rear (Figure 3). This results in a cold aisle (Maintenance) and a hot aisle (Wiring). The air supply to the cold aisle comes from ducting from top down. Hot air recovery from the hot aisle is generally done through ducting on top. GR-3028, "Thermal Management In Telecommunications Central Offices" is the guiding Telcordia document.

Section 4 is the meat of the document. This section addresses environmental criteria in a CO:

- temperature, humidity, and altitude
- fire resistance
- equipment handling
- earthquake, office vibration, and transportation vibration
- airborne contaminants
- acoustic noise
- illumination

Section 5 describes the Environmental Test Methods used to prove that your equipment meets Section 4.

**Figure 2-1 Framework Base (Typical) — Floor Anchoring Hole Pattern**



**Figure 1: From Page 2-2 of GR-63-CORE, Issue 3, March 2006**

All of the environmental criteria above are important, however, there is not enough room in this article to go into detail. Let's look at some key areas.

Temperature, Humidity, and Altitude

Key to this area is the short-term limits, short-term being defined as “a period of not more than 96 consecutive hours and a total of not more than 15 days in 1 year. (This refers to a total of 360 hours in any given year, but no more than 15 occurrences during that 1-year period.)”. That’s four long days of wicked hot temperatures! Your equipment needs to stay operational from -5°C to 50°C (23°F to 122°F) if it’s sold at the frame level or -5°C to 55°C (23°F to 131°F) if it’s a shelf level product.

Fire Resistance

Your product is going to get burned. Let me repeat that. YOUR PRODUCT IS GOING TO GET BURNED. You can’t do a simulation – you have to burn it. This is not the same requirement you see in the 60950 safety standards. In 60950, there is a heavy reliance on the use of a Fire Enclosure to contain fire. You can have a compliant Fire Enclosure designed to 60950 and fail the NEBS Fire Resistance test. Material selection and construction techniques are emphasized in 60950. The risk of ignition is reduced by putting a limit on the maximum temperature of components under normal and single fault conditions; if there is ignition, the spread of flame is reduced by using flame retardant materials or by adequate separation. Using these proven practices will help, but not guarantee passing the NEBS Fire Resistance test. The best way to pass this test is to understand it.

In the early days of NEBS (circa 1985), a 5-3/4 inch diameter by 2-3/8 inch deep pan containing 200 ml of isopropyl alcohol was ignited 2 inches below the bottom of the lowest unit. Fire was not allowed to spread to adjacent equipment assemblies.

Figure 2-2 Typical 6-Lineup Floor Plan for Nominal 300 mm (12-in) Deep Frames

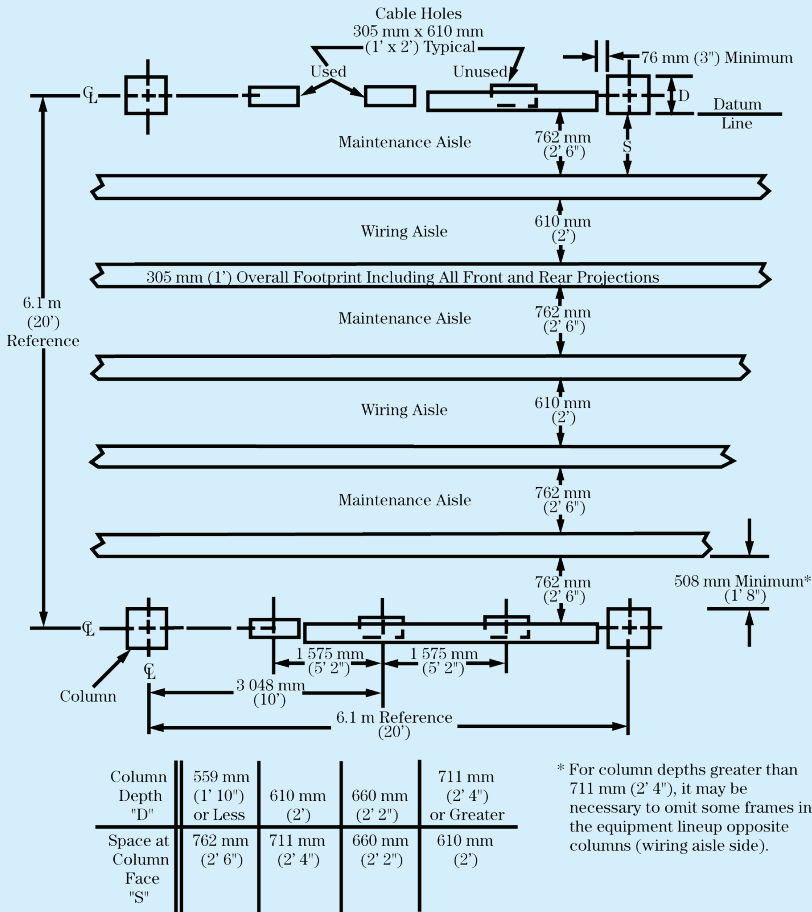


Figure 2: From Page 2-4 of GR-63-CORE, Issue 3, March 2006

Figure 4-2 Profile View of Conforming Equipment Airflow Schemes Dashed Method Is Preferred

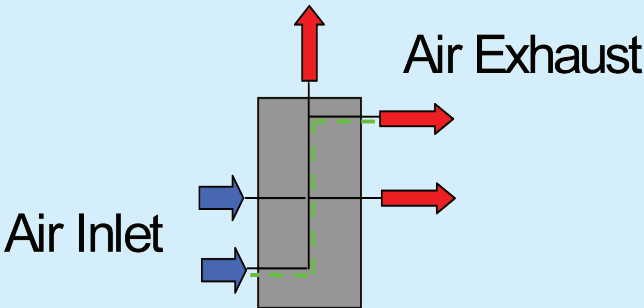


Figure 3: From Page 4-10 of GR-63-CORE, Issue 3, March 2006



#### NOTE:

GR-63-CORE is currently under review with an estimated completion date of December 2011. The new issue will be Issue 4. Some topics being addressed include:

- Spatial objectives with consideration of newer equipment environments, including wireless sites and telecom data centers.
- Evaluation of industry requirements for energy efficiency and thermal management, such as: target heat dissipation values on a per chassis basis, airflow management, cooling efficiency at the rack level, and proprietary requirements for product efficiency and cooling effectiveness.
- Fire spread and fire hazard characterization requirement review.
- Potential reduction of testing cost for some environmental tests, such as the office vibration test.
- Update of hygroscopic dust test method to reflect the latest methods in GR-1274, Generic Requirements for Reliability Qualification Testing of Printed Wiring Assemblies (PWAs) Exposed to Airborne Hygroscopic Dust.

Furthermore, 15 minutes after flame outbreak, a Class 5 B:C portable fire extinguisher must put out the fire. If one fire extinguisher didn't do the job, the number required was recorded. If you used internal fans, you had to do the test twice.

Bellcore Technical Advisory, TA-NWT-000063, Issue 2, December 1992 introduced the currently used methane line burner. The original test was deemed to be severe. The line burner would be based on burning characteristics of typical printed circuit board. Calorimetric techniques would be used to determine the flame size and duration. As time went on, this method also was deemed too severe as it was tougher on smaller line cards and easier on larger ones.

The test now follows ANSI T1.319-2002 "Equipment Assemblies – Fire Propagation Risk Assessment Criteria". A methane line burner (Figure 4) is inserted into the product and allowed to burn for 5½ minutes following a pre-defined gas flow profile. All nearby flammable material is ignited. This is a simplification. There are many variables, including: fuel load, air flow, compartments, fan use, size and shape of printed circuit boards, and exemptions.

Some design guidelines:

- Understand where and what the flames touch.
- Use metal wherever possible.
- Use the least flammable parts throughout.

- Watch out for flame exposure to printed circuit board edges, including daughter and memory cards.
- Watch your airflow. Fan position is key. Keep fans away from sources that may ignite; recess your fans if possible as being too close to the outside edge could result in flaming material leaving the enclosure.

## Earthquake

Will your equipment work after an 8.2 earthquake? Only a seismic test will prove if it does. GR-63-CORE lists five earthquake zones in the continental United States: Zone 0, no ground acceleration, through Zone 4, 0.40g of ground acceleration. California, Nevada, and the junction of Idaho, Montana and Wyoming have the distinction of being in Zone 4. Even though the great majority of products pass this test the first time, it's best to do a thorough review of your mechanical design. Watch especially for cabling prior to the test due to the significant displacement the product will undergo.

## GR-1089-CORE

The title of this Telcordia document is "Electromagnetic Compatibility (EMC) and Electrical Safety". As you can see from the list below, major areas of EMC are covered, as are some obvious and unique safety concerns:

- electrostatic discharge
- electromagnetic interference
- lightning and power fault
- steady-state power induction
- DC potential difference

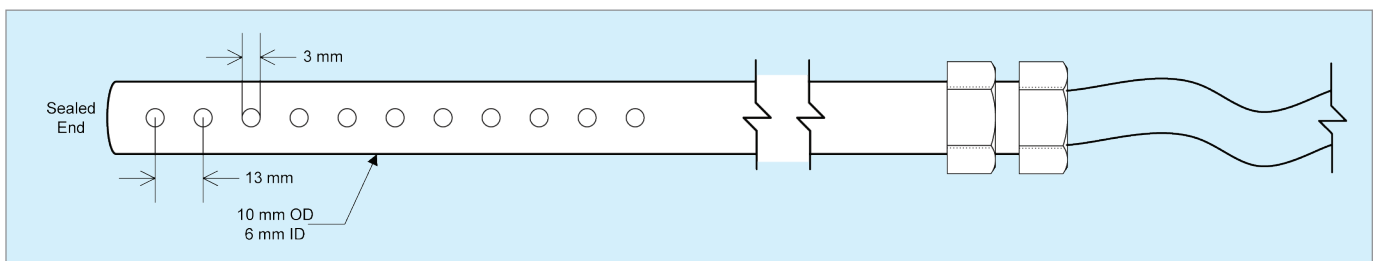


Figure 4

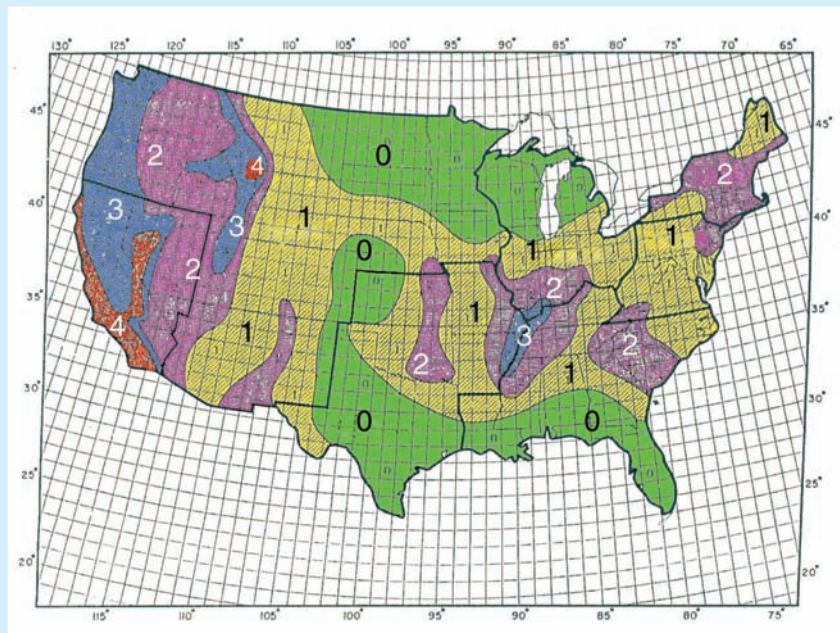
- electrical and optical safety
- corrosion
- bonding and grounding
- DC power port of telecommunications load equipment

Other NEBS related documents include:

- GR-78-CORE, *Generic Requirements for the Physical Design and Manufacture of Telecommunications Products and Equipment*
- GR-3160-CORE, *NEBS™ Requirements for Telecommunications Data Center Equipment and Spaces*
- GR-1217-CORE, *Generic Requirements for Separable Electrical Connectors Used in Telecommunications Hardware*
- GR-468-CORE, *Generic Reliability Assurance Requirements for Optoelectronic Devices Used in Telecommunications Equipment*
- GR-357-CORE, *Generic Requirements for Assuring the Reliability of Components Used in Telecommunications Equipment*
- GR-3028-CORE, *Thermal Management In Telecommunications Central Offices: Thermal GR-3028*
- GR-1221-CORE, *Generic Reliability Assurance Requirements for Passive Optical Components*
- GR-2930-CORE, *Network Equipment Building System NEBS(TM) Raised Floor Generic Requirements for Network and Data Centers*
- GR-2969-CORE, *Generic Requirements for the Design and Manufacture of Short-Life Information Handling Products and Equipment*

There's more to NEBS than physical and electrical protection. Network reliability is key. Emergency phone service depends on it. GR-78-CORE provides guidance on how to design and build reliable products for telecom network use. It applies to design, engineering, manufacturing, and workmanship.

**Figure 4-3 Telcordia Earthquake Zone Map**



**Figure 5: From Page 4-23 of GR-63-CORE, Issue 3, March 2006**

But wait, there's more...

With 35,000 COs scattered across the country and tons of equipment from multiple vendors, order must come from chaos. Yes, another document: GR-485-CORE "COMMON LANGUAGE® Equipment Codes (CLEI™ Codes) – Generic Requirements for Processes Guidelines" (pronounced "klee-i"). CLEI Codes are 10-character, alpha-numeric codes having a one to one relationship with a product's part number. The codes are used to identify network equipment, including field replaceable units (FRUs). The largest carriers use CLEI Codes, and they have been adopted by other worldwide carriers. The use of these codes, in the form of a label on your product, help service providers manage their infrastructure and supply chain. There is a cost associated with each CLEI Code.

Even with high availability (99.999% or "5 nines"), something is going to break. COs tend to be lightly manned

so there has to be a method to notify personnel that there's a problem. Enter alarms. Telcordia document GR-474-CORE "Alarm and Control for Network Elements" provides guidance on network equipment maintenance. Your equipment must have a means of tying into the CO's Operations Center when a failure or transient condition occurs. There must be an indication on your product that there's a problem (local indication), a means must be provided to tie into the audible and visual indications that are available at various locations in the CO, and ultimately, trouble indication must find its way to the Operations Center. Contacts on the product are the typical method of notification.

## TEAMWORK

It is next to impossible for one person to grasp all of these requirements. Expertise is required in many engineering fields: electromagnetic compatibility, product safety, electrical, mechanical, chemical, and reliability.

It takes a team approach to design, test, and qualify a product to NEBS. A good approach is to appoint a NEBS technical lead who has an excellent grasp of the requirements and can manage the program, or hire a NEBS consultant. **IN**

## REFERENCES

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- Lorusso, D., *EMC Pre-testing Simplifies NEBS Compliance*, ITEM Publications' Interference Technology, May, 2008.
- Telcordia ROADMAP-TO-NEBS-1 *Telcordia Roadmap to NEBS™ Documents*.

- GR-63-CORE, *NEBS™ Requirements: Physical Protection*.
- GR-1089-CORE, *Electromagnetic Compatibility and Electrical Safety – Generic Criteria for Network Telecommunications Equipment*.
- SR-3580, *NEBS Criteria Levels*.
- GR-78-CORE, *Generic Requirements for the Physical Design and Manufacture of Telecommunications Products and Equipment*.
- GR-485-CORE, *COMMON LANGUAGE® Equipment Codes (CLEI™ Codes) – Generic Requirements for Processes Guidelines*.
- ANSI T1.319-2002, *Equipment Assemblies – Fire Propagation Risk Assessment Criteria*.
- IEC 60950, *Information Technology Equipment – Safety – Part 1: General Requirements*.

## RESOURCES

- [www.nebs-faq.com](http://www.nebs-faq.com) (Resource for NEBS Compliance information)
- [www.telcordia.com](http://www.telcordia.com) (The creator and keeper of NEBS documents)
- [www.verizonnebs.com](http://www.verizonnebs.com) (Verizon's NEBS Compliance Web Page)

(the author)

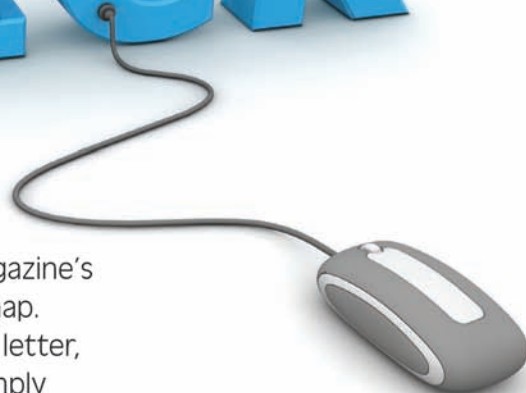
### DAVE LORUSSO

Dave is a regulatory consultant based in Austin, Texas, where he lives with his wife Kathy and their Boston Terrier, Abilene. Dave is an expert in NEBS, Product Safety and EMC. He has published numerous articles on compliance engineering. He can be reached at [dave@lorusso.com](mailto:dave@lorusso.com) or 512-695-5871.



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# Guide to Testing Conducted Emissions Part 2

Based on the methods in EN 55022 and EN 55011

BY KEITH ARMSTRONG

*Editor's note: This is a continuation of "Guide to Testing Conducted Emissions Part 1" which ran in the July 2011 issue of In Compliance Magazine.*

*Authors note: Since this guide was first written, the standard it covers has been updated and some details may have changed. Always use the relevant version of the test standard.*

## THE TEST SITE

Conducted emissions testing may be carried out on an Open Area Test Site (OATS) intended for testing radiated emissions, but it is not necessary to use an OATS and conducted emissions can be tested relatively easily, with high accuracy, in the comfort of your own building.

The test site requirements for conducted emissions are very relaxed compared with the problems of radiated testing, and a simple arrangement of metal plates can be sufficient if the ambient noise of the site is low enough in the frequency range to be measured. Ambient noises can be separated out from the emissions of the EUT by first making a measurement with the EUT switched off – using the peak (PK) detector to save time – then again with the EUT switched on to create a list of 'suspect frequencies' that are known to be caused by the EUT and not by the ambients. Where it is thought that an EUT emission might be lying on top of an ambient, check the reading by "zooming in" the frequency span of the measuring instrument and switching the EUT off and on again. (Figure 1)





Dealing with numbers of ambients can take a lot of time, especially where they change during a measurement. Where noisy ambients are a problem (either conducted via the site's mains supply or radiated) a low-cost screened room with a filtered mains supply can be used. There is no need for any RF absorber (cones or ferrite) in the room to control the room resonances.

for broadcast receivers and lighting equipment, respectively) also require a similar test, although EN 55015 extends the measurement range down to 9 kHz for some apparatus.

To appreciate the constraints on fully compliant conducted emissions tests, it helps to be familiar with the 'test equivalent circuit' shown in Figure 2.

The equivalent circuit shows that stray capacitance between the EUT and the GRP is an important part of the coupling path. The standard test set-up for table-top EUTs in a screened room (as shown by Figure 9 of [1]) and regularizes stray capacitance by insisting on a fixed separation distance between the two; 400mm is the norm, with at least 800mm clearance from

## Virtually all CISPR-based test standards specify limits on conducted emissions of the AC (mains) supply, measured from 150 kHz to 30 MHz.

### FULL COMPLIANCE TESTING

Virtually all CISPR-based test standards specify limits on conducted emissions of the AC (mains) supply, measured from 150 kHz to 30 MHz. The three most commonly referenced standards EN 55011, EN 55014-1 and EN 55022 (based on CISPR 11, CISPR 14-1 and CISPR 22, respectively) all set such limits and their methods are largely common, although there are detailed differences. EN 55013 and EN 55015 (based on CISPR 13 and CISPR 15

This shows that in the mains port test you are measuring a combination of DM and CM sources on each line (L or N) with respect to the ground reference plane (GRP), which is connected to the EUT's 'earth' connections if it has any.

The factors outside the EUT that control the coupling, and hence the measured value, are:

- stray capacitance from EUT to GRP
- RF impedance of the mains cable
- RF impedance of the LISN

all other conducting surfaces. A fully compliant test requires great care in achieving these distances. All test houses have a 800mm high wooden table on which the EUT can be spaced 400mm away from a vertical GRP (or a wall of a screened room). An alternative that is allowed in some standards is a 400mm separation from the bottom of the EUT to a horizontal GRP (the floor of a screened room).

The third important aspect is the impedance introduced by the mains

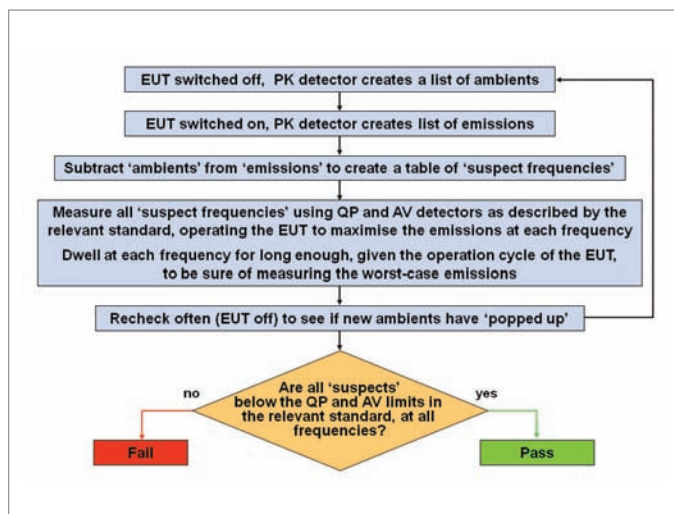


Figure 1: A typical compliance measurement procedure to deal with ambients, for *each* mains conductor

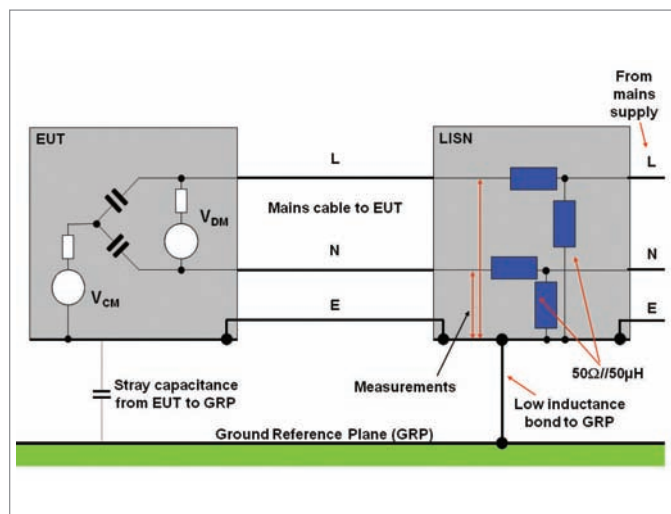


Figure 2: The 'test equivalent circuit' for a conducted emissions test on an equipment's single phase AC mains supply

cable, which can have a significant effect above 15 MHz and so must be controlled. Laying it on the GRP will introduce excess stray capacitance. Coiling extra length will introduce more inductance. Keeping it off the GRP, bundling it if necessary in the way prescribed by the standard, controls both these factors and minimizes the variations introduced by the cable. However, nobody bundles cables exactly the same way, making cable bundling rather hit-and-miss. It is preferable to use a standard unbundled 1m length of cable for these tests, whatever the length that will be supplied with the final product.

All the necessary test set-up details for table-top and other styles of EUT (e.g. floor standing equipment) will be found in the relevant sections of the appropriate test standard. [2] contains some useful detail on performing full compliance conducted emissions tests, especially with regard to the control of test instrumentation (Figure 4).

## ON-SITE TESTING OF SYSTEMS AND INSTALLATIONS

This was discussed in general and from the point of view of radiated emissions

testing in Section 1.11 of [3]. Chapter 10 of [4] is also a useful reference.

Which ground reference to use is a crucial factor when testing on-site. At an EMC test site it is defined by the ground reference plane (GRP, see earlier), but in-situ referencing has to make do with what exists and what can practically be achieved. CISPR 16-2 recommends the following:

The existing ground at the place of installation should be used as reference ground. This should be selected by taking high frequency (RF) criteria into consideration. Generally, this is accomplished by connecting the EUT via wide straps, with a length-to-width ratio not exceeding 3, to structural conductive parts of buildings that are connected to earth ground. These include metallic water pipes, central heating pipes, lightning wires to earth ground, concrete reinforcing steel and steel beams.

In general, the safety and neutral conductors of the power installation are not suitable as reference ground as these may carry extraneous disturbance voltages and can have undefined RF impedances.

If no suitable reference ground is available in the surroundings of the test object or at the place of measurement, sufficiently large conductive structures such as metal foils, metal sheets or wire meshes set up in the proximity can be used as reference ground for measurement.

“Sufficiently large” probably means that the added metal foils, sheets or meshes should underlie the whole of the EUT and spread beyond it for at least half its height, so as to maximize its stray capacitance. But it all depends on what you are trying to achieve – if you are trying to test a product which will be manufactured in volume and sold into other environments, maximizing stray capacitance with metal sheets corresponds more closely to the proper test set-up (see above) and represents a worst-case set-up.

However, if you are measuring the conducted emissions from a custom-made item of apparatus when it is installed at its permanent site, it is then more reasonable to determine whether this single apparatus is compliant as installed by using only the existing bonded metal structures and not add to them (for example, by following the Technical Construction File route for the compliance of a large system).

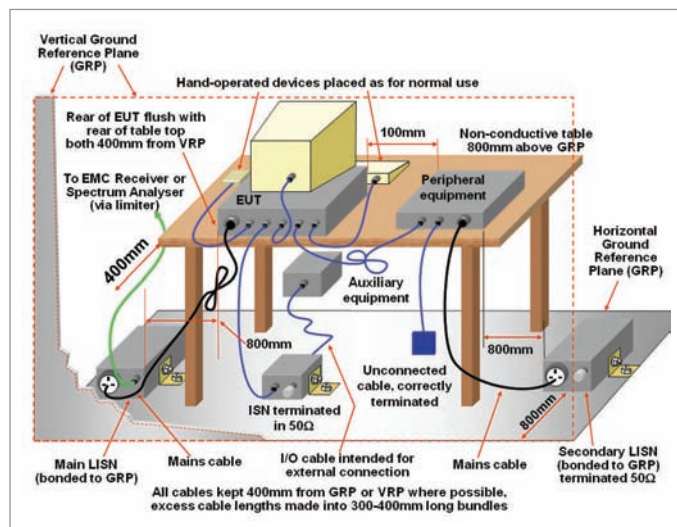


Figure 3: Example of a conducted emissions test setup in a screened room (derived from Figure 9 of [2])

Frequency in MHz	Measured QP signal dBμV	LISN's transducer factor dB	Transient limiter's cal. factor dB	Cable cal. factor dB	Receiver QP cal. factor dB	Final measured QP value dBμV	EN55022 Class B QP limit dBμV	Margin and pass/fail
0.1502	53.9	0.1	10.3	0.01	-0.4	63.91	66	-2.09
0.5374	51.8	0.05	10.1	0.02	-0.6	61.37	56	5.37 fail
4.012	44.6	0.0	10.1	0.1	0.5	55.3	60	-4.7
8.024	46.8	0.0	10.0	0.15	0.7	57.65	60	-2.35
12.036	50.6	0.0	10.0	0.2	0.3	61.1	60	1.1 fail
16.048	53.1	0.0	10.0	0.25	0.2	63.55	60	3.55 fail
20.060	48.9	0.05	10.1	0.3	-0.2	59.15	60	-0.85
24.072	41.5	0.1	10.2	0.35	-0.4	51.75	60	-8.15

The above table is an example of a spreadsheet to calculate the Quasi-Peak (QP) detector measurements for one mains conductor — similar spreadsheets are required for other conductors and to calculate the Average (AV) detector measurements

More sophisticated spectrum analysers or receivers, or their control software, can apply these correction factors automatically (when the calibration data has been entered into their internal memory)

Pass / fail can then be seen immediately from their displays, saving a great deal of time and making diagnostic and QA testing much more intuitive

Figure 4: Example of a spreadsheet used to calculate actual conducted emission in dBμV

Both LISN and voltage probe tests require a reference, which would typically be the boundary of the system where the power supply connects to it – often the terminals of a power outlet or a supply transformer dedicated to the system. Transducer reference connections must be bonded using a very short, wide strap to the chosen reference point – lengths of green-and-yellow wire are not adequate.

The layout of the mains cable should be as close as possible to normal operation during the test and excess cable or coils of cable should be avoided. Whatever the mains cable layout is, it should be fixed for the duration of the tests and drawn (or photographed) for the test report.

Almost no test standards provide adequate guidance for in-situ testing of conducted emissions on the AC (mains) supply, so site-specific test plans have to be developed. Many decisions will have to be taken by EMC engineers on the spot. Some basic practices (which also apply to conducted tests in the laboratory) also apply here:

Take an ambient scan with the EUT switched off. Create a list of ambients. With the EUT switched on and operating, take a peak detector sweep with a reasonably fast scan speed, taking into account the EUT's cycle time, to create a list of significant emission frequencies. Subtract known ambients from this list, leaving a list of 'suspects'.

Test the suspect frequencies individually using the quasi-peak and average detectors as required to make the comparison with the limits in the relevant standard, modifying the EUT's operation to maximize the emissions if this is relevant.

It is a good idea to recheck the ambients from time-to-time during a test to make sure that new ambient sources (such as someone using an electric drill nearby) aren't being mistaken for EUT emissions.

This procedure is repeated for all the mains phases at each location to be measured.

## LOADING, FILTERING AND ISOLATION

When being tested for conducted emissions, the EUT should be operated in its normal manner. Some equipment may require the use of resistive loads to replace auxiliary equipment that it would be impractical to bring to the OATS or other test site.

If you are testing on a site that suffers from high levels of electrical noise in its mains power supply, it may be possible to use filters to help reduce the noise levels. There are a number of issues that will need to be taken into account to suppress the interfering frequencies effectively. Suitable filtering techniques are described in Chapter 8 of [4] and Part 4 of [5].

Mains isolation transformers can sometimes be used to help reduce the electrical noise at an emissions test site by breaking ground current paths. The lower their leakage and the higher their isolation the better (in other words the lower their low primary-to-secondary capacitance).

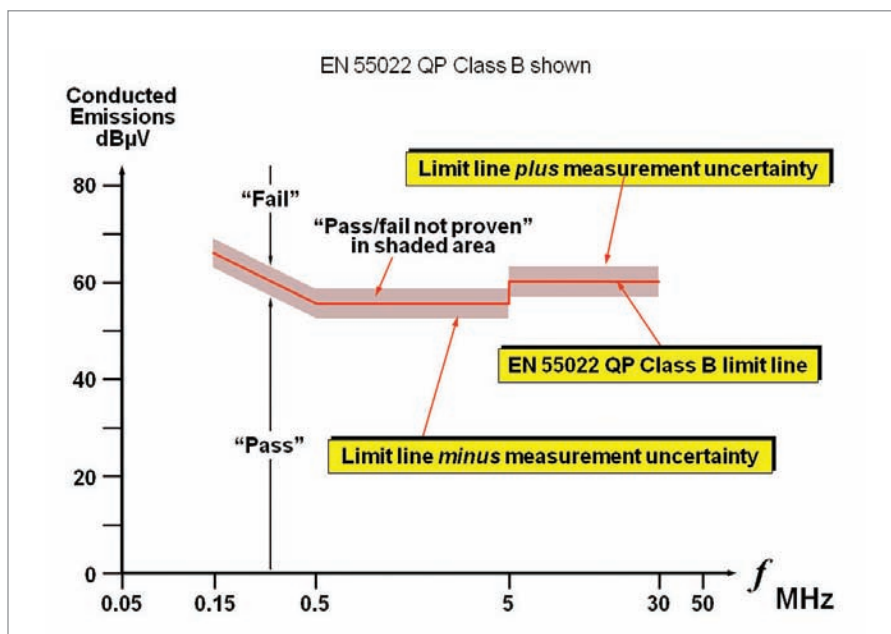


Figure 5: Example of reporting measurement uncertainty

## Important Safety Note:

Always take all safety precautions when working with hazardous voltages, such as 230 V or 400 V (3-phase) electricity. If you are not quite certain about all of these precautions – obtain and follow the guidance of an electrical “health and safety at work” expert. When constructing equipment that employs hazardous voltages, always fully apply the latest versions of the relevant parts of EN 61010-1, at least.



If working on exposed live equipment while performing emissions tests (e.g., when trying to modify an EUT to make it pass the test), an isolating transformer can help reduce electric shock hazards. As before, high-isolation types are the best, also choose transformers that are rated for the likely surge levels (at least 6 kV, using the IEC 61000-4-5 test method) to help ensure safety.

## MEASUREMENT UNCERTAINTY

All measurements suffer from inaccuracies, and EMC measurements are no exception. Accredited test labs in the UK are required to calculate the measurement uncertainty for their conducted emissions tests and make

Only if the emissions were above the upper limit line would the report state “Fail” and only if they were below the lower limit line would the report state “Pass”.

It is very easy to make erroneous emissions measurements, and the process of calculating the measurement uncertainty helps to ensure good quality results (Figure 5).

## LOW-COST AND/OR NON-COMPLIANT TESTING

Testing using alternative methods from those in EN 55022 or EN 55011 cannot give any confidence that “full-compliance” tests for conducted RF emissions would be passed. But such non-compliant tests may be valuable

enough to do accurately even on a purpose-built EMC testing site. So the more money it is desired to save, the greater will be the skill and attention to detail required.

## CORRELATING ALTERNATIVE TEST METHODS

When an alternative conducted RF emissions test method is used for design, development or troubleshooting after a test failure, repeatability is very important (even though correlation with EN 55022 or EN 55011 may not be). All such tests will need to follow a procedure that has been carefully worked out to help ensure that adequate repeatability is achieved.

**It is very easy to make erroneous emissions measurements, and the process of calculating the measurement uncertainty helps to ensure good quality results.**

the result available to customers. The method described by LAB 34 (from the United Kingdom Accreditation Service, UKAS) is suitable for calculating measurement uncertainty. A typical measurement uncertainty for a full compliance conducted emissions test to EN 55022 or EN 55011 would be  $\pm 2.5$  dB.

In the UK it has been the custom for accredited test laboratories to draw lines on either side of the limit line to which the test is being made. The upper line represents the limit line plus the measurement uncertainty, and the lower line the limit line minus the measurement uncertainty. Then, in a test report for a full compliance emissions test, if the emissions fell between the upper and lower limit lines, the report would state “Pass not proven”.

for improving the performance and reliability of a product, and its ability to be used in close proximity to other equipment.

Many equipment rental companies have stocks of the calibrated test gear needed to do conducted RF emissions tests properly, and will rent them out for daily, weekly, or monthly periods. So the easiest way to perform these tests with reasonable accuracy and lowest cost is often to hire the equipment and do the tests yourself.

A comprehensive discussion of low-cost and ‘pre-compliance’ testing methods for conducted emissions can be found in [6]. But always remember that saving money on test labs by doing testing oneself requires skill and attention to detail. RF testing is difficult

When alternative methods are used as part of a QA program or to check variants, upgrades or small modifications, a ‘golden product’ is recommended to act as some sort of ‘calibration’ for the test equipment and test method. Golden product techniques allow low-cost EMC test gear and faster test methods to be used with much more confidence. Refer to Section 1.9 of [3] for a detailed description of how to use the golden product correlation method.

If alternative methods are used to gain sufficient confidence for declaring compliance to the EMC Directive, the golden product method is very strongly recommended. Without a golden product or some similar basis for correlating a full compliance test with the alternative method actually used, the alternative method can only give

any confidence at all by using severely reduced emissions limits, and this can result in very expensive products.

The closer a test method is to using the proper test transducers and methodology in the relevant standards, the more likely it is that a good correlation will be achieved. So-called “pre-compliance” testing should always use the correct test equipment and methods, with the deviations from the full compliance tests not being sufficient to cause significant measurement errors.

## BUYING SECOND-HAND TEST GEAR

Some rental companies sell off their rental equipment after a few years, and second-hand test gear is also available from a number of other sources. An unexpired calibration certificate on a second-hand purchase is well worth having, if only because it makes the possibility of expensive repairs to achieve your first calibration less likely.

When buying second-hand immunity test gear, it is very important indeed to

check that it is capable of testing the versions of the standards that you need to use. Some of the test gear is only available second-hand because it is not capable of performing compliant tests to the latest versions of the relevant immunity standards. Such equipment should cost less than compliant test gear, and may still be useful for preliminary investigations, QA testing, etc.

## EN 55022 AND EN 55011 AND COMPLIANCE WITH THE EMC DIRECTIVE

This handbook is concerned with testing conducted emissions on the AC (mains) supply lead, to the typical domestic/commercial/industrial EN standards over the frequency range of 150 kHz to 30 MHz. Some people will need to measure below 150 kHz or above 30 MHz – for example when measuring equipment to some automotive or military standards.

The radio-frequency (RF) emissions standard for information technology and telecommunications equipment, and business machines is the venerable

CISPR 22 [7], which has been adopted in the European Union (EU) as EN 55022 [1] and listed under the Electromagnetic Compatibility Directive (EMCD) [8]. Although EN 55022 is a product family standard in its own right, its test methods are often called up as a *basic* test method by other emissions standards (generic, product, and product-family) listed under the EMCD, such as the generic emissions standard for residential, commercial and light industrial environments: EN 50081-1 (soon to be made obsolete by EN 61000-6-3).

CISPR 11 [9] is another RF emissions standard, originally developed for industrial, scientific and medical (ISM) equipment that uses RF energy to perform its intended function. It has been adopted in the EU as EN 55011 [10], with some modifications from the original CISPR document, and listed under the EMC Directive. It too has an extra duty as a basic test method for generic, product and product-family emissions standards, such as the generic emissions standard for the industrial environment: EN 50081-2 (soon to be made obsolete by EN 61000-6-4).

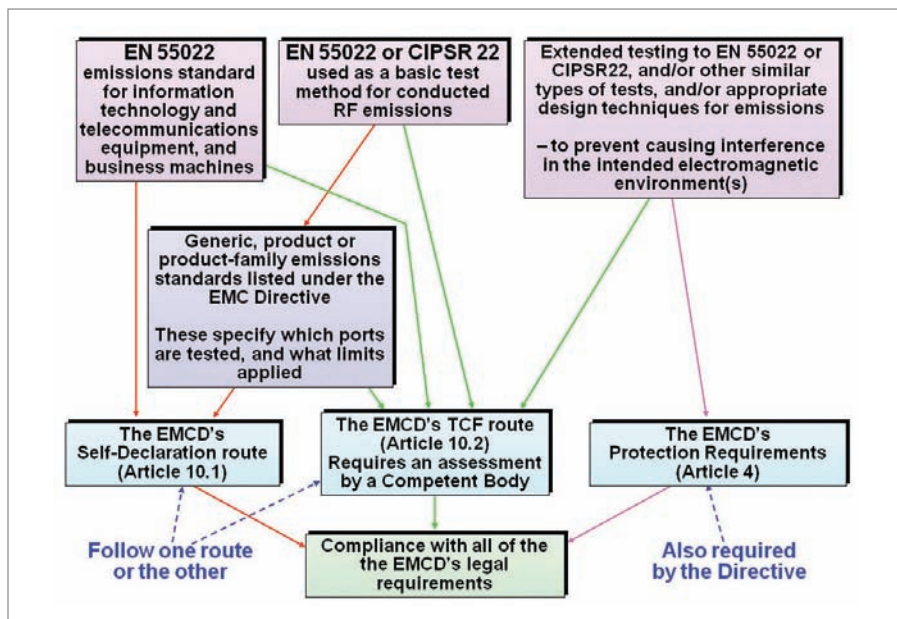


Figure 6: Relationship between EN 55022 and the EMC Directive (EMCD)

When a product-family standard like EN 55022 or EN 55011 is used as a basic test method by other standards, only the actual test methodology and equipment specified in the basic standard is used. The emissions limits and other aspects relevant to the type of product the basic standard was originally written for are not employed.

When complying with the conformity assessment part of the EMCD, you can either follow the “standards route” (Article 10.1 of [8]) or the Technical Construction File (TCF) Route (Article 10.2 of [8]). When EN 55022 and EN 55011 are used for their specified types of equipment, they should be listed on the equipment’s EMC Declaration of Conformity (DoC). But when they are used as basic test methods they should

not be so listed – only the relevant generic, product or product-family harmonized EMC standards (that in turn call up EN 55022 or EN 55011) should be listed.

When using the TCF route, it is possible to use CISPR 22, EN 55022, CISPR 11 or EN 55011 directly, in which case they *should* be listed on the equipment's EMC DoC. In such cases the product manufacturer should assess the electromagnetic environment of the equipment and ensure that it is designed and/or tested so as to comply with the EMC Directive's essential 'Protection Requirements' (Article 4 of [8]).

There may be significant financial or compliance benefits in performing conducted RF emissions tests which go beyond simple compliance with the *minimum* conformity assessment requirements when following the Self-Declaration route under the EMC Directive. This is especially true where sensitive electrical or electronic equipment (e.g., radio or TV receivers, scientific instrumentation, etc.) could be used nearby. The emissions limits in EN 55022 are chosen to protect radio and TV receivers whose antennas are at least 10 meters away from the equipment being tested. Even then, the limits are not low enough to *guarantee* protection. In the case of EN 55011, this 'protection distance' is 30 m.

Many items of equipment are operated closer than 10 (or 30) meters to radio or TV receivers. In such cases, simply complying with the emissions limits in EN 55022 or EN 55011 may not ensure conformity with the EMC Directive's Protection Requirements.

Close proximity to sensitive electrical or electronic equipment is specifically *not* covered by any of the generic, product or product-family immunity standards listed under the EMC Directive. This means that it is up to the manufacturer to assess the electromagnetic (EM) environment

that their product will be used in, and test it accordingly to comply with the EMC Directive's Protection Requirements. How to deal with this issue is described in the later section, "When EN 55022 (or EN 55011) are insufficient in real life".

Compliance with the EMC Protection Requirements is a legal requirement that applies *in addition* to the requirement to follow one of the conformity assessment routes (Self-Declaration, Article 10.1 or TCF, Article 10.2). Products that pass tests to the relevant emissions standard listed under the EMCD, but nevertheless cause interference in normal use because their emissions are too high for their intended real-life EM environment, do not comply with the EMC Directive's Protection Requirements and are therefore illegally CE marked.

Applying emissions tests which go beyond the minimum requirements of the EMC Directive's listed standards (e.g. by extending the tested frequency ranges and/or applying lower limits) can also be a way to improve the

functional performance of equipment, increase customer satisfaction and reduce exposure to product liability claims.

The second edition of the EMC Directive, 2004/108/EC [10], replaces [8] on the 20<sup>th</sup> July 2007. Equipment already being supplied in conformity with 89/336/EEC was allowed to be supplied until 20<sup>th</sup> July 2009, by which date it too must comply with [10] if it is to continue to be supplied in the EU. Whereas [8] requires the involvement of a Competent Body with all TCFs, [10] effectively allows the TCF route to be used with the *optional* involvement of a Notified Body (the new term for Competent Bodies).

Under 2004/108/EC, all 'fixed installations' must comply with the EMC Directive's Essential Requirements and have documentation that shows how this has been achieved. Equipment manufactured specifically for use at a named 'fixed installation' may not have to comply with any EMC requirements at all when it is supplied, but testing to EN 61000-4-27 at specified levels could be one

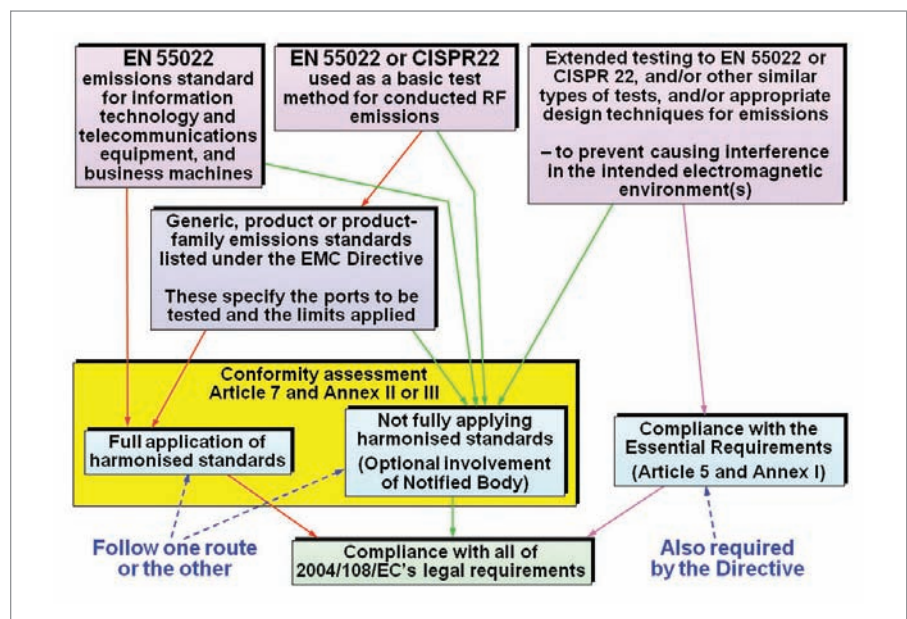


Figure 7: Relationship between EN 55022 and the second edition of the EMC Directive (2004/108/EC)



of the EMC specifications imposed on the supplier by the purchaser to help ensure that a particular 'fixed installation' complies with the Essential Requirements of [10].

This series of handbooks is concerned with testing to the EN standards for typical domestic, commercial, light industrial and industrial environments.

testing in a manner that will also be of use for CISPR 22, EN 55011 and CISPR 11. Details peculiar to EN 55011 testing are not gone into here, and there are a number of modifications to these standards in preparation at the time of writing (especially CISPR 22 and EN 55022) which will also not be described here. It is always best to use the latest version of the test standard,

function, or requires high reliability or is mission-critical, mere compliance with the EMC Directive is often insufficient for ensuring that it has been designed correctly. Additional and/or tougher emissions requirements may need to be applied. Refer to the IEE's guide [11] and the on-line article [12] for more on this.

## Each new version of a CISPR emissions standard includes a date on which it supersedes its previous version.

But other kinds of immunity tests may be required by the EMC standards for automotive, aerospace, rail, marine and military environments. To improve reliability and/or safety, some of these industries have developed their own test standards based on their own particular kinds of EM environments.

This handbook describes, in basic terms, how to apply EN 55022:1994, and describes conducted emissions

except where regulatory requirements for the EU (or elsewhere) specify the version or edition to be used. Since many national tests for RF emissions in countries outside the EU are based on CISPR standards, this handbook may also be of use where non-EU EMC specifications apply.

Where an electronic product could interfere with equipment performing a safety-related or legal metrology

### WHAT TO DO WHEN NEW VERSIONS OF TEST STANDARDS ARE ISSUED

It is clearly impractical for manufacturers to rush to test labs to retest all of their types of equipment on the very day a new version of a test standard is issued, so each new version of a CISPR emissions standard includes a date on which it supersedes its previous version. This is the "date of withdrawal" (DOW), and it provides a transition period during which manufacturers can choose between using the old or the new versions of the standard. After the DOW only the new version should be used. The DOW is preserved in the EN versions of the IEC standards.

Where a generic or product EMC standard uses an emissions standard such as EN 55022 as a basic test method, it will specify either a dated reference (e.g., "EN 55022:1998") or an undated reference (e.g., "EN 55022"). If it specifies a dated reference, then this is the version of the basic test method standard that should be used. If it specifies an undated reference, then the *latest* published version of the standard should be used. The generic and product standards also have DOWs,

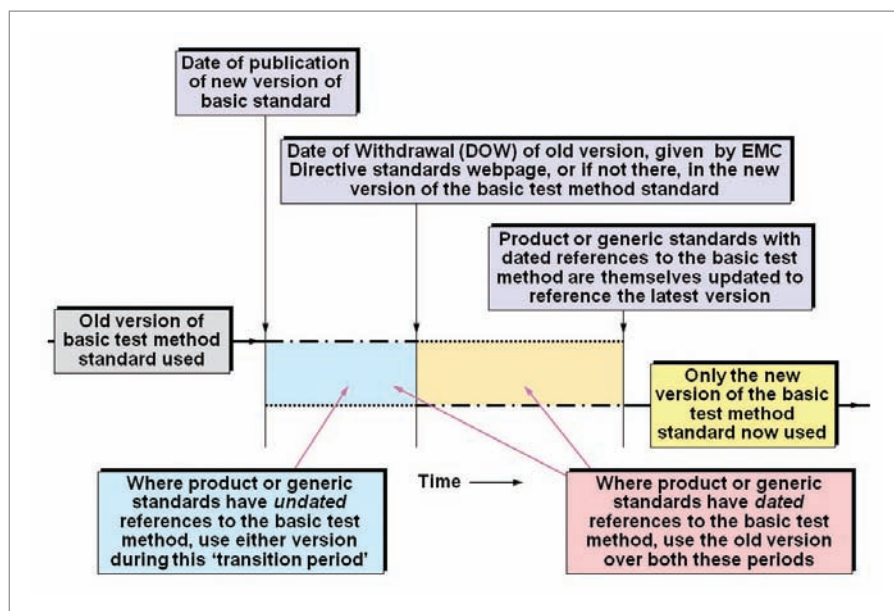


Figure 8: What to do when new versions of standards used as basic test methods are issued



## *Built For Speed.*

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so there is always a transition period before the new version must be used.

But the European Commission (EC) has ruled that, where compliance with an EU Directive is concerned, only the DOW dates that are published in the *Official Journal of the EU* (OJ) have any relevance and not any DOW dates put into standards by their committees. These will often be the same dates, but not always. So it is always best to use the DOW dates published on the Commission's homepage for EMC Directive standards: <http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/emc.html>, instead of the DOW dates published in the standards themselves.

Usually it makes best commercial sense to test new equipment to the latest version of a standard, retesting older equipment when they are due for retesting anyway as a result of a design change or upgrade (as long as this happens before the DOW). Some equipment is sold for such short periods of time that they may never need to be retested to any new versions of standards (Figure 8). 

## REFERENCES

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7. CISPR 22:1993, "*Limits and methods of measurement of radio disturbance characteristics of information technology equipment*" (Note: Amendment A1:1995 and Amendment A2:1996 both apply.)
8. European Union Directive 89/336/EEC (as amended) on Electromagnetic Compatibility. The Directive's official EU homepage includes a downloadable version of the EMC Directive; a table of all the EN standards listed under the Directive; a guidance document on how to apply the Directive; lists of appointed EMC Competent Bodies; and progress on the 2nd Edition EMC Directive; all at: [http://europa.eu.int/comm/enterprise/electr\\_equipment/emc/index.htm](http://europa.eu.int/comm/enterprise/electr_equipment/emc/index.htm).
9. CISPR 11:1997, "*Industrial, scientific and medical (ISM) radiofrequency equipment — Radio disturbance characteristics — Limits and methods of measurement*" (Note: Amendment A1:1999 applies and Amendment A2:2002 is available for use now and must be applied from 1<sup>st</sup> October 2005.)
10. EN 55011:1998, "*Industrial, scientific and medical (ISM) radiofrequency equipment — Radio disturbance characteristics — Limits and methods*"

*of measurement*" (Note: Amendment A1:1999 applies and Amendment A2:2002 is available for use now and must be applied from 1<sup>st</sup> October 2005.)

11. The IEE's 2000 guide: "*EMC & Functional Safety*", can be downloaded as a 'Core' document plus nine 'Industry Annexes' from <http://www.iee.org/Policy/Areas/Emc/index.cfm>. It is recommended that everyone downloads the Core document and at least reads its first few pages. Complying with this IEE guide could reduce exposure to liability claims.
12. "*EMC-related Functional Safety – An Update*", Keith Armstrong, EMC & Compliance Journal, Issue 44, January 2003, pp 24-30, at: <http://www.compliance-club.com/KeithArmstrongPortfolio>.

EN and CISPR standards may be purchased from the British Standards Institution (BSI) at: [orders@bsi-global.com](mailto:orders@bsi-global.com). To enquire about a product or service call BSI Customer Services on +44 (0)20 8996 9001 or e-mail them at [cservices@bsi-global.com](mailto:cservices@bsi-global.com). CISPR standards may be purchased with a credit card from the on-line bookstore at <http://www.iec.ch>, and many of them can be delivered by email within the hour.

## ACKNOWLEDGEMENTS

Some of this material was previously published in 2001-2002 in the *EMC Compliance Journal*'s series "EMC Testing": <http://www.compliance-club.com> or <http://www.compliance-club.com/KeithArmstrongPortfolio>. Many thanks are due to Tim Williams of Elmac Services: <http://www.elmac.co.uk>; [timw@elmac.co.uk](mailto:timw@elmac.co.uk), my co-author for that series.

### (the author)

#### KEITH ARMSTRONG

After working as an electronic designer, then project manager and design department manager, Keith started Cherry Clough Consultants in 1990 to help companies reduce financial risks and project timescales through the use of proven good EMC engineering practices. Over the last 20 years, Keith has presented many papers, demonstrations, and training courses on good EMC engineering techniques and on EMC for Functional Safety, worldwide, and also written very many articles on these topics. He chairs the IET's Working Group on EMC for Functional Safety, and is the UK Government's appointed expert to the IEC committees working on 61000-1-2 (EMC & Functional Safety), 60601-1-2 (EMC for Medical Devices), and 61000-6-7 (Generic standard on EMC & Functional Safety).





## EMC and the Smart Grid

BY MARK MONTROSE

The smart grid is a rapidly emerging topic in the field of electrical and power engineering that affects everyone worldwide. The IEEE is actively engaged in the Smart Grid Form (<http://smartgrid.ieee.org/>).

The grid is an electrical network utilizing digital technology to deliver electricity from suppliers to consumers using two-way digital communications to control everything electrical at consumers' homes or industrial locations. The grid could save energy, reduce costs and increase reliability and transparency if risks inherent in processing massive amount information simultaneously are avoided. This is where compliance engineering may have a higher focus in the future. The "Smart Grid" is being promoted as a way of addressing energy independence, global warming and emergency concerns.


The Internet has made it practical to apply sensing, measurement and control with two-way communications related to electricity production, transmission and distribution all at a high technology level. In the future, generation of electricity will become a major concern for our survival. There may be a shortage of power worldwide if careful management from generation to utilization is not well managed.



The item of concern for engineers both today and in the future is to ensure reliable operation that is free from harmful interference or disruption. There are five major areas of challenge to ensure a reliable Smart Grid system is not disrupted by a transient or terrorist event. As example of a terrorist event is someone using the Internet to shut down the grid's communication systems. The following are opportunities for both safety and EMC engineers worldwide. The concern present is the manner of

testing large scale systems of systems from disruption throughout the frequency spectrum, and where in situ testing is not possible.

- **Integrated communication networks:** Elements of the grid communicating with each other.
- **Sensing and measurements:** Data communication received in the control center.
- **Terrorism:** Intentional or unintentional disruption; terrestrial (lightning), extra-terrestrial (solar flares), physical damage (natural disasters), or cyberspace (hacking into the infrastructure).
- **Using advanced components:** New technology for advanced capabilities.
- **Integrating Broadband Over Powerline (BPL):** Ensuring Wideband Local Area Networks signals present on power lines do not cause EMI to communication services.

With the Smart Grid network, our focus as compliance engineers, both safety and EMC, must be on determining what to work on first; emission or immunity threats, compliance with regulatory standards or electromagnetic compatibility, testing components or finished assemblies, incorporating functional safety, or implementing power saving features. A major concern for the industry is not having knowledgeable safety and EMC engineers to guarantee the grid never goes down. 

(the author)

MARK I. MONTROSE

is an EMC consultant with Montrose Compliance Services, Inc. having 30 years of applied EMC experience. He currently sits on the Board of Directors of the IEEE (Division VI Director) and is a long term past member of the IEEE EMC Society Board of Directors as well as Champion and first President of the IEEE Product Safety Engineering Society. He provides professional consulting and training seminars worldwide and can be reached at [mark@montrosecpliance.com](mailto:mark@montrosecpliance.com).



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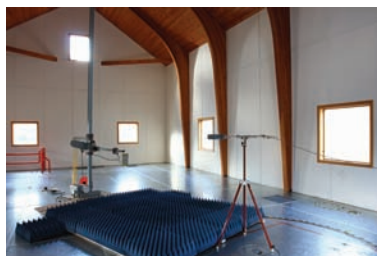
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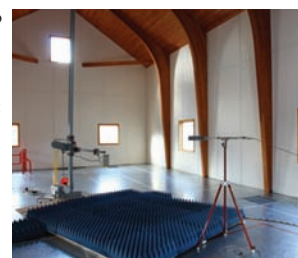
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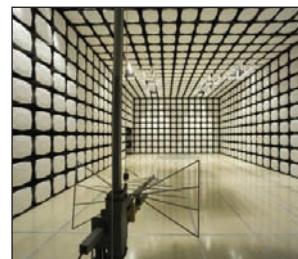
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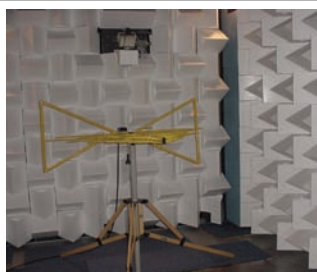


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**KEITH ARMSTRONG**

After working as an electronic designer, then project manager and design department manager, Keith started Cherry Clough Consultants in 1990 to help companies reduce financial risks and project timescales through the use of proven good EMC engineering practices. For Keith's full bio, please see page 68.



**NIELS JONASSEN, MSC, DSC**, worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. Mr. Jonassen passed away in 2006. For Mr. Jonassen's full bio, please see page 23.

**BRIAN LAWRENCE**

began his career in electromagnetics at Plessey Research Labs, designing "Stealth" materials for the British armed services. In 1973 he moved to the USA and established a new manufacturing plant for Plessey to provide these materials to the US Navy. For Brian's full bio, please see page 19.

**DAVE LORUSSO**

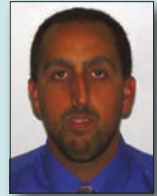
Dave is a regulatory consultant based in Austin, Texas, where he lives with his wife Kathy and their Boston Terrier, Abilene. Dave is an expert in NEBS, Product Safety and EMC. He has published numerous articles on compliance engineering. For Dave's full bio, see pages 25 and 56.

**MARK I. MONTROSE**

is an EMC consultant with Montrose Compliance Services, Inc. having 30 years of applied EMC experience. He currently sits on the Board of Directors of the IEEE (Division VI Director) and is a long term past member of the IEEE EMC Society Board of Directors. For Mark's full bio, please see page 69.

**KEITH SELLERS**

the Managing Scientist at Trace Laboratories, Inc.'s facility in Hunt Valley, MD (ksellers@tracelabs.com), has been with Trace since 1999 and holds a bachelor's degree in Chemical Engineering from the University of Delaware. Keith's primary work is in the areas of contamination and root cause failure analysis. For Keith's full bio, please see page 41.

**KENNETH WYATT**

Kenneth Wyatt, Sr. EMC Engineer, Wyatt Technical Services LLC, holds degrees in biology and electronic engineering and has worked as a senior EMC engineer for Hewlett-Packard and Agilent Technologies for 21 years. He also worked as a product development engineer for 10 years at various aerospace firms. For Ken's full bio, please see page 49.



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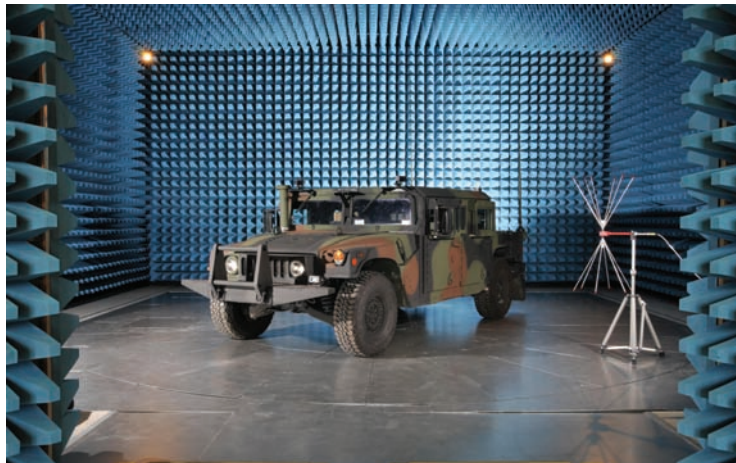
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