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Volume 4 ● Number 6

DEPARTMENTS

FEATURES

News in Compliance

FCC News

Commission Proposes Part 15 Rules for Tank Level Radars

The U.S. Federal Communications Commission (FCC) has proposed changes to its Part 15 rules to accommodate devices used to measure levels of materials and liquids in enclosed tanks.

According to a Further Notice of Proposed Rule Making issued in March 2012, the Commission is seeking to adopt technical rules for the unlicensed operation of so-called level probing radars (LPRs) in a number of different frequencies. LPRs are low-power radars that measure the level of various substances, such as gasoline or oil, in man-made or natural containers. LPRs can also be used in open-air environments to measure levels of materials, such as coal piles or water basin levels.

The Commission believes that the adoption of technical rules would enable LPR devices to continue to operate on an unlicensed basis in the proposed frequency bands without causing harmful interference with other authorized services. Further, the Commission says that the changes would allow for the expanded development of a wider range of radar level-measuring devices, while harmonizing U.S. regulations with those in effect in the European Union.

The complete text of the Commission's Notice of Proposed Rule Making is available at incompliancemag.com/news/1206_01.

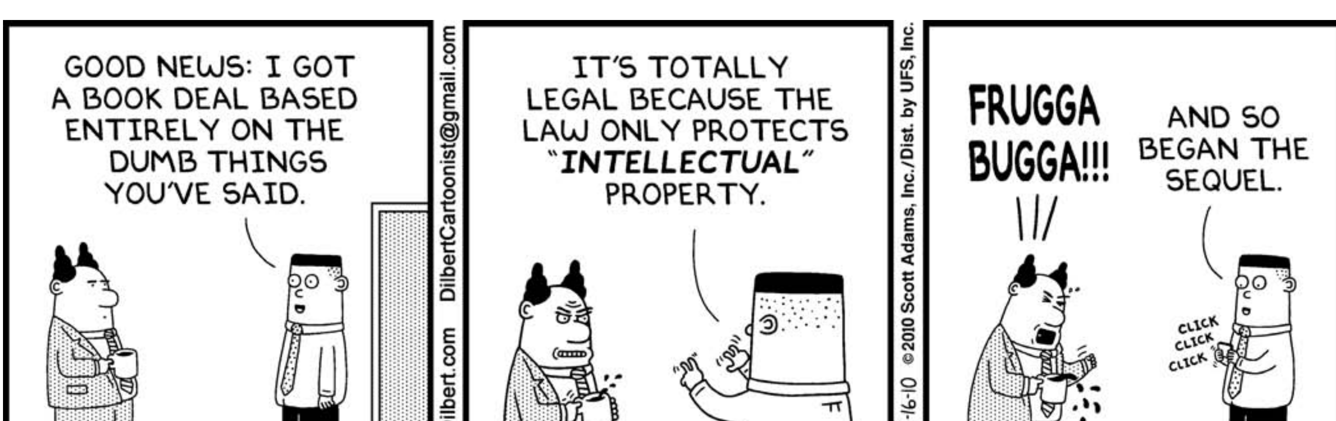
> The FCC has proposed changes to its Part 15 rules to accommodate devices used to measure levels of materials and liquids in enclosed tanks.

Commission Seeks Comment on Emergency Communication by Amateur Radio Operators

The U.S. Federal Communications Commission (FCC) is seeking comments and recommendations on the uses and capabilities of amateur radio operations in emergency situations.

Amateur radio operators have played a vital role in natural disasters, providing a critical communications link for both first responders and victims. Mandated by the recently enacted *Middle Class Tax Relief and Job Creation Act of 2012*, the Commission's research in this area is intended to provide a thorough review of the importance of emergency amateur radio communications, identify recommendations for the enhanced use of amateur radio operators, and determine ways to better integrate amateur radio operators into future Federal emergency response initiatives and programs.

The complete text of the Commission's request for comments on emergency amateur radio communications is available at incompliancemag.com/news/1206_02. Comments are due by May 17, 2012, and the Commission's final report is expected to be submitted to Congress later this year.



FCC News

FCC Adopts Latest Version of HAC Standard

Manufacturers of digital wireless phones seeking certification of their devices for compliance with U.S. hearing aid compatibility (HAC) requirements can now use the measurement and rating procedures contained in the latest version of ANSI C63.19.

In a recently-issued Report and Order, the U.S. Federal Communications Commission (FCC) has authorized the use of ANSI C63.19-2011 *American National Standard for Methods and Measurement of Compatibility between Wireless Communication Devices and Hearing Aids* in applications for certification of equipment.

> Manufacturers of digital wireless phones seeking certification of their devices for compliance with U.S. HAC requirements can now use the measurement and rating procedures contained in the latest version of ANSI C63.19.

Manufacturers can also continue to use the 2007 version of the standard for compatibility testing and for equipment rating. However, they must rely on only one version of the standard, and must identify in their application the version being used. Grants of certification issued before January 1, 2010 under previous versions of ANSI C63.19 remain valid for HAC purposes.

The complete text of the Commission's Third Report and Order on HAC mobile handsets is available at incompliancemag.com/news/1206_03.

News in Compliance

European Union News

EU Commission Revises Standards List for R&TTE Directive

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

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

The extensive list of Cenelec and ETSI standards was published in April 2012 in the *Official Journal of the European Union*, and replaces all previously published standards lists for the Directive. The revised list of standards can be viewed at incompliancemag.com/news/1206_04.

EU Releases Updated Standards List for EMC Directive

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

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

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

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

The complete list of standards can be viewed at incompliancemag.com/news/1206_05.

EU Commission Publishes Standards List for Directives on Pressure Equipment, Pressure Vessels

The Commission of the European Union (EU) has published an updated list of standards that can be used to demonstrate conformity with the essential requirements of its Directive 97/23/EC concerning pressure equipment, also known as the Pressure Equipment Directive (PED).

The PED addresses safety requirements covering the design, manufacture and testing of a range of equipment subject to a pressure hazard. The types of equipment covered under the scope of the Directive include pressurized storage containers, heat exchangers, steam generators, boilers, industrial piping, and other equipment used in the process and energy production industries, and in the supply of utilities, heating, air conditioning and gas storage.

The list of CEN standards, which was published in April 2012 in the *Official Journal of the European Union*, replaces all previously published standards lists for the PED. The complete list of standards can be viewed at incompliancemag.com/news/1206_06.

> The EU Commission has released revised standards lists for the R&TTE Directive, the EMC Directive and the Pressure Equipment Directive. The lists were published in April in the *Official Journal of the European Union.*

When Good Enough Is Not Good Enough

It's a tough, competitive world. If you let your guard down for a second, your competition could knock you out of the game. So you've got to keep finding ways to get better, faster, more accurate. That's the way we think at AR, and that's why our customers welcome our new products and new technologies. We can help you gain a competitive edge with innovations like the following:

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AR can provide an all-in-one test system for any EMC application from DC to 50 GHz. Everything you need is right at your fingertips. Our systems make testing easy, accurate, efficient and affordable.

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News in Compliance

CPSC News

CPSC Says It Has Stopped 650,000 Unsafe Products at the Border

The U.S. Consumer Product Safety Commission (CPSC) says that its enforcement efforts have prevented nearly 650,000 potentially hazardous products from reaching consumers during the last three months of 2011.

Working in conjunction with U.S. Customs and Border Protection agents, CPSC port investigators reportedly screened more than 2900 imported shipments at ports of entry into the U.S. Using various testing methods and equipment, investigators identified about 240 different products that violated mandatory federal standards, consisting of 647,000 individual product units.

Topping the list of seized products were children's products containing lead levels in excess of federal limits, toys with small parts that could present a choking hazard to young children, and toys and childcare articles with banned phthalates. Other seized items included defective hair dryers, lamps and holiday gifts. The majority of seized products originated in China, with a handful of products originating in Mexico and Japan.

An extensive list of the products seized by the CPSC during the fourth quarter of 2011 is available at incompliancemag.com/news/1206_07.

Dishwashers Recalled Due to Fire Hazard

Viking Range Corporation of Greenwood, MS is recalling about 2000 of its Viking-brand dishwashers manufactured in the United States.

The company reports that an electrical component in the dishwasher can overheat, posing a fire hazard to consumers. Viking says that it received 21 reports of incidents related to the recalled dishwashers, including five reports of property damage. However, the company has not received any reports of injuries.

The dishwashers included in this recall were sold at appliance and specialty retail stores nationwide from June 2010 through March 2012 for between $1425 and $2000.

Additional details about this recall are available at incompliancemag.com/news/1206_08.

Adjustable Mattress Bases Recalled Due to Fire Hazard

Leggett & Platt of Georgetown, KY has recalled about 25,000 power foundations or adjustable bases manufactured in the United States for use with sleeping mattresses.

According to the company, electrical components in the motor control board of the bases can fail and short, causing overheating and posing a potential fire hazard to consumers. Leggett & Platt has received 29 complaints of overheating in the electronic motor control board located in a housing underneath the deck of the power foundation, but no reports of injuries or property damage.

The recalled mattress foundations and bases were sold through mattress retailers nationwide from March 2008 through October 2011 for between $1700 and $2200.

More information about this recall is available at incompliancemag.com/news/1206_09.

You Can't Make This Stuff Up

Many U.S. companies often look for foreign markets as a way of boosting sales. But the executives at Kohler, the well-known maker of bathroom plumbing products, probably never anticipated the overseas demand for one of their more unusual offerings.

The *Wall Street Journal* reports that Kohler has hit it big in China with a high-end robotic toilet that retails for about $6400. The Numi-model toilet incorporates motion detectors and a remote control to open and close the toilet seat, and to flush the toilet after use. The Numi also features three separate bidet settings, a built-in stereo system, and (wait for it!) leg-warming porcelain to keep the user warm and comfortable.

The consulting firm McKinsey & Company reports that luxury-good sales to China's emerging upper middle class increased 16% in 2009, and could account for 20% of worldwide sales by 2015. This is good news for Kohler, whose sales in China now account for about half of the company's total revenue. The demand has helped to buoy the prospects for the company, which has reduced its American workforce by nearly a third in recent years.

Kohler reports that the demand for the Numi toilet is so strong that the product is on backorder.

UL Standards Update

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

STANDARDS

UL 299: Dry Chemical Fire Extinguishers
New Edition dated April 13, 2012

UL 1022: Standard for Line Isolation Monitors
New Edition dated April 16, 2012

UL 1066: Standard for Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures
New Edition dated April 13, 2012

UL 1340: Standard for Hoists
New Edition dated April 3, 2012

UL 1681: Standard for Wiring Device Configurations
New Edition dated April 10, 2012

UL 2789: Environmental Claim Validation Procedure for Calculation of Estimated Recyclability Rate
New Edition dated April 19, 2012

UL 2791: Standard for Sustainability for Drain and/or Grease Trap Additives: Biologically-based
New Edition dated April 16, 2012

UL 2792: Standard for Sustainability for Cleaning and Degreasing Compounds: Biologically-based
New Edition dated April 16, 2012

UL 2794: Standard for Sustainability for Disinfectants and Disinfectant Cleaners
New Edition dated March 30, 2012

UL 2795: Standard for Sustainability for Carpet and Upholstery Care Products
New Edition dated April 12, 2012

REVISIONS

UL 50E: Enclosures for Electrical Equipment, Environmental Considerations
Revision dated April 27, 2012

UL 50: Enclosures for Electrical Equipment, Non-Environmental Considerations
Revision dated April 27, 2012

UL 217: Standard for Single and Multiple Station Smoke Alarms
Revision dated April 16, 2012

UL 464: Standard for Audible Signal Appliances
Revision dated April 16, 2012

UL 484: Standard for Room Air Conditioners
Revision dated April 6, 2012

UL 499: Standard for Electric Heating Appliances
Revision dated April 11, 2012

UL 697: Standard for Toy Transformers
Revision dated April 12, 2012

UL 858: Standard for Household Electric Ranges
Revision dated April 18, 2012

UL 1069: Standard for Hospital Signaling and Nurse Call Equipment
Revision dated April 10, 2012

UL 1206: Standard for Electric Commercial Clothes-Washing Equipment
Revision dated April 11, 2012

UL 1323: Standard for Scaffold Hoists
Revision dated April 27, 2012

UL 1412: Standard for Fusing Resistors and Temperature-Limited Resistors for Radio- and Television- Type Appliances
Revision dated April 18, 2012

UL 1626: Standard for Residential Sprinklers for Fire-Protection Service
Revision dated April 12, 2012

UL 1647: Standard for Motor-Operated Massage and Exercise Machines
Revision dated April 25, 2012

UL 1730: Standard for Smoke Detector Monitors and Accessories for Individual Living Units of Multifamily Residences and Hotel/Motel Rooms
Revision dated April 11, 2012

UL 2431: Standard for Durability of Spray-Applied Fire Resistive Materials
Revision dated April 24, 2012

Clarification: In our January 2012 issue, we ran the column "Speaking Out." For clarification purposes, please note that our "Speaking Out" column is a guest column intended to allow members of the Compliance Community the opportunity to voice opinions on current compliance issues.

Well Under Way

BY BRIAN LAWRENCE

The process of merging iNARTE into the RABQSA International organization is now well under way. All new and renewed iNARTE Certificates are now issued under the hands of the RABQSA President, Peter Holtmann and their Certification Chairman, Adam Maxwell. New Certificate recipients will also note the new legend that, ***iNARTE is a brand of RABQSA International***.

The iNARTE office in New Bern, NC will continue to act as the administrative headquarters for iNARTE operations until such time that RABQSA headquarters staff in Milwaukee has completed assimilation of the various iNARTE programs. All iNARTE certificate holders and certification candidates may be assured of continuing service and attention through this transition.

At the final meeting of the iNARTE Board of Directors the motion to dissolve the board and merge the iNARTE operations into RABQSA International was adopted unanimously.

Two members of the iNARTE Board will be elected to serve on the RABQSA board. This selection process is under way. Together with these two elected members, others from the iNARTE board have volunteered to serve on a new iNARTE Advisory Board. The Advisory Board will serve to develop future iNARTE brand strategy for its continuing development and growth at its new home with RABQSA.

Learn more about RABQSA at http://www.rabqsa.com.

The RABQSA 2011Annual Report is available at http://rabqsa.com/docs/rabqsa-annual-report-fy2011.pdf.

SOME NEW EMC CREDENTIALING OPTIONS

This year EMC professionals have several options to validate their engineering excellence through iNARTE certification. Our traditional programs for EMC Engineers and EMC Technicians remain current and very much in demand. However, within the ever expanding field of EMI/EMC influence, certain specialty skills

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Date of Expiration: January 31, 2010

iNARTE
International Association for Radio, Telecommunications and Electromagnetics

finds

Count Alessandro Volta

has demonstrated knowledge, proficiency, expertise and experience in Product Safety Engineering and is hereby certified in this discipline as a fully qualified Product Safety Engineer in accordance with iNARTE administrative rules and guidelines.

Adam Maxwell, Certification Chairman

Peter Holtmann, President, RABQSA International

iNARTE is a brand of RABQSA International

The iNARTE board at their final meeting, from the top left:

Mike Violette, President of Washington Laboratories, Peter Holtmann, President and CEO of RABQSA, Kimball Williams, IEEE SEM Section Chair, Elya Joffe, President IEEE PSES, Lawrence Behr, Chairman of LBA Group, Inc., Richard Georgerian, Senior Member at IEEE, Michael Hayden, President of iNARTE, Inc., Terry Welsher, Senior VP at the ESDA.

iNARTE Informer

have emerged and practitioners in these areas are worthy of recognition. Accordingly, iNARTE has responded and we are pleased to be able to introduce the following programs that are now available, or are in late stages of development such that they will be offered within the next few months:

EMC Design Engineer and Senior EMC Design Engineer

A credential for engineers who work in the design and development phase of electronic system and who are involved in the application of EMC principles to PCB layout and circuit design. At the EMC Design Engineer level, this credential is intended to identify the most able young graduate engineers with little or no work experience who wish to build a career in system design, development and analysis. At the Senior EMC Design Engineer level, a typical candidate would have four or five years of design work experience and would have the capability to direct and train the younger engineers. Both of these credentials are available today and iNARTE is accepting applications and reservations. Later this year we will offer a Master EMC Design Engineer certificate for those gurus of the industry who missed out on the Grandfather program last year but still wish to be recognized.

Many iNARTE certified EMC Engineers are probably now involved in design work and adding this credential at the Senior level will be a validation of your expanded role within the EMC community. Unlike the traditional iNARTE EMC program that requires you to remain current through annual recertification, the EMC Design Engineer and Senior EMC Design Engineer credentials are issued for life and attest to your fundamental knowledge and experience in applying EMC principles in designing for compliance.

MIL-STD Specialist

More than 20 years ago, when the traditional iNARTE EMC certification programs were developed at the instigation of the US Navy, the question pools were largely populated with MIL-STD subject matter. As the requirement for EMC compliance propagated through the commercial sectors, more and more industry specific regulatory standards were introduced and questions related to commercial standards, test facilities and test methodology began to take precedence in the iNARTE question pools. This issue has become so evident today that many engineers and technicians, whose work is primarily in the evaluation of military equipment against MIL STD EMI and EMS requirements, feel that iNARTE EMC certification is no longer applicable to their specialty. Accordingly, we are pleased to introduce this new credential specifically designed for the EMC Technician working in the military sector.

Wireless Device Certification Professional

This new credential is in the final stages of development in cooperation with an international Program Development Committee of device certification experts. The launch date is expected to be in July 2012. The program is intended to validate the special knowledge and experience required of professional engineers and technicians whose work involves the test and evaluation of a wide variety of licensed and unlicensed wireless devices for compliance with international regulatory agency requirements. The program is intended to, “raise the bar”, for wireless device certification by developing an internationally recognized set of criteria for the credentialing of personnel involved in this work. The program is intended to harmonize the understanding of the technical requirements and the process involved to improve the wireless device certification system. Question

QUESTION OF THE MONTH

Last month we asked:

For proper operation, what should the pass band impedance of a low-pass filter be as compared to the impedance of the transmission line into which it is inserted?

A) Substantially higher
B) About the same
C) Substantially lower
D) Twice the transmission-line impedance

The correct answer is B) About the same

This month’s question is:

The skin depth of a metal conductor is defined as ___________.

A) The distance into the conductor at which currents have been attenuated to 1/e of their value at the surface.
B) The distance into the conductor at which currents have been attenuated, by 2.718–1.
C) The distance into the conductor at which currents have been attenuated 1 neper.
D) All of the above
E) None of the above

pools will be directed to FCC and IC requirements but will include optional RTTE questions. In the future other international requirements will be incorporated into the program. iNARTE will be ready to accept applications for credentialing under this new program by June 1st, 2012. Watch for full details to be posted on our web site.

Spectrum Management

This new credential is still in development by our Program Committee. It is targeted for launch in 2012. The program will establish certification criteria for Spectrum Managers and Frequency Coordinators with the intent of developing a uniform level of expertise and quality in the following disciplines:

- Antenna and Radio Wave Propagation
- Basic Spectrum Electronic Principles
- Frequency Licenses and Assignments
- Interference Resolution
- Spectrum Analysis
- Spectrum Certification
- Spectrum Engineering
- Spectrum Monitoring and Compliance
- Spectrum Policy (Rules and Regulations)

(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 Anechoic Chamber product line. As a result of acquisitions Rayproof merged into Lindgren RF Enclosures and later into ETS-Lindgren. Following a career of more than 40 years in the EMC 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 in 2012 merged with RABQSA International, a subsidiary of the American Society for Quality, ASQ. Brian remains associated with RABQSA through this merger process.

Polarization

For Better or Worse

BY NIELS JONASSEN, sponsored by the ESD Association

In a previous article we discussed the phenomenon of induction, that is, the effect of an electric field on a conductor (see Mr. Static in the September 2011 issue). If a conductor is placed in an electric field, charges will move within the conductor until the interior field is zero. If the conductor is grounded, the free induced charge disappears. If the ground connection is broken and the conductor is removed from the field, the conductor will retain a net charge. It has been charged by induction.

INTRODUCTION

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

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

~ The ESD Association

Now suppose that the material placed in the electric field is an insulator. This being the case, the above processes cannot take place because of the absence of mobile charge carriers. But the field may disturb the otherwise symmetrical distribution of positive and negative charges in the molecular structure of the insulator. Where this slight relative shift of electrons and nuclei is created in an electric field we have an effect called polarization.

But before we begin explaining what polarization is, we should touch briefly upon what it means to compliance engineers and other electronics industry professionals. And its meaning is twofold. For polarization can be not only beneficial, making it possible to increase the capacitance of capacitors, but also detrimental, causing plateout to occur on all types of surfaces in an electric field, for instance on wafers in cleanrooms.

EXAMPLES

Figure 1 shows an atom in a field-free region. The time-mean distribution of the atom's charges is symmetrical, so that there is no external field. The atom is neutral. If an electric field E is applied (Figure 2), the symmetry will be disturbed. The electrons, or rather the center of distribution of the electrons, will be displaced in the opposite direction of the field. For some materials, the nucleus may shift its position in the direction of the field.

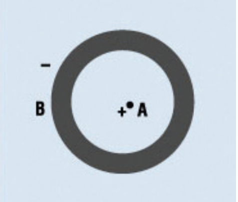


Figure 1: Atom in field-free region with nucleus (A) and symmetrical electron cloud (B).

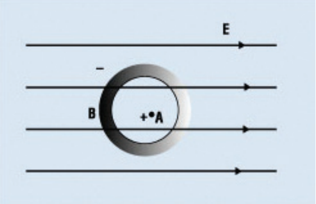


Figure 2: Atom in electric field (E) with nucleus (A) and asymmetrical electron cloud (B).

The situation shown in Figure 2 may be represented by a negative charge and a positive charge separated by a distance dependent on the field strength Figure 3). This is called an electrical dipole, and such dipoles are formed throughout the insulator, hence the name polarization.

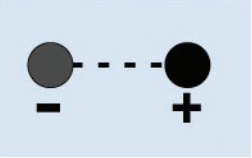


Figure 3: Electrical dipole.

An insulator in which dipoles may be formed is often called a dielectric. The dipoles line up end to end along the field lines. If the field is rectilinear, we can imagine a situation like the one shown in Figure 4. The internal positive and negative charges cancel each other, and the dipole string acts like one long dipole (Figure 5). So what will these polarization dipoles do to the field inside the dielectric? Let's answer this question in two steps.

A conductor "A" placed in an electric field with the strength E_0 is shown in Figure 6. The field binds (in this case) a negative charge on the left side (i.e., the bound induced charge) and frees an equally large positive charge on the right side (i.e., the free induced charge). Thus, the total field inside the conductor is zero. The free charge may be removed if the conductor is grounded. (An explanation of this situation was given in the article on induction in the September 2011 issue). If, however, the body A is a dielectric, the situation is different (see Figure 7). The external field E_0 causes polarization, that is, it forms dipole strings. These strings will be stacked on top of each

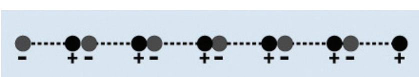


Figure 4: Dipole string.

Figure 5: Simplified dipole string.

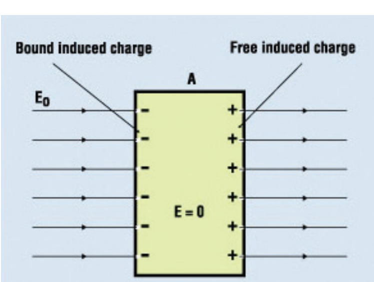


Figure 6: Conductor in electric field (induction).

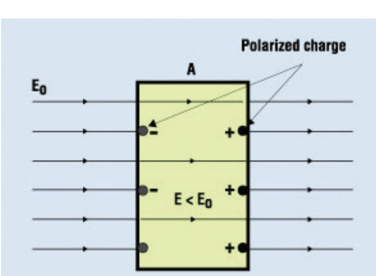


Figure 7: Dielectric in electric field (polarization).

The charges of the dipoles are called polarized charges. In contrast to induced charges, polarized charges cannot be removed from the dielectric.

other, creating a dipole field E_p in the opposite direction of and superimposed on E_0.

The resulting field

$$E = E_0 - E_p$$

is smaller than E_0, and it turns out that

$$\frac{E_0}{E} = \varepsilon_r$$

is a constant characteristic for the dielectric in question. The value ε_r is called the relative permittivity or dielectric constant. Many commonly used dielectrics have ε_r values from 2 to 7. The charges of the dipoles are called polarized charges. In contrast to induced charges, polarized charges cannot be removed from the dielectric. The situation shown in Figure 7 is the simplest possible, with the external field being homogeneous and the field lines being perpendicular to the sides of the dielectric. If the field lines are not perpendicular to the sides of the dielectric, E_0 and E will not be parallel. In such a case, a "refraction" happens at the interface, and we have a parallel to Snell's law of optical refraction, where the optical refractive indices are substituted by the relative permittivities.

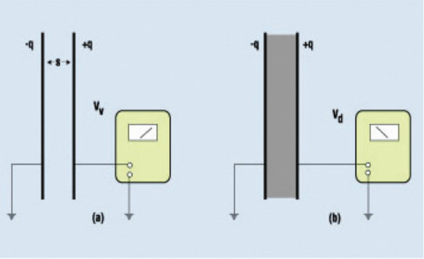


Figure 8: A parallel-plate capacitor connected to an electrometer.

Let's consider two practical effects of polarization.

Effect on Capacitance. Figure 8a shows a parallel-plate capacitor connected to an electrometer. The assumption is that the capacitance of the electrometer is negligible compared with that of the parallel-plate capacitor. There is air (or vacuum) between the capacitor plates. The system is charged with a charge *q*, and a voltage V_v is displayed on the electrometer. When the space between the capacitor plates is filled with a dielectric (Figure 8b) the voltage drops to V_d. As previously explained, the field strength in the dielectric will be $\boldsymbol{\varepsilon}_r$ times smaller than it was in air, and because the voltage difference across the capacitor is the field strength times the plate spacing, *s*, we have the following:

$$\varepsilon_r = \frac{E_v}{E_d} = \frac{E_v \cdot s}{E_d \cdot s} = \frac{V_v}{V_d} \ .$$

And, since the charge *q* is the same in the two situations,

$$C_d = \varepsilon_r \cdot C_v.$$

The capacitance thus increased by the factor $\boldsymbol{\varepsilon}_r$ when the interspace was filled by the dielectric. Using a dielectric in a capacitor has another advantage—an increase in the breakdown voltage. This occurs because the breakdown field strength of a dielectric is usually considerably higher than that of air.

Polarization Plateout. Figure 9 shows an airborne, insulative (dielectric) particle P in an inhomogeneous field E. The field polarizes the particle.

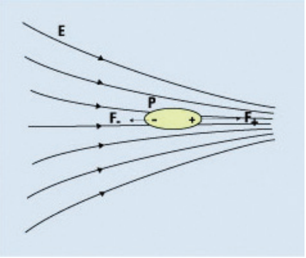


Figure 9: Polarization plateout.

The positive and negative polarized charges have the same numerical value, but because the field strength is higher at the positive end than at the negative one, the positive force F_+ will be stronger than the negative force F_-. The result is a net force

$$F = F_+ - F_-$$

in the direction of increasing field strength. The uncharged particle tends to move in an inhomogeneous field and eventually lands or plates out on the first solid or liquid surface intersecting the field lines. (It should be noted that if the particle P is conductive, induction will make it behave in a similar way.)

Suppose we have a positively charged surface, for instance, a sheet of plastic. The sheet will obviously attract negatively charged, airborne particles and reject the positive ones, but what may be just as relevant is that it definitely will also make the neutral particles move, not necessarily toward the charged surface, but always

Let's finish this by looking at another well-known example of polarization plateout—the field in front of a monitor or TV screen.

in the direction of increasing field strength. An important example of this is the occurrence of static charges in cleanrooms. Although the air is clean, there are always some airborne particles around. For example, if a wafer carrier has a charge, it may cause, by polarization plateout, some of the particles to land on the wafer surface with very unwanted results, at worst a ruined wafer.

Let's finish this by looking at another well-known example of polarization plateout—the field in front of a monitor or TV screen. The field (created by the electrodes in the tube) is strongest at the surface of the screen, so the particles plate out there.

Now if a viewer faces the front of the screen, he or she will be virtually at ground potential, so the field lines will converge toward his or her face, especially around the nose and chin, and possibly around the ears. These areas are now the primary sites of plateout. It has been demonstrated that the plateout rate of airborne particles to the viewer's face is much higher in the situation just discussed than when the viewer is in a field-free region. It has also been suggested that this effect could be the cause of skin diseases and other ailments contracted in the presence of airborne allergens. This claim, however, does not seem to have been scientifically proven.

CONCLUSION

The purpose of this article has been to give an idea of some of the basic features of the phenomenon of polarization. It should be stressed, however, that the presentation is far from complete. A thorough treatment would have resulted in a much longer paper with an exercise in atomic physics and higher mathematics that probably would have scared some readers away.

(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.

From IEC to ISO

BY GEOFFREY PECKHAM

In this column, we'll explore how symbols migrate from IEC standards into ISO standards – and the importance of standardization.

To better specify the safety labels you use on your products, it's helpful to understand the history behind how the safety symbols came to look the way they do. Why does a symbol have a certain proportion, shape, and size and why are these important to achieving universal understanding?

To begin with, let's start with who is responsible for standardization. When it comes to the standardization of symbols, the two key global groups are the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). Breaking it down further, among these groups, there are two highly active technical committees: ISO/TC 145 and IEC SC3C.

IEC and ISO cooperate closely, and even develop standards jointly. But, where do their separate areas of responsibility lie? ISO/TC 145 covers the standardization of public information symbols, non-electrical function and control symbols and all safety symbols, each category of symbols having its own standard. On the other side of the aisle, IEC SC3C standardizes function and control symbols for only electrotechnologies, collecting these symbols in a single standard titled, IEC 60417 *Graphical symbols for use on equipment*.

What has to be clearly understood is that the IEC does not have responsibility for the development of *safety* symbols – the symbols intended to communicate a safety message in graphic form. That area of responsibility lies with ISO and falls within the scope of ISO/TC 145's subcommittee 2.

Now to see how this works. The world needs a standardized, uniform safety symbol for people to easily recognize that an electrical hazard exists. So what happens? Is this a stalemate between standards because IEC is in charge of electrical symbols and ISO is in charge of safety symbols? No. Why? Because IEC and ISO can work together, allowing what is accomplished in one group to "migrate" to become something new in the other.

In the case of visually defining electrical hazards, the electrical hazard lightning bolt symbol was first standardized by

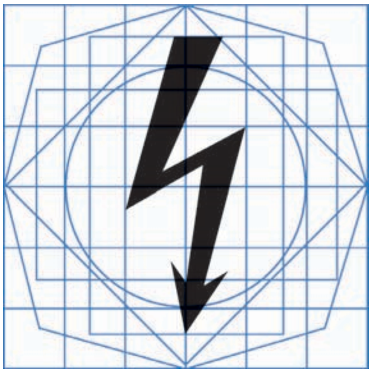


Figure 1: IEC 60417 symbol no. 5036 (shown on a drawing template) meaning "Dangerous voltage".

Figure 2: ISO 7010 symbol no. W012 meaning "Warning; electricity".

Figure 3: Four examples of ISO safety symbols.

IEC for use on function and controls, such as buttons, to indicate "dangerous voltage." (See Figure 1). To create the definitive ISO electrical hazard safety symbol, ISO/TC 145, in its wisdom, picked up this IEC symbol verbatim and placed it inside the ISO standardized colored surround shape for a "warning" safety sign. The result, published in *ISO 7010 Graphical symbols, registered safety signs,* is the world's standardized safety symbol for "Warning; electricity." (See Figure 2).

There's a science to creating icons that are intended to communicate their message. Exactness is critical and it's achieved by following prescribed drawing methods. IEC SC3C and ISO/TC 145 both use carefully constructed design templates to ensure that standardized symbols are consistently drawn. Visual weight, placement within the template, and line widths are taken into account to ensure symbols have a high degree of legibility. And legibility is important because this is what allows people to see, differentiate and discern visual elements. Without it, the next step, comprehension, cannot occur.

Uniformly applying best practice design principles that yield perceivable graphical symbols is what this is all about. Figure 3 illustrates how four different symbols share a consistency in their design; the "weight" of the black graphical symbols inside their triangles is similar; the amount of referential color (yellow) that remains is close, and there is a balance to the position of each of the symbols within their triangular frame.

Why is exactness in the development and use of internationally standardized symbols so important? Because when you, as a product design engineer, specify the use of these symbols on your products' safety signs and labels, your goal is to achieve instant recognition. You don't want people to have to "decipher" the sign (Figure 4). Uniformity in graphical symbol design brings clarity to communication. And when it comes to safety signs and labels, there is no more critical place where you need to achieve clear, concise communication. Anything less could cost lives.

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

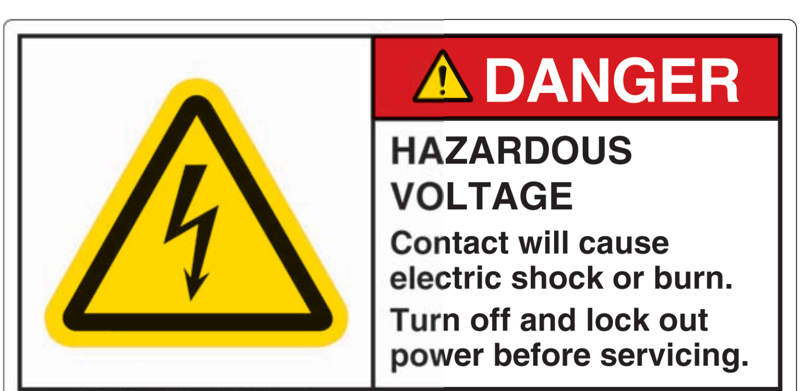


Figure 4: A typical product safety label, courtesy of Clarion Safety Systems © 2012, incorporating the ISO electrical hazard safety symbol.

(the author)

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

MYTH vs. Reality

Common-mode Field Transfer

Coupling Between Circuit Boards and Conductive Chassis Structures

BY W. MICHAEL KING

The myth: Digital (high frequency spectra) circuit boards can be isolated from chassis structures.

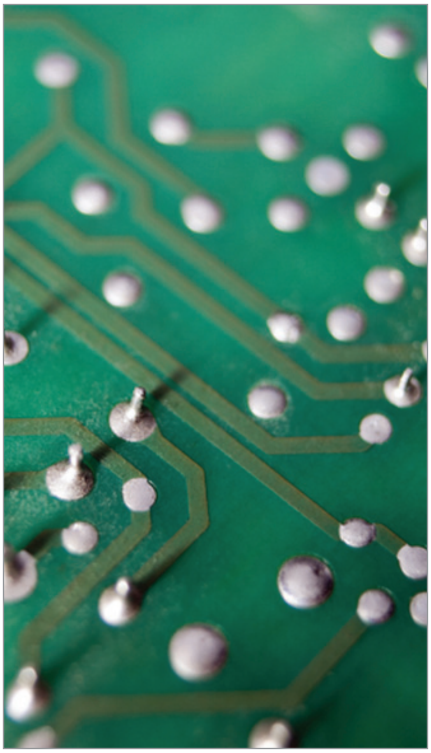
The reality: Digital (and all high-speed, high-frequency spectra) circuit board are *always* coupled to chassis!

Of all the "myths" and "realities" in the description of systems and system-product implementation, possibly the most controversial (and least understood) is founded on the topic of the isolation versus grounding of circuit boards with respect to conductive chassis structures. Once the topic is opened, the controversy quickly moves from grounding as single-point versus multi-point. Since the concept originates with the field-transfer (coupling) relationships between circuit board and chassis, that is an appropriate place to start examining the controversies and their related processes.

When a circuit board is positioned above a conductive chassis structure, an immediate form of coupling occurs: distributed capacitance. The magnitude of the capacitance is determined by the surface area of the circuit board over the chassis plane and the distance of separation between the two structures. Since distributed capacitance is simply the dimensional relationships between these structures (board and chassis), one fact is inescapable: *the boards are coupled to the chassis!* This observation moves the discussion quickly from the fact of coupling, to the magnitude of coupling and the performance significance of that magnitude.
Due at the minimum to distributed capacitance, another inescapable fact appears: *at higher frequency spectra, there is no such thing as a circuit board that is truly isolated from conductive chassis structures!* Note that distributed capacitance values as small as 10 pico farads will yield coupling transfers in the region of a few tens of ohms in the spectra from approximately 300 MHz and higher.

Viewing the detail of circuit board construction, a sequence of patterned layout inductance is established by layout details, including routing patterns and "Swiss-cheese" through the ground and power planes. The routing patterns and "Swiss-cheese" effect setup a form of distributed inductance. When common-mode electrical currents are impressed across these holes and patterns, electrical potentials occur as a sequence of losses. These potentials are the beginning of electromagnetic waves and their related impedances. In effect, a distributed transmission line process is immediately formed with inductance patterned in the circuit board and distributed capacitance between the board and any conductive chassis plane. All transmission lines, distributed or intentional, are characterized with some value of impedance.

If electrical potentials are formed across the board and if these 'find' the impedance of distributed capacitance, electrical currents will be displaced



through the impedance set up by distributed capacitance. Note that the currents formed are developed across relatively low impedance values of distributed capacitance. Since the impedance of any electromagnetic wave at any point is equal to the value of the E-field intensity (in volts/meter) divided by the current of H-field intensity (in amperes/meter), the coupling between the circuit board and the chassis immediately becomes a spectral electromagnetic field by nature and structure.

When viewed as an impedance formed through a distributed transmission line coupled process or considered as an electromagnetic wave transfer function, circuit boards are indeed coupled to chassis planes. In terms of approximate magnitude for consideration, note that near fields (close to sources at, for example, 0.5 centimeters) with magnetic field dominance (described by sources that have low impedance and high current) will propagate in impedances below 40 ohms at frequencies below 1 GHz. These same conditions will exhibit electromagnetic field transfers below 20 ohm at frequencies below approximately 500 MHz. In light of this observation, the discussion can expand beyond the fact of coupling, to focus instead on the design consequences of that coupling. IN

(the author)

W. MICHAEL KING

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

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

Technology Advancements in Board Level Shields for EMI Mitigation

Not your daddy's metal can

BY GARY FENICAL AND PAUL CROTTY

PC BOARD EMI

If properly done, PC board (PCB) design control techniques can be the most cost effective means of resolving EMI issues. The techniques involve:

- partitioning
- board stack-up
- use of isolating lines
- routing
- board level shields

Other techniques involving additional component costs include high frequency grounding of the board and filtering techniques. It is important to mention that if these techniques are designed in at the initial stage, there will be minimal impact to schedule and cost. Correct techniques begin with component placement. Critical circuits (i.e. clock circuits, clock driver, etc.) and functions should be grouped together, providing the shortest trace lengths between components.

Engineers should consider the use of multi-layer boards, having many ground planes, designing high-speed traces (such as transmission lines), and employing proper and adequate filtering and decoupling components. In addition, designers should add placements for filtering components, but place jumpers or "zero-ohm resistors" to hold them in place and only add the real components if required to by the test. Early board prototype testing can produce useful insight into potential problem areas. Board areas with high radiation and the measuring of interconnect cable noise currents are indicators of potential system radiation sources.

Both radiated noise and conducted noise can be a problem in these systems. For conducted noise issues, the use of ferrite chokes and proper signal line layout can prevent a host of issues when considered in the design phase rather than later on.

It is a well-known fact in the EMC community that the closer you are to the source of an EMI problem, the more efficient and less expensive it is to fix. One cannot get any closer than by using a board level shield (BLS). Having stated that, it is important to mention that there is no substitute for proper circuit design and layout.

Looking at a basic formula for RF emissions:

$E = 1.316\ AIF^2/(DS)$

where:

E = microvolts / meter
A = radiating loop area in cm^2
I = current in amps
F = frequency in MHz
D = measurement distance in meters
S = shielding effectiveness ratio

Let's examine the formula and break it down to better understand it. First we will eliminate 1.316 as it is a constant. D is the measurement distance specified by the standard to which you are testing. D can also represent the distance from the device to an object with which it may interfere. In any case, these are factors beyond the control of the device designer. If we further examine this formula, we see that emissions (E) increase linearly with current and loop area but increases exponentially with frequency. We see that it is extremely important to keep loop area as small as possible, especially for high current and/or high frequency circuits. We have seen over many decades that the most common cause of failure is caused by excessive loop area. Whether the excessive loop areas are caused by poor layout or by the offensive signal coupling into other circuits with large loop areas, the result is the same; failure to meet your mandatory emissions requirements. PCB layout software that does not include EMC software will generally not consider loop area. Therefore, the designer must take control and lay out high current and high frequency circuits manually to be sure to minimize loop area. Of course, if you cover the entire loop area with a shield, there is no loop area exposed and that value goes to zero. Again, keeping the loop area as small as possible allows for the smallest possible shield.

Going back to the formula we see that one term has not been addressed, S. S is for shielding. Once the designer has chosen the circuit components, which will determine the frequency and current, and has reduced the loop area to the smallest possible geometry, if the device does not meet its requirements, there is only one thing left to do. Shielding! Looking tot the opening statement of the article, the closer this shielding design is to the problem, the better. Allowing for proper BLS mounting must be done at the PCB design stage. It is essentially impossible to properly mount a BLS after the board has been laid out.

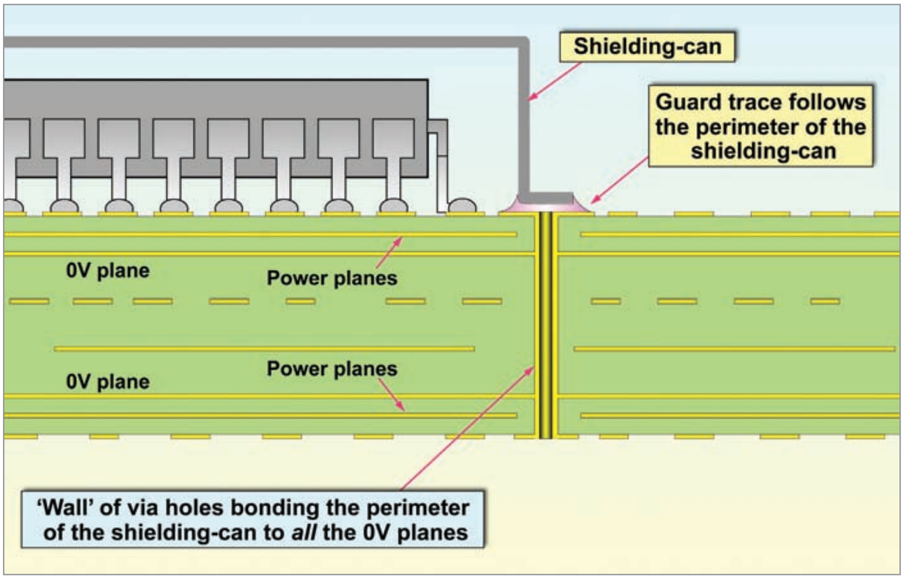


Figure 1: Section through one of the perimeter via holes (Courtesy of Eur Ing Keith Armstrong C.Eng MIEE MIEEE, Cherry Clough Consultants)

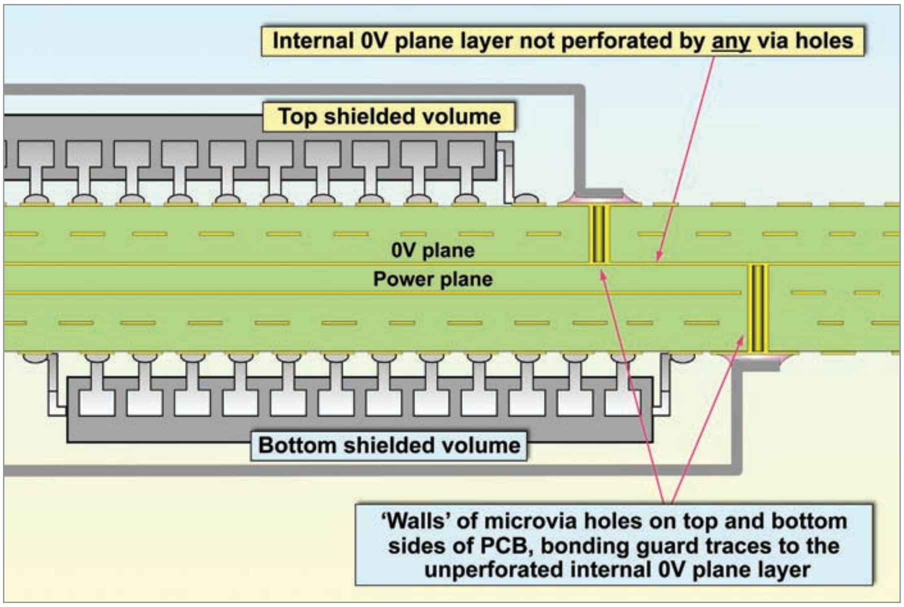


Figure 2: Courtesy of Eur Ing Keith Armstrong C.Eng MIEE MIEEE, Cherry Clough Consultants

Consider this; the BLS supplier only provides 5 sides of the required 6-sided Faraday cage you are attempting to build. It is up to the PCB designer to build into the PCB the sixth side, usually an imbedded ground plane. The designer must also provide properly spaced mounting pads, as well as determine if through-hole or surface mounted methods will be used. Although BLS parts are needed to manage EMI requirements for both immunity (for product performance) and regulatory needs (FCC, EU etc.), the board shield design is usually not the only factor in EMI performance. As mentioned, the sixth side of the

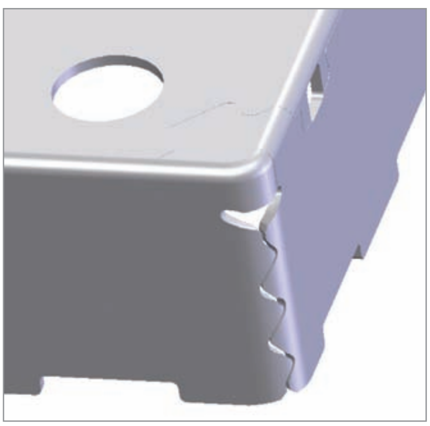


Figure 3: Rigid corner technology (US Pat 7,488,902 B2)

Faraday cage is the PCB ground plane, and the PCB design itself has much influence on overall EMI performance. Remember that these same basic design principles hold true for susceptibility. Therefore, BLS works equally well for emissions and/or susceptibility.

Board level shields are generally categorized into four basic types:

1. one-piece
2. two-piece
3. drawn
4. one-piece with removable sections

A one-piece BLS is typically a stamped and formed sheet metal can, often produced on high-speed presses. These are usually the least expensive for high-volume production. A two-piece BLS is also stamped, with individual fences and covers. The two-piece BLS can be provided assembled, or as individual components. These are often used where access to PCB components is necessary for inspection, testing or rework. One-piece with removable sections is a one-piece BLS with removable areas that are scored for easy removal and access to components for adjustment or repair. A separate replacement cover is required. A drawn BLS is a one-piece BLS that uses drawn stamping technology to produce a BLS with no slits or apertures at the corners.

BLS FLATNESS

As more fine pitch components are utilized on a PCB, thinner solder paste thicknesses are required to prevent shorts or bridges. This has translated into better flatness requirements for SMT board level shields. Current flatness requirements are typically 0.10mm to 0.05mm. Drawn shields and rigid corner technology (US Patent 7,488,902 B2 Figure 3) can

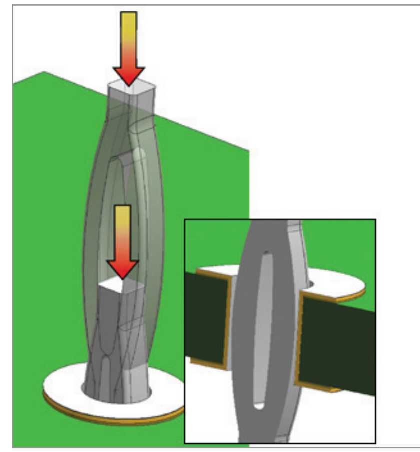


Figure 4: Eye-of-needle/compliant pin

For some applications, it is important to have the capability to rework areas on the PCB covered by the BLS. This may be part of the initial manufacturing process or later work in the field.

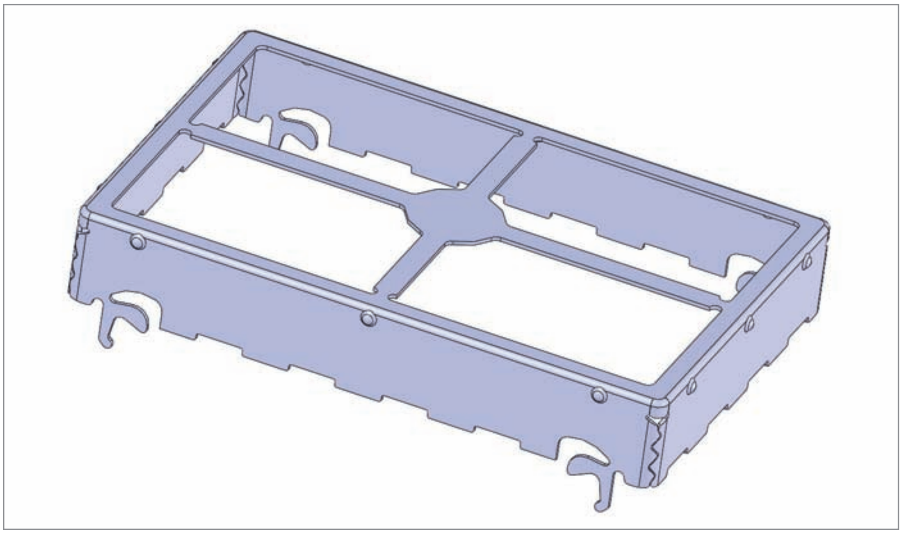


Figure 5: Through-hole lock pin

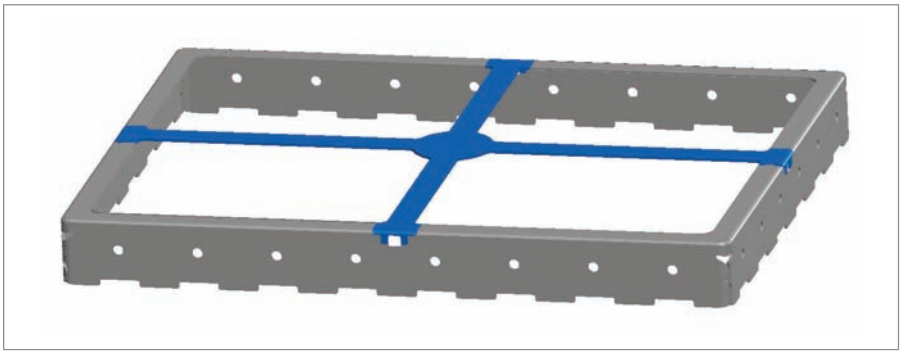


Figure 6: ReMovl pickup bridge BLS frame

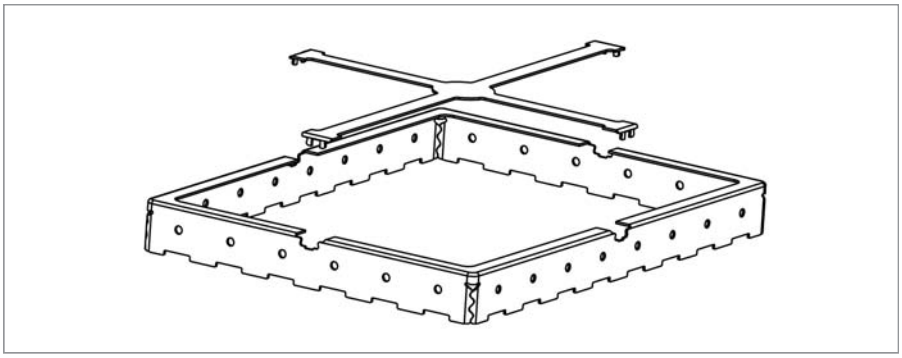


Figure 7: Bridge removed

improve flatness capabilities by acting as a stiffener for the whole shield. Additionally, where acceptable, through hole features can be utilized to ensure a good mate exists between the BLS and PCB during assembly and reflow. Existing products and solutions are eye-of-needle pins and other compliant pins (Figure 4).

A newly available product is the through-hole lock pin (Figure 5), which allows for precise and repeatable fixturing of the BLS (frame or single piece) to the PCB for the subsequent reflow operation (conformal to the PCB).

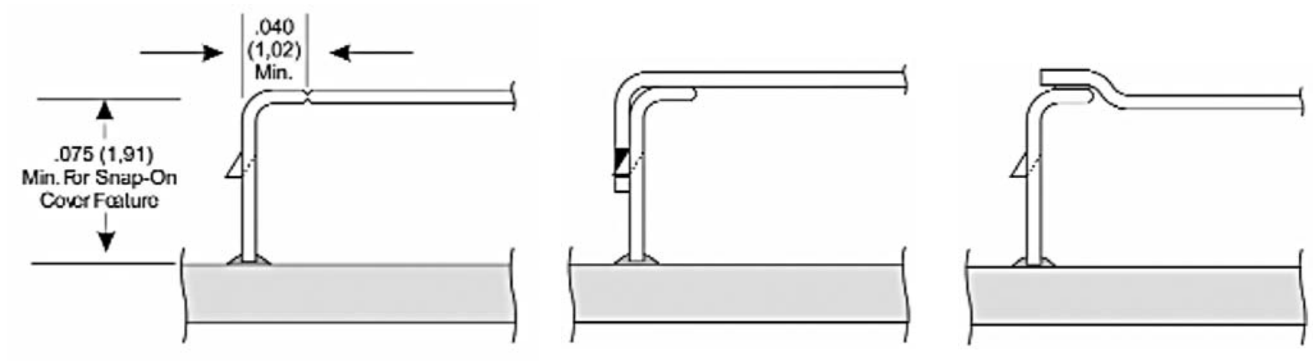
POST REFLOW INSPECTION/TESTING

In the PCB manufacturing process, there are often post reflow inspection or testing requirements that need as much open access to the PCB components as possible. For SMT BLS frames, the pickup bridge can be in the way of this inspection or testing requirement and must be removed. Post installation/reflow access to PCB components under the BLS pickup bridge is a common requirement. Manual removal of the pickup bridge by cutting or bending has been a necessary, labor-intensive step. A new product feature is the ReMovl pickup bridge (Figure 6). It is a pre-cut bridge for easy toolless removal or automated removal (Figure 7).

PRODUCT REWORK

For some applications, it is important to have the capability to rework areas on the PCB covered by the BLS. This may be part of the initial manufacturing process or later work in the field. Single piece BLS with simple rework capability is required. One solution is the EZ Peel BLS with scored lid (Figure 8). However, separate replacement covers are required, and this can lead to inconsistent performance on removal and replacement of the scored section.

An alternative to this solution is the ReCovr BLS, a good alternative to the EZ Peel solution since it can reuse the original cover (Figures 9 and 10, page 30). It has the advantages of a two-piece BLS at a cost comparable to a one-piece BLS. Recent enhancements to the latching features of this design improve the cover retention force



Original EZ Peel Can

After removal of scored section and application of snap-in lid

After removal of scored section and application of dish lid

Figure 8: EZ Peel BLS

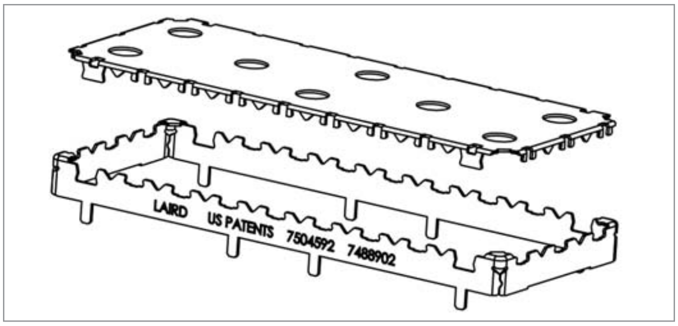


Figure 9: ReCovr with lid removed

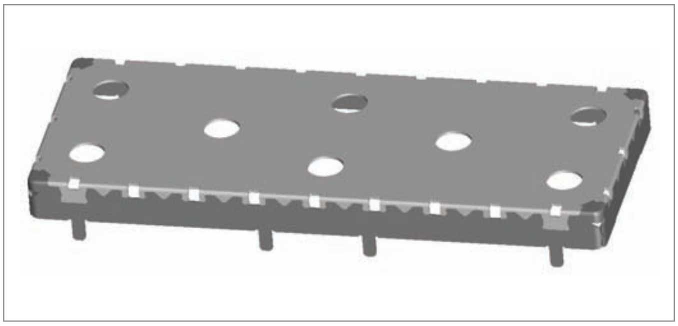


Figure 10: ReCovr with lid in place

both as delivered, and after removal and replacement. This feature allows for applications where shock and vibration may be encountered.

LONG-TERM PERFORMANCE AND RELIABILITY

While many BLS applications have short product lifecycles, there are also many longer-term applications in automotive, industrial automation and military programs which require sustained performance over many years. In these cases, both corrosion concerns and tin whiskering must be considered in the base material and plating choices.

MULTI-FUNCTIONAL BLS

As relative PCB space continues to shrink and power/heat generation per unit area grows, more multi-functional BLS and thermal products will be needed. One potential solution exists with BLS and integrated thermal pads. If the frame assembly to PCB includes a pickup bridge for automated placement, this bridge needs to be removed to allow for contact of thermal interface material to the PCB component. The Removl pickup bridge is an ideal option for this application. The ReMovl pickup bridge facilitates the manufacturing process by simplifying the removal of the pickup bridge.

BOARD LEVEL SHIELDS
PRODUCT SELECTION GUIDE

BLS Design Type / Features	Key Attributes & Application Consideration	Corner Feature				Unique Product Features	Mounting Features			Size & Shape				
		Traditional Folded	Rigid Corner	Full Drawn w/ Flange	Full Drawn Zero Flange	ReMovl Pick & Place Bridge	SMT Castellations	Thru Hole Loc Pins	Pins, Tabs, Etc	Interior Walls	Typical Material Thickness	Low Height (less than 2 mm)	Typical Length & Width	Flatness (Size Dep)
			Improves Flatness by increasing torsional rigidity	Most mechanically rigid, but depth attainable is material and configuration dependent	Similar to Full Drawn, Tooling more complex	Easy removal of pick and place bridge for post reflow inspection		Through hole style pin that engages to underside of PCB by mechanical engagement						
SINGLE PIECE														
Single Piece	Simple low cost BLS Solution	Opt	Std	Opt (height/matl limits)	Opt	N/A	Std	Opt	Opt	No	0.2	Yes	10- 75 mm	0.08
TWO PIECE														
Traditional	Post Reflow Component Access for inspect, test, cleaning, etc. Various cover retention features available to address rattling, EMI, and shock/ vibration concerns. Optional pre-assembled deliverable													
Frame		Opt	Std	Opt (height/matl limits)	Low Height Option	Opt	Std	Opt	Opt	Opt	0.2	Yes	10- 75 mm	0.08
Cover		Std	Opt	Opt (height/matl limits)	N/A	N/A	N/A	N/A	N/A	N/A	0.15	Yes	10- 75 mm	0.15
ReCovr	Lower total cost 2 piece solution. Eaveless side wall for maximum component access.	N/A	Req'd	N/A	N/A	N/A	Std	N/A	Opt	No	0.3	No	10-40 mm	0.1
EZ Peel	Support for legacy products. ReCovr can often be a more reliable alternative. EZ Peel can utilize a separate replacement cover if desired.	Std	N/A	Opt		N/A	Std	N/A	Opt	No	0.12	Yes	10-30 mm	0.1
97-2000	Large BLS Applications. Can accommodate internal walls for EMI compartmentation.													
Frame		N/A	N/A	N/A	N/A	N/A	Std	Opt	Opt	Opt	0.4	No	50-300 mm	0.2
Cover		Std	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.25	0.25	No	50-300 mm	0.2

BLS MATERIALS MATRIX

Material Type	Description / Specs	Comments	Cost Position	Applications
CRS, Tin Plated	1010 / 1008 CRS	High Permeability Material for low Freq Applications, Very Good Solderability, Mitigation options for Tin Whisker Growth, Pre-plated, Bare stamped edges	Best	Most common BLS solutions
Nickel Silver	CA770, CA752	Environmental Performance & Aesthetic Quality, Good Mechanical / Strength Properties, Good Solderability, Active Flux may be required	Good	Hi Performance BLS solutions (Mechanical & Environmental)
Stainless Steel	Typical 301 and 316 Series	Environmental Performance, Good option for the cover of 2 piece designs	Better	BLS Covers, Specialty Military
Copper Alloys	Phosphor Bronze, Beryllium Copper, Brass	Can be chosen for unique requirements that integrate spring contacts, Typically Plated for Solderability and/or corrosion resistance	Good	Specialty BLS applications Integrated Spring Contacts

Figure 11

CUSTOMER REQUIREMENTS/ INDUSTRY DRIVERS

Today, based on current customer application needs for BLS products, there are even more choices and product features available. These technology innovations were driven by the application needs across multiple industries. These additional design choices are summarized in Figure 11.

CONCLUSION

As you now see, board level shields are not just five-sided metal boxes anymore. Today's advanced BLS designs provide solutions for many manufacturing, performance and rework requirements. Understanding all the options and utilizing the BLS design selection guide can help lead you to the most efficient and cost effective solution. In addition to the guide, remember that a trained field application engineer may still be the best choice for proper BLS design and feature selection.

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Single Antenna Measurement Using Gated Time Domain and The Mirror Method

This article provides a basis for using gated time domain and a highly reflective mirror to measure the gain, phase, beamwidth and radiation pattern of broadband antennas. The tests were completed using the Anritsu VectorStar VNA. The speed and data points (100,000) make possible high resolution in time domain. Three commercial reference horns were measured and an aperture and mirror conductivity correction applied. The resulting data agreed reasonably well with the published data. Two additional classical methods were also performed for validation.

BY MICHAEL HILLBUN, MATTHEW J. MARTIN AND DAVID SEABURY

Antenna measurement involves the determination of received power over a distance with a known source power. The simple implementation of the Friis equation reduces to three variables, the G_{Tx}, G_{Rx} and path levels.

$$P_r = \left(\frac{\lambda}{4\pi r}\right)^2 G_{Tx} G_{Rx} P_t \qquad (1)$$

The classical methodology for solving for G_{Rx} involves substitution into the link of a known reference or the knowledge of the path and G_{Tx}, the two antenna method where two identically constructed antennas reduce the problem to path knowledge, and finally the 3 equation 3 unknown approach where all three variables are solved through all possible combinations of three antennas. With the practical advent of time domain, the two antenna method is extended with the use of a mirror image of itself creating a perfect clone. By performing an Az over EL spherical scan, beam width contours can be measured. The aperture of the mirror can be determined. The integration of the received power over the mirror aperture and the total efficiency form a correction factor, making it unnecessary to have a large mirror. This enables measurements at variable distances. The two and three antenna method and calibration lab data are the data validation basis.

TIME DOMAIN TEST AND MEASUREMENT - REFLECTION

While most Purcell mirror methods used metallic sheets, they exhibit conductive losses which can affect the results. An aluminum coated 0.36M^2 plastic mirror 0.2”(5MM) thick was used for this measurement (Figure 1).

The plastic body of the mirror can be made to benefit measurements based on its thickness. The thickness of the mirror and the refractive index combine to make the body exhibit antireflection at quarter wave frequencies.

In this case, the reflection at the mirror is:

$$\rho = \frac{1-\varepsilon}{1+\varepsilon} = -.5 \qquad (2)$$

The reflection of the mirror surface is significant. The ¼ wave thickness occurs at 4.1GHz. As with classical quarter wave coatings, 100% reflection will occur when the penetrating wave reflects back and combines with the reflected wave. The affect is easily seen using a 217 ohm two port transmission line with 377 ohm port impedances (Figure 2).

At 4 GHz, the aluminum mirror coating reflection power $\rho_M = -1$ will combine with the acrylic reflection, and total reflection occurs. Everywhere else, the mirror is little improved. The mirror finite conductivity will reduce the amount of reflected power. The Poynting vector power loss is:

$$P_L = \frac{1}{2}\mathrm{Re}[\overline{E}x\overline{H}] \qquad (3)$$

It can be shown that for good conductors, the induced current density along the conductor surface is given by

$$\overline{J} = \overline{n}x\overline{H} \qquad (4)$$

The conductor conductivity σ and skin depth δ yield an impedance given by:

$$Z_c = \frac{E}{J} = \frac{1+j}{\sigma\delta} = R_s + j\omega L_s \qquad (5)$$

Substituting (3) and (4) into (2) yields the classical surface power loss:

$$P_L = \frac{1}{2}R_s|J_s| \text{ Watts/M}^2 \qquad (6)$$

The surface resistivity calculated from the planar skin depth yields a correction to the reflection for the single antenna measurement.

The loss is not significant; however, because the mirror area increases as the square of the size, loss can be high. A 2-meter square mirror with silver backing would have nearly 1.5dB loss at 18GHz (Figure 3).

As depicted in Figure 1, the mirror aperture cannot be large enough to receive the entire pattern. If the aperture efficiency is defined as:

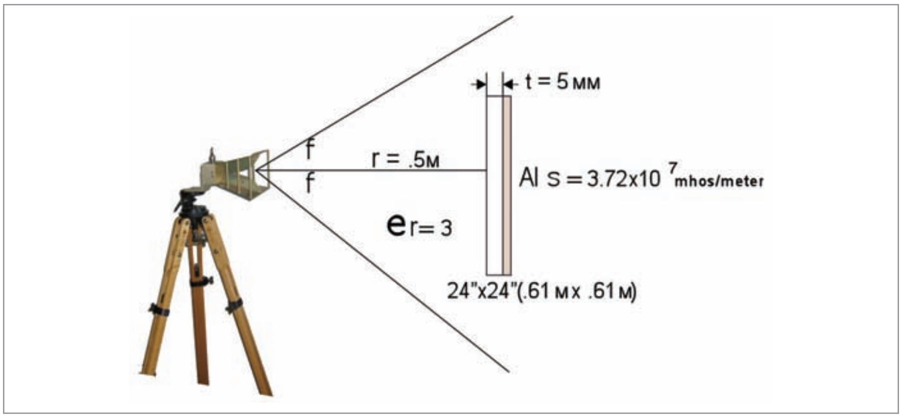

Figure 1: Test configuration for the measurement of the antenna and its mirror image

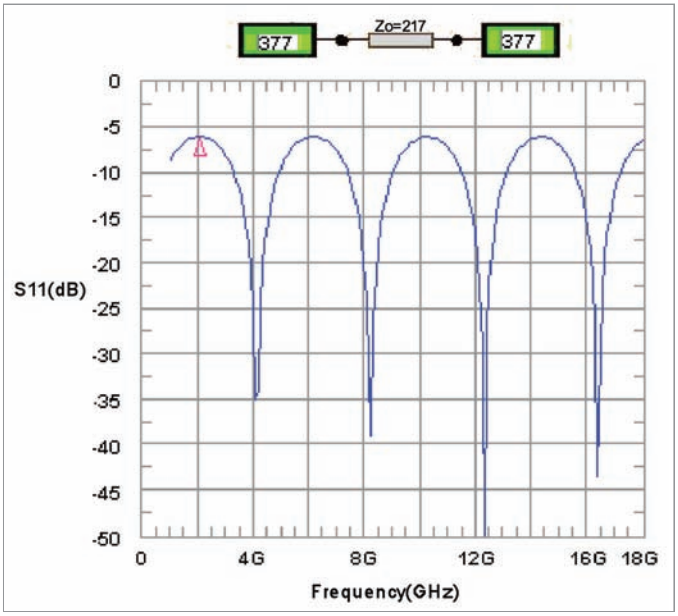

Figure 2: Mirror dielectric reflection simulated with the DE Antenna Measurement & Network Simulator

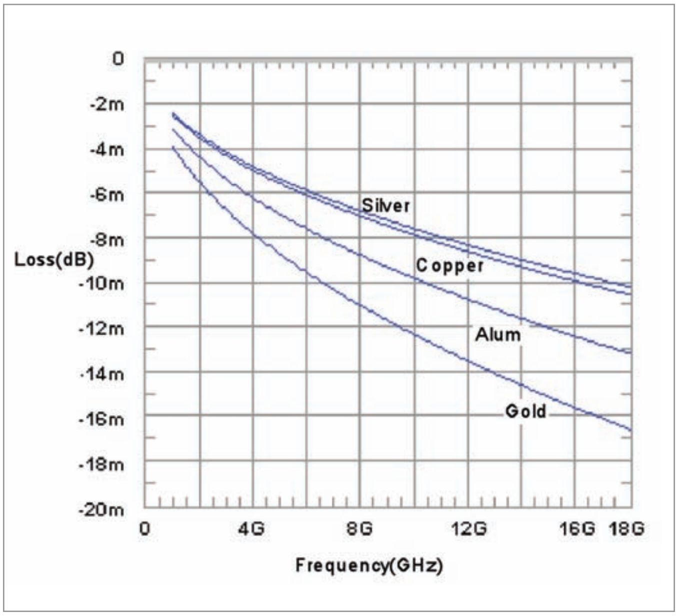

Figure 3: Mirror conductivity loss for a 0.61M² mirror with silver, copper, aluminum and gold backing

$$\varepsilon = \frac{P_r}{P_{TX}}$$

P_r = *Total incident power*

P_{TX} = *Total transmitted power* (7)

then integration across the mirror face and a spherical Az/EL scan can be used to correct the results.

$$\varepsilon_T = \frac{\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\int_{0}^{2\pi} P_d G_r(\theta,\phi) R^2 Cos(\phi)\, d\theta\, d\phi}{P_{TX}} \quad (8)$$

$$\varepsilon_M = \frac{\int_{-\varphi_{EL}}^{\varphi_{EL}}\int_{-\varphi_{Az}}^{\varphi_{AZ}} P_d G_r(\theta,\phi) R^2 Cos(\phi)\, d\theta\, d\phi}{P_{TX}} \quad (9)$$

$$\varphi_{EL} = \tan^{-1}\left(\frac{h}{2r}\right) \quad \varphi_{Az} = \tan^{-1}\left(\frac{w}{2r}\right) \quad (10)$$

$$\kappa = \frac{\varepsilon_T}{\varepsilon_M} \quad (11)$$

Where *h* is the mirror height, *w* is the mirror width and κ is the correction factor. It is necessary for the mirror shape to match the Az/EL scan type. Az over EL and EL over Az require a rectangular mirror.

MEASUREMENT RESULTS

A standard 1-18GHz horn and Anritsu Vectorstar VNA were used in time domain. The Diamond Engineering Antenna Test System provided the Az/EL rotation, data collection and data processing (Figure 4). The horn calibration data extended from 1 to 18GHz. The VNA was calibrated from 0.7 to 20GHz with 801 data points. The time domain mode was band pass, nonharmonic sweep. This is the simplest mode possible. The loss of the DC level means that phase cannot be accurately measured. These measurements were only concerned with amplitude.

A harmonic sweep, high resolution and bandwidth (10,000 points) were performed for mismatch identification inside the horn.

The time domain resolution in terms of distance is approximated by:

$$\Delta d \approx \frac{2c}{BW} = \frac{.6}{BWghz}\ meters \quad (12)$$

This results in about 3.1cm resolution.

The second consideration is Aliasing. Unlike real time domain, the Ifft-based method is build on cyclic properties. The response repeats itself depending on the frequency step size.

$$d_{Aliasfree} \approx \frac{.5c}{\Delta f} = \frac{.15}{\Delta f\ ghz}\ meters \quad (13)$$

This results in about a 7 meter range.

The ungated time domain response shows the discontinuities of the horn and the mirror (Figure 5, page 36).

The time profile shows the extent of the horn length is 21cm. The gate was

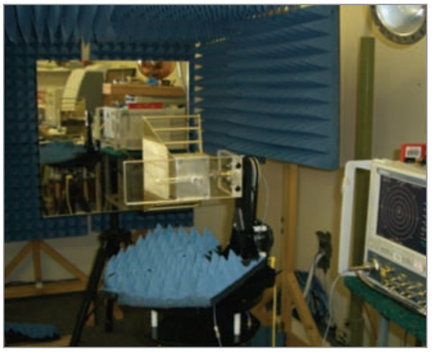

Figure 4: Horn mirror measurement test setup

then set to the center with a span of 10.5cm (Figure 6). This assumes the mismatch between the horn-air-aperture is identical to the probe mismatch. For a good match, this is a small error and can be considered the center.

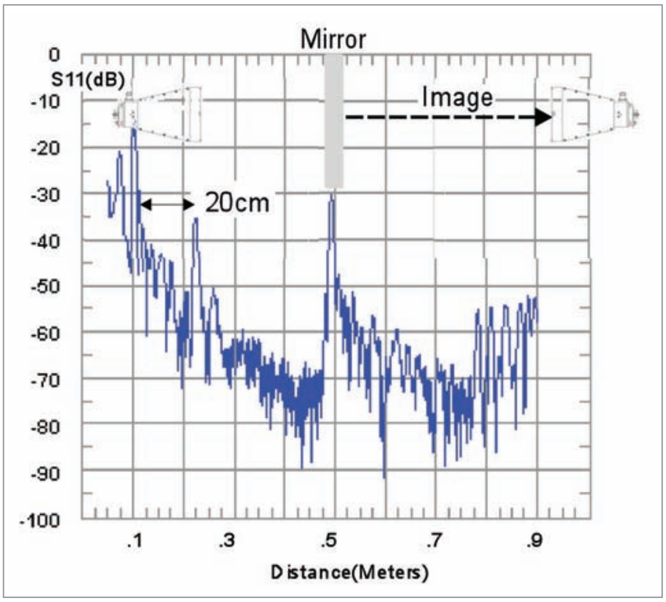

Figure 5: Time domain response showing the horn mismatch, horn aperture, mirror and reflection

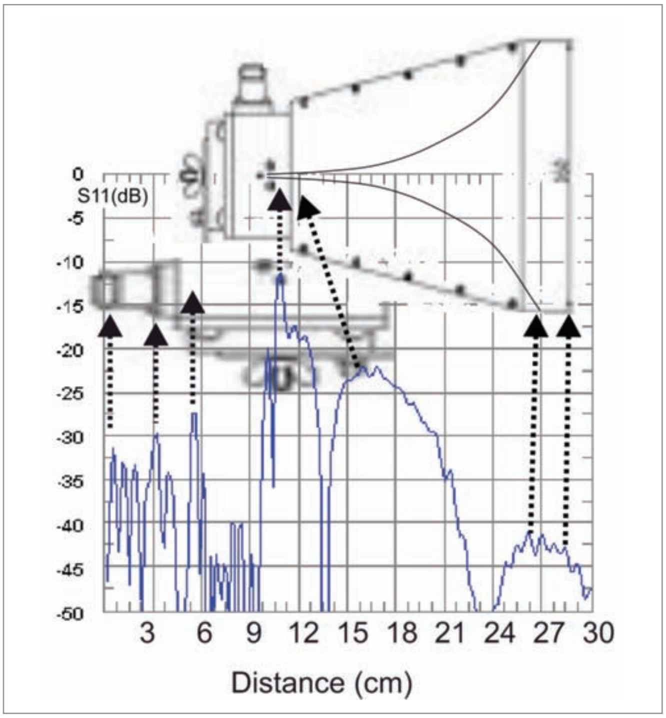

Figure 6: High resolution harmonic sweep shows the location and magnitude of discontinuities inside the test antenna (Vivaldi arrow is tilted due to cavity extent)

Next, the gated signal is transformed back to the frequency domain yielding the original horn, the path, the horn image and the losses (Figure 7). Since the equivalent time pulse traverses the entire network twice, each attenuation component is doubled with the exception of the losses since they have no time extent. The corrections were calculated using the Diamond Engineering icon-based Antenna Network & Measurement simulator.

The measurement-enabled schematic represents a single path removal, the measurement, a single horn (sqrt(S)) and the mirror correction icon (Figure 8). The resulting gain of the test horn is the total gain $G_\varphi + G_\theta$. It is not possible to separate the gain components with this method. Figure 9 shows the resulting gain with and without the aperture and conductivity correction and the manufactures published data.

There is good agreement up to 15GHz. The manufactures data differs from the reflection method data by 1.8dB. It can be seen the steep slope is the cause of the larger delta. The negative slope indicates the beam is breaking up (Figures 10, 11 and 12, page 38).

The mirror method has the ability to measure the AUT phase. For accurate phase measurement, the gating must be correctly

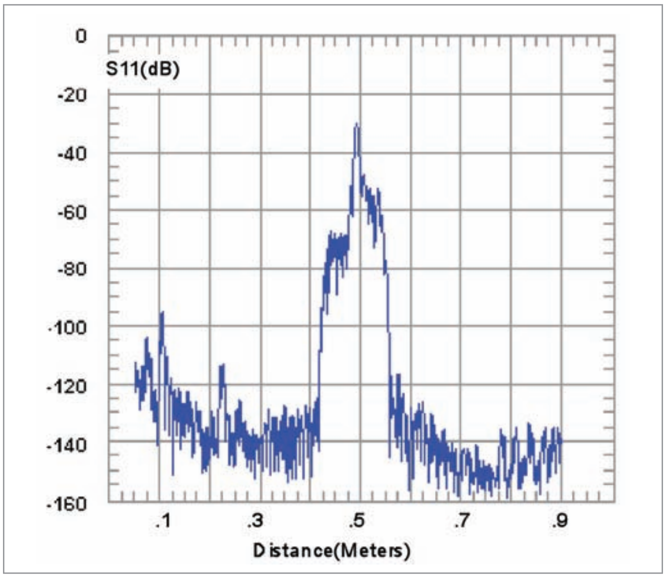

Figure 7: Time gate applied to the time domain negates the discontinuities up to the mirror

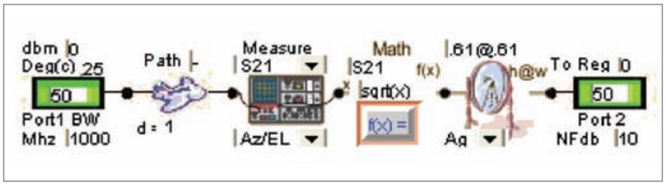

Figure 8: A measurement-enabled schematic

set. The mirror produces the horn image at twice the distance. The VNA in S11 time domain divides the time/distance by 2. The gated frequency data phase includes the two-way path, as seen in the group delay for the gated data (Figure 13).

The group delay indicates the phase slope is correct even in band pass mode.

TWO- AND THREE-ANTENNA METHODS

The two-antenna method is based on identical antennas. The network reduces to Figure 14.

Similar reference horns were positioned 1 meter and boresite aligned (Figure 15). The Anritsu Vectorstar was auto calibrated using a bandwith of 100Hz and 801 data points. Figure 16 shows excellent agreement with the calibration data.

The three-point method was also performed using the two identical horns and a similar horn from another manufacture. The three-point method involved the solution to the Friis equation by establishing a 3x3 matrix.

$$[S21]_{Link} = [G][P] \qquad (15)$$

or

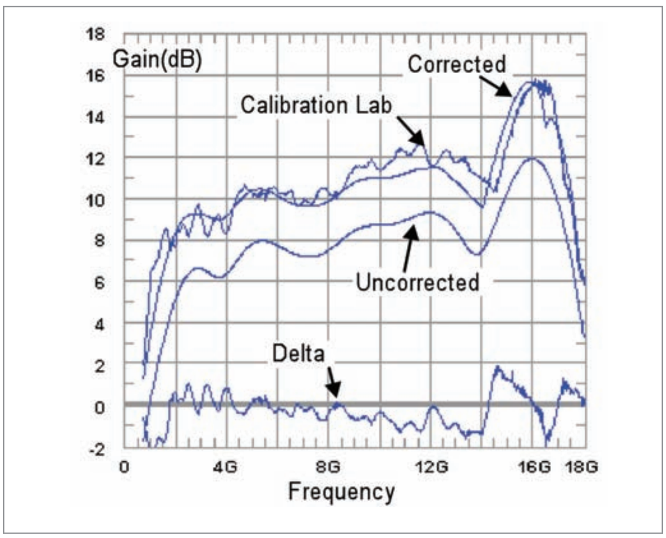

Figure 9: Gain of the test horn with and without correction and the calibration lab data

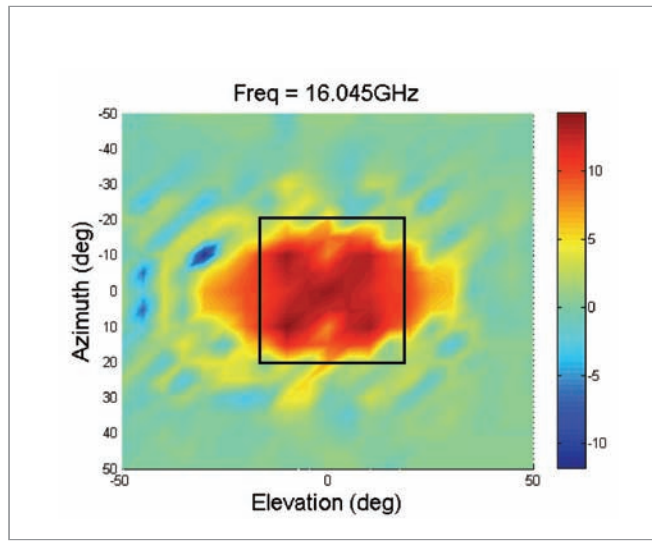

Figure 10: Beam distortion with the mirror overlay occurring at 16GHz.

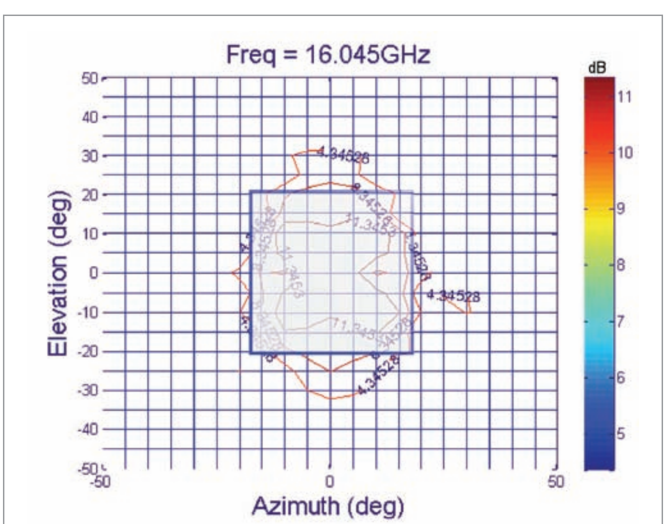

Figure 11: Showing the breakup of the beam, -3,-6 and -10dB beamwidth contours with the mirror overlay showing areas of correction at 16GHz

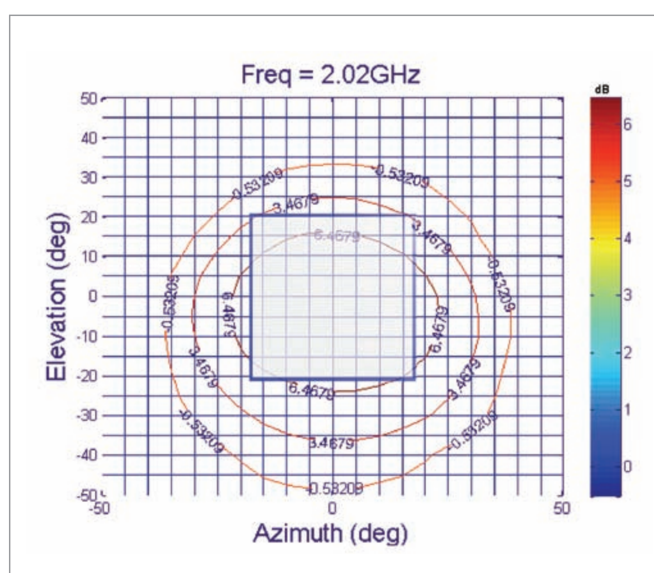

Figure 12: -3,-6 & -10dB Normal beamwidth contours with the mirror overlay showing areas of correction at 2GHz

$$[G] = [S21]_{Link}[P]^{-1} \quad (16)$$

The matrix is created by measuring the link with every possible combination of the three antennas. While the three antenna method implies an exact solution, it is subject to ones ability to interchange antennas without affecting path or alignment.

Figure 17 (page 40) shows the results of the three-antenna method. For the two identical horns, good agreement with the two-antenna method is apparent from Figure 16 (page 40).

CONCLUSIONS

A novel, customized, antenna time-domain measurement has been presented as an alternative to the classical measurement techniques in frequency domain. The advent of high speed wideband vector analyzers utilizing IFFT make the single-antenna method simple and practical. A correction routine has been demonstrated to be an effective tool for measurement accuracy. Calibration lab measurement data was verified using two- and three-antenna methods of measurement. The mirror method with time domain was shown to have good agreement with the verified data.

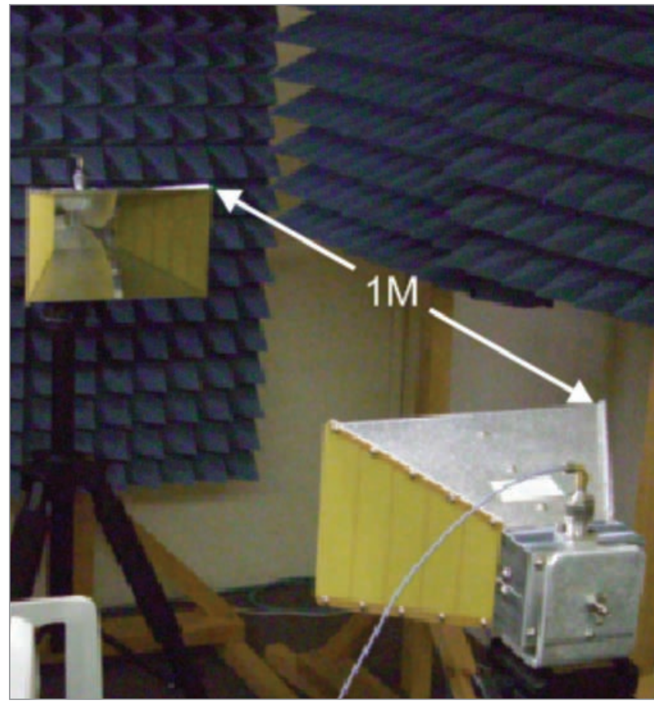

Figure 15: Two-antenna test setup

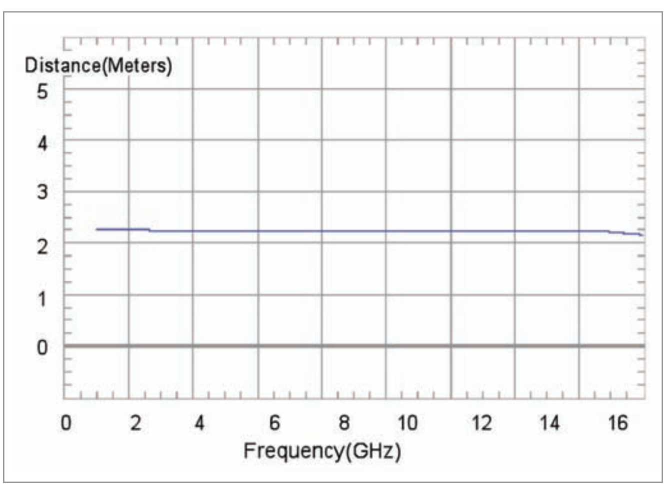

Figure 13: Gated frequency group delay showing the entire two-way path from a mirror located at 1.15 meters

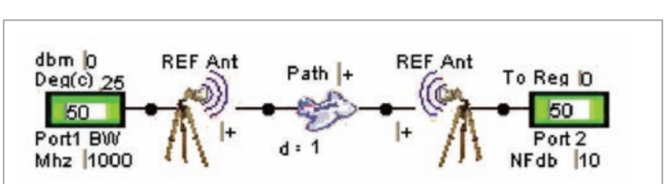

Figure 14: Two identical antennas enable the entire link to be reduced to one unknown $\sqrt{\frac{G_{Tx}G_{Rx}}{Path}}$

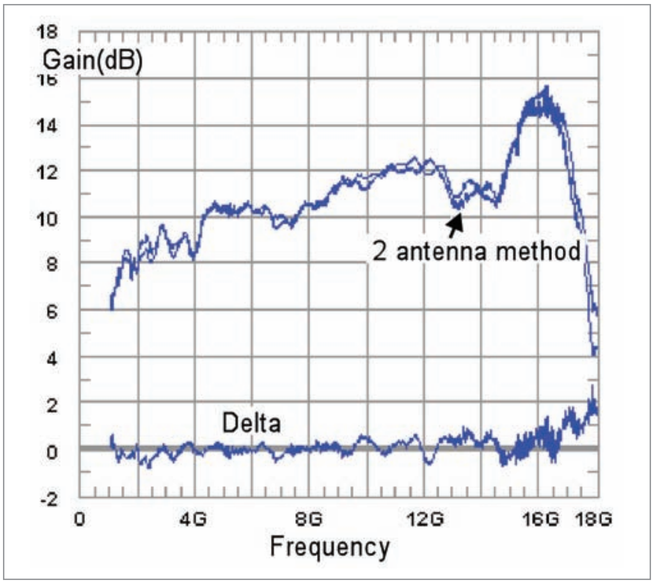

Figure 16: Two-antenna method gain and calibration lab gain

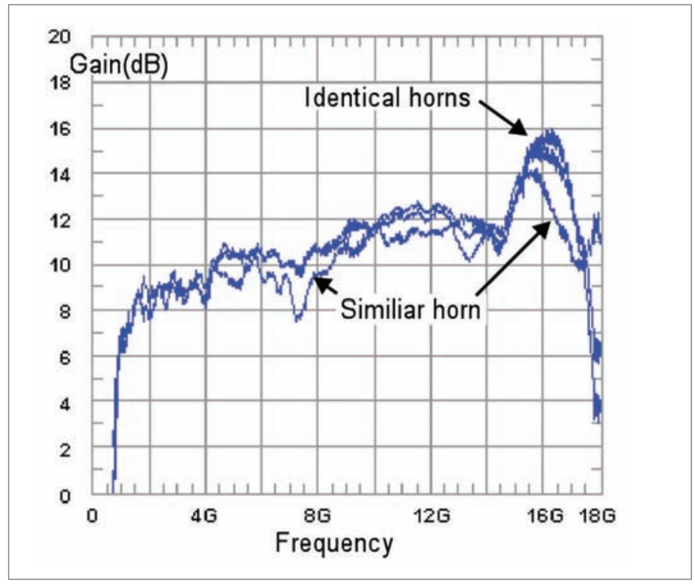

Figure 17: Three-antenna method resulting in the gain of each antenna

ACKNOWLEDGEMENT

It is the authors' pleasure to acknowledge the innovation of colleague Matthew J. Martin and the cooperation and support of the Panashield team. We are particularly grateful to Anritsu Inc. for the use of test equipment and Sunol Sciences for the use of two identical horns.

REFERENCES

1. J. D. Young, D. E. Svoboda, and W. D. Burnside, " A Comparison of Time and Frequency Domain Measurement Techniques in Antenna Theory" *IEEE Transactions on Antennas and Propagation*, July, 1973, pp. 581-583.
2. R. Q. Lee, M. F. Baddour, "Absolute Gain Measurement by the Image Method under Mismatched condition", *International AP-S Symposium*, June 15-19, 1987.
3. R. V. de Jongh, M. Hajian, L. P. Ligthart, *Department of Electrical Engineering, International Research Center for Telecommunications Transmission and Radar, IEEE Antennas and Propagation Magazine*, vol. 39, No.5, October 1997.
4. E. K. Miller, *Time-Domain Measurements in Electromagnetics,* New York, Van Nostrand Reinhold Company, 1986.
5. *Time Domain Measurements Using Vector Network Analyzers,* Application note www.anritsu.com.
6. E. M. Peucell, "A method for Measuring the Absolute Gain of Microwave Antennas" *RL Report No. 41-9.*
7. Ramo, Whinnery And Van Duzer, *"Fields And Waves In Communication Electronics,* John Whiley & Sons, Inc. 1967.

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Recent Changes to GR-63-CORE

BY CLAYTON FORBES

Telcordia recently released GR-63-CORE Issue 4 "Physical Protection Requirements for Network Telecommunications Equipment", with a total of 27 new requirements (Rs) and objectives (Os). It has been six years since the document was updated and, as in previous releases, the specification has numerous technical changes.

The first change you will notice is the reactivation of Section 3. Going back to the Issue 2 version of the specification in 2002, Section 3 was a look forward to generic framework requirements. In the Issue 3 release of 2006, this section was deleted from the document and was left dormant. For the Issue 4 release, the section is activated and renamed as "Equipment Spatial Design Requirements for Frames and Chassis". Activating this section allows for segregation between the office space planning requirements (Rs) and objectives (Os) and equipment spatial Rs and Os. In Section 4, some of the technical changes that will be reviewed include a new operational high temperature requirement based on the airflow of the equipment under test (EUT), new energy efficiency requirements, and an optional operational random vibration test, to name a few. Some tests remain unchanged and will be skipped in this recap. These include surface temperature, mix flowing gas, hygroscopic dust, and acoustics.

SECTION 2 - FACILITY AND SPACE PLANNING REQUIREMENTS

In previous issues of the document, space planning requirements and objectives were intertwined with test requirements throughout Section 4. In the latest version, the Section 4 Rs and Os dealing with building layouts, such as Central Office Lighting Requirement R4-98 and Objective O4-99, are moved to Section 2 and relabeled as R2-31 and O2-32. Other requirements and objectives that are moved around in the document can be tracked between the versions by using their absolute number, which is the bracketed number in the Rs or Os. By doing this, Sections 3 and 4 have become much cleaner and easier to follow for both manufacturers and laboratories.

SECTION 3 - EQUIPMENT SPATIAL DESIGN REQUIREMENTS FOR FRAMES AND CHASSIS

Section 3 now defines the spatial requirements for frames and chassis. The section includes most of the original Rs and Os from Section 2 and thirteen new Rs and Os. The thirteen new Rs and Os include R3-4 and R3-5 say that access to anchoring bolts is needed when shelves are installed in a frame. R3-7 is that a frame must have the ability to join to an adjacent frame at the top. R3-8 states that a dimensional drawing of the equipment must be supplied and enclosed in the test report. R3-29 demands that the mounting holes for a chassis be a closed slot.

> The operating temperature test has undergone significant changes. An ongoing issue with equipment being supplied to end-users is the airflow cooling pattern they use.

TEMPERATURE TESTING

For the three storage temperature tests (low-temperature exposure and thermal shock, high relative humidity exposure, and high-temperature exposure and thermal shock) there is no change to the testing. The specification does clarify that testing the units in an unpackaged state is an acceptable test method. It also allows for slower ramp rates during the high humidity exposure test. The slower ramp rates allow the test to remain non-condensing for larger systems.

The operating temperature test has undergone significant changes. An ongoing issue with equipment being supplied to end-users is the airflow cooling pattern they use. Equipment with airflow patterns that deviate from the required preferential pattern of R4-34 or O4-35 will now be tested

Table 5.1 Variable Test Temperatures for Frame-level Products

Operating Tests				
Effective Air Inlet Location	Operating Temperature and Humidity	Operating Altitude	Operation with Fan Failure	Temperature Margin Determination
Front aisle or none	T_{OH}=50^{0}C	T_{AL}=30^{0}C T_{AM}=40^{0}C T_{AH}=50^{0}C	T_{FH}=40^{0}C	T_{ML}=50^{0}C
All others	T_{OH}=60^{0}C	T_{AL}=40^{0}C T_{AM}=50^{0}C T_{AH}=60^{0}C	T_{FH}=50^{0}C	T_{ML}=60^{0}C

Table 5.2 Variable Test Temperatures for Shelf-level Products

Operating Tests				
Effective Air Inlet Location	Operating Temperature and Humidity	Operating Altitude	Operation with Fan Failure	Temperature Margin Determination
Front aisle or none	T_{OH}=55^{0}C	T_{AL}=35^{0}C T_{AM}=44^{0}C T_{AH}=55^{0}C	T_{FH}=40^{0}C	T_{ML}=55^{0}C
All others	T_{OH}=65^{0}C	T_{AL}=45^{0}C T_{AM}=55^{0}C T_{AH}=65^{0}C	T_{FH}=50^{0}C	T_{ML}=65^{0}C

Figure 1: Tables 5.1 and 5.2 from the GR-63-CORE

Altitude testing remains essentially the same with two exceptions. The temperatures for the test are raised to align with the changes in the operational temperature and humidity test.

to a higher operational temperature. The high operational temperature test is performed at either 50^0C or 55^0C depending on whether the equipment under test (EUT) is frame level equipment or shelf (chassis) level. Now if the equipment has a non-preferential air intake, i.e. not in the front of the EUT, the maximum operating temperature rises to 60^0C or 65^0C depending whether it is a rack or a shelf. These new high temperature requirements are from Table 5-1 and 5-2 of the specification (Figure 1). Equipment with the non-preferential air intake can still be tested to the lower temperature levels if it is supplied and tested with an air deflector or air baffle that changes its air intake to the front of the equipment as stated in O4-36. Another change to the operating temperature profile was done to align the test with the requirements of ETSI EN 300 019-2-3 Class 3.2. During the 96 hour humidity dwell, the temperature and humidity are raised from 28^0C, 90% RH to 30^0C, 93% RH.

ALTITUDE, TEMPERATURE MARGIN, FAN COOLED EQUIPMENT

Altitude testing remains essentially the same with two exceptions. The temperatures for the test are raised to align with the changes in the operational temperature and humidity test. These temperature changes are also shown in Table 5-1 and 5-2 (Figure 1). The second change is to the alternate altitude test method using temperature compensation. In Issue 3, if the equipment met the configuration criteria to apply the temperature compensation method, it could be used. This entailed adding 1^0C/1000 feet to the operational temperature. For a shelf level product, the test temperature was 61^0C, 55^0C for the operational requirement, and 6^0C to simulate the 6000 feet from Objective 04-11. Objective 04-12 from Issue 3 is met by default since its required temperature for a shelf product is 58^0C. In Issue 4, the altitude of the test site can be considered and subtracted from the temperature compensation. If the test site is 3000 feet above sea level, the test will be performed at 58^0C, 55^0C from Objective 04-10 and 3^0C for the altitude compensation ([6,000 feet- 3000 feet(lab ambient)]/1000 feet/1^0C). Objective O4-11 will still be met as well.

Temperature margin testing remains unchanged for equipment with front air intakes or equipment with air diverters as previously described. For equipment with air intakes other than the front face, the starting temperature is increased to 60^0C or 65^0C as listed in Table 5-1 or Table 5-2.

The fan-cooled equipment criteria changes involve removing the humidity requirement from R4-14. Testing is now performed at either 40^0C or 50^0C, depending on airflow, with un-monitored humidity. The other change in the section moves the fan filters requirements from paragraph 4.5.4 in Issue 3 to 4.1.5.2 in Issue 4.

HEAT DISSIPATION, AIRFLOW AND ENERGY EFFICIENCY

Heat dissipation remains as it was in Issue 3. Some guidance on how to perform the calculations is added by stepping through an example in paragraph 5.1.6. This provides consistency between manufacturers on how to report the value. Along with the standard heat dissipation calculation, there is a new requirement R4-31 for energy efficiency. The requirement directs you to use the Alliance for Telecommunication Industry Solutions ATIS-0600015. The document listed is a general requirement document and one of seven documents presently in that ATIS family. Based on the type of equipment being tested, you default to one of those documents (listed at the end of the article). If your equipment does not fit in one of those categories, you default to a telecommunications carrier document such as Verizon's VZ.TPR.9205 and then to an industry standard document.

The next section in the document with changes is equipment airflow. A large part of the telecommunication service providers (TSP) cost is energy usage for environmental control of their equipment space. One of the major contributors to the high cost is a mixture of equipment with contrasting airflow patterns; hot air exhausting into the cool air aisle. To standardize equipment airflow in the equipment space, the objectives in this section are turned into requirements. As mentioned above, if the EUT deviates from the acceptable airflow pattern, operating temperature testing is performed 10^0C higher than the previous standard. If an air baffle is used during the qualification to redirect the air to the proper pattern, then the test can be performed at the lower high temperature levels.

FIRE RESISTANCE

After the major changes that fire resistance went through for the Issue 3 update, including scaling of the line burner, the changes in Issue 4 are

> After the major changes that fire resistance went through for the Issue 3 update, the changes in Issue 4 are relatively small but still significant.

relatively small but still significant. The first change in the section deals with high velocity fans internal to the EUT. It's not uncommon during full scale fire resistance testing for the line burner to consistently self-extinguish due to the high velocity airflow. Once the protocol of ATIS-0600319.2008 has been completed and the EUT has complied due to the line burner self-extinguishing, one additional burn for that location will need to be performed. That burn will be done with the fans in a non-operating mode in accordance with two new objectives 04-44 for frames or O4-50 for shelves. The second change deals with printed circuit boards (PCBs) having a distance to each other equal to or greater than 25 mm. Under Issue 3, varying distances between the adjacent cards caused no change in the burn profile. The new Issue 4 protocol for adjacent PCBs greater than 25mm away, is to leave the PCB in place and insert the line burner through the faceplate on the component side of the card. The line burner peak flow rate is then calculated in the same way as other burns, using the vertical height of the card and adjusted to 50% of the calculated flow rate.

MECHANICAL TESTING

The Category "A" packaged drop test is updated to change the required (1) edge and (2) corners the packaged product is dropped on. The change was performed to align with shipping industry standards .The number of drops remained at a total of 13.

The unpackaged drop is the key change in this section for equipment weighing less than 25 kg. The traditional free fall flat drops onto a non-yielding surface (concrete) from 3.9 inches or 3 inches, depending on its weight, remains, but the number of flat drops was increased to all possible rest surfaces. The two corner drops and two edge drops were changed to pivot drops. These pivot drops, known in the industry as a bench handling, were adopted from MIL-STD-810G Procedure VI of Method 516. The new test procedure is to place the unpackaged, unpowered equipment onto a wooden bench surface or non-yielding surface on its normal rest face. While using one edge as a pivot point, the opposite edge is lifted 4 inches or 45^0, whichever is less. The elevated edge is then allowed to free fall onto the bench top. This procedure is then repeated for the pivot edge and the two adjacent edges along the bottom. The drop sequence is then repeated for any other surface the unit could be rested on normally. If your item is able to be rested on a bench top on any of the surfaces, the number of drops would increase from the five required in Issue 3 to 30 in Issue 4. The 30 drops would include six free fall drops, one of each face, and 24 pivot drops, four on each face's edge.

Seismic testing has a clarification on which bolt the load cell should be placed on during the test if concrete anchors are omitted from the testing. The load cell is placed on the bolt at the innermost position, if the framework allows for a variety of anchor locations. In the test cases that were analyzed, this position was found to have the highest loads relative to the other mounting bolts locations. The second clarification is for testing of multiple shelves in a single frame. In accordance with the specification, units weighing less than 23 kg have to be placed at the top of

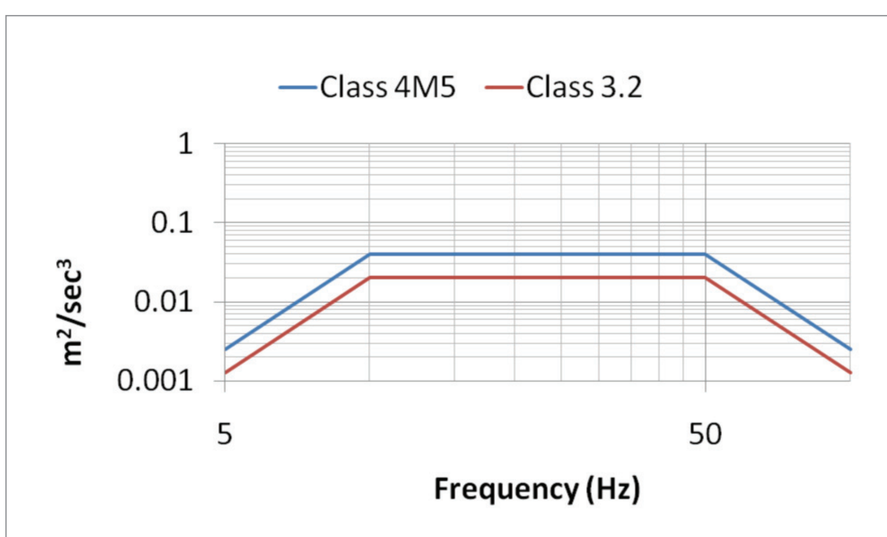


Figure 2

Office vibration has an additional test option to use a random vibration profile in lieu of the traditional 0.1 g sine sweep. The random vibration curve was adopted to align testing with European requirements.

the rack. In order to allow multiple units to undergo seismic testing in a single frame, direction is given that the smallest unit is to be placed at the top of the rack at the highest location. However. the lowest unit still has to be within the top 20% of the frame.

Office vibration has an additional test option to use a random vibration profile in lieu of the traditional 0.1 g sine sweep. The random vibration curve was adopted from the Class 4M5 requirements of EN ETSI 019-2-4 to align testing with European requirements. The issue with this alignment, done to reduce testing, will be the fixture requirements from each of the documents. GR-63-CORE has the requirement that shelf level products are placed at a specified height in a telecom frame depending on their weight. ETSI EN 300 019-2-4 requires that the test article be placed in a rigid fixture per IEC 60068-2-47, which telecom two-post frames do not comply to. However since European requirements for weather-protected equipment is performed to Class 3.2 of EN ETSI 019-2-3, the Issue 4 test curve is +3 dB higher as shown below (Figure 2). Based on this difference, a response accelerometer can be placed at the mounting location of the EUT in the telecom frame to verify it envelopes the Class 3.2 requirements. If it does not, separate tests will need to be performed for each of the documents.

The final change in the document in the acoustic section is the removal of the acceptance criteria for unattended locations. IN

REFERENCES

ETSI EN 300 019-2-3 v2.2.2 (2003-04) – *Environmental Conditions and environmental tests for telecommunications equipment; Part 2-3: Specification of environmental tests; Stationary use at weatherprotected locations.*

ETSI EN 300 019-2-4 v2.2.2 (2003-04) – *Environmental Conditions and environmental tests for telecommunications equipment; Part 2-4: Specification of environmental tests; Stationary use at non-weatherprotected locations.*

ATIS-0600015.2009- *Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting – General Requirements.*

ATIS-0600015.01.2009-*Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting -- Server Requirements.*

ATIS-0600015.02.2009-_*Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting – Transport Requirements.*

ATIS-0600015.03.2009-_*Energy Efficiency for Telecommunications Equipment: Methodology for Measurement and Reporting for Router and Ethernet Switch Products.*

ATIS-0600015.04.2010-_*Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting DC Power Plant – Rectifier Requirements.*

ATIS-0600015.05.2010- *Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting Facility Energy Efficiency.*

ATIS-0600015.06.2011-_*Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting of Radio Base Station Metrics.*

ATIS-0600319.2008- *Equipment Assemblies—Fire Propagation Risk Assessment Criteria.*

MIL-STD-810G October 31, 2008- *Department of Defense Test Method Standard Environmental Engineering Considerations and Laboratory Tests.*

VZ.TPR.9305 Issue 4, May 2011- *Verizon NEBS^{TM} Compliance: NEBS Compliance Requirements for Telecommunications Equipment.*

VZ.TPR.9205 Issue 5, October 2011- *Verizon NEBS^{TM} Compliance: Energy Efficiency Clarification Document.*

(the author)

CLAYTON FORBES has been working in the testing industry for 30 years, 24 of those years with NTS. Currently he is the Operations manager for NTS' Northeast Division and was a member of the GR-63-CORE re-write committee. Clayton has served as a technical advisor on various committees in both the commercial and military industries He is presently serving his second term as Vice Chair for the ATIS STEP-NPP committee and also participate on the SC-135 committee who's responsibilities include RTCA/160 specification.

Fifty-Year Old EMI Testing Problems Solved!

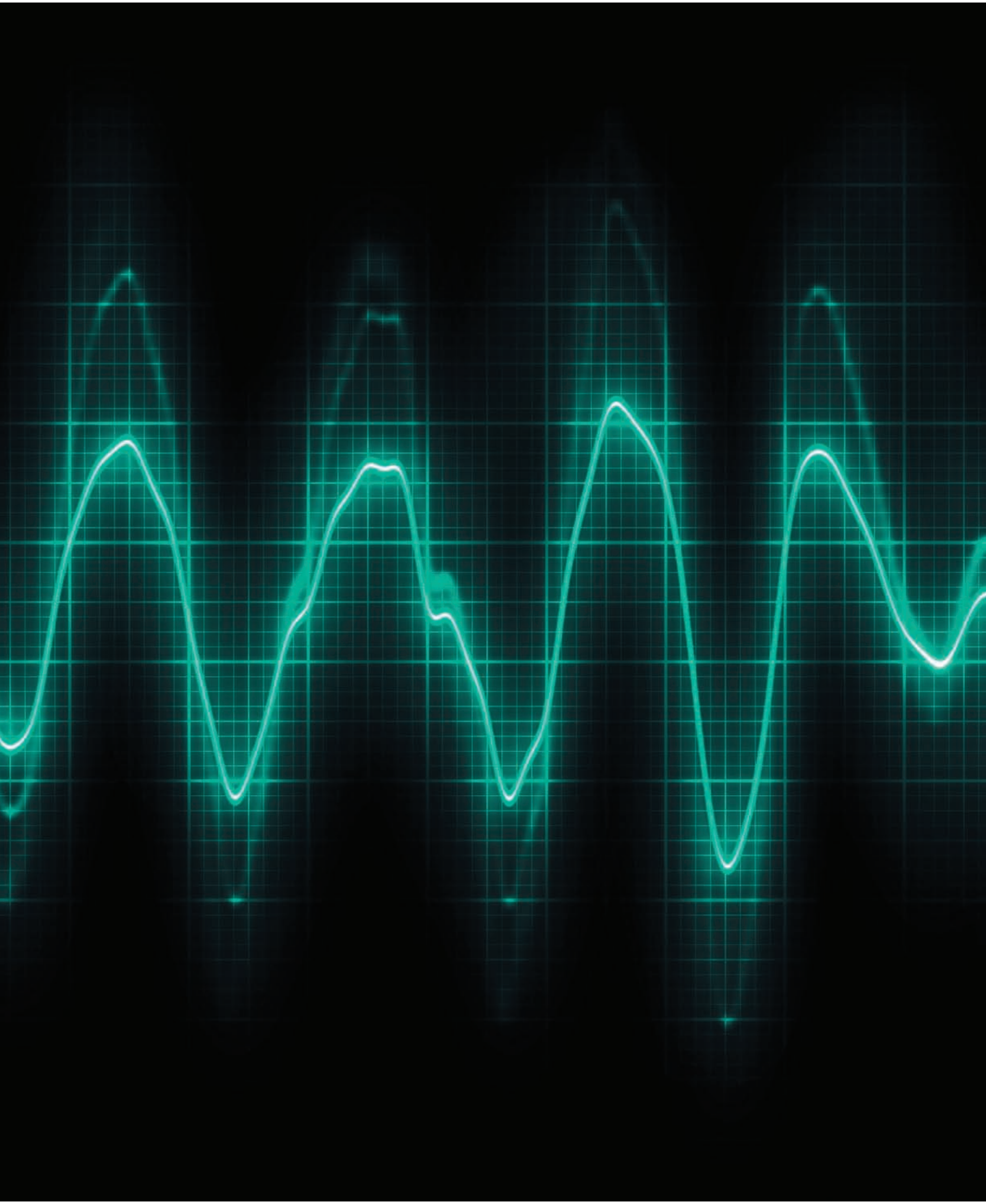
There have been inherent problems with audio frequency conducted susceptibility tests since their inception. These are: ensuring that the injected signal drops across the test sample; monitoring the signal that is developed across the test sample, both from the point-of-view of isolating the instrumentation so it doesn't ground the input power return and, more problematically, monitoring injected ripple riding on an ac bus potential. These issues are resolved using a novel but inexpensive transducer described herein.

BY KEN JAVOR

Requirements for equipment to operate compatibly with various levels of ac ripple imposed on primary power inputs (both ac and dc) have existed in US military standards since the 1950s, and in commercial avionics requirements, such as RTCA/DO-160, since at least the 1960s. The basic set-up for this testing is either that in Figure 1, or something very similar.

By inspection, the series injected potential must drop across the test sample power input, and/or the power source. Ideally, enough of the injected potential drops across the test sample so that the required ripple potential is developed there. The purpose of the 10 uF feedthrough capacitor is to be a low impedance shunt at frequencies where the LISNs become a significant impedance, forcing most of the injected potential to drop across the test sample. For a dc bus, the capacitor value can be increased without bound, and a value such as 10,000 uF ensures, for all practicality, that the injected potential does indeed appear across the test sample. But for a 400 cycle bus, 10 uF is an upper bound, and thus its appearance both in MIL-STD-461 and RTCA/DO-160.

The bottom line here is that it is critical to monitor the ripple across the test sample input; monitoring at the injection point is insufficient.



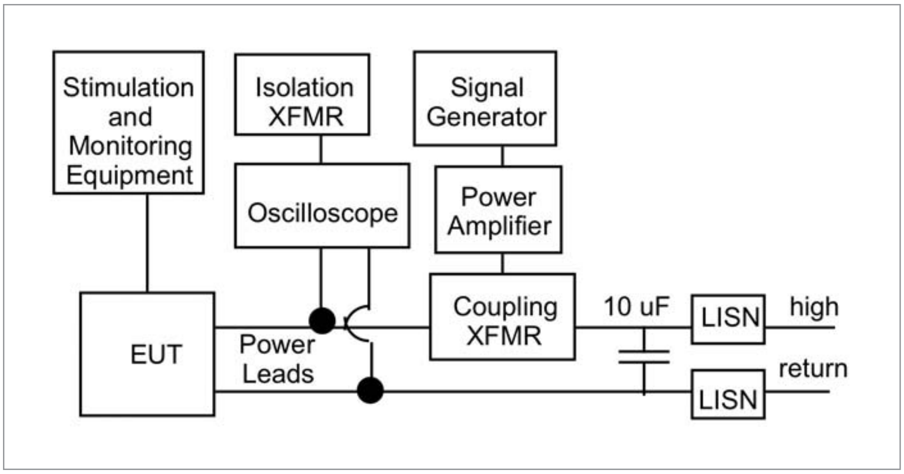


Figure 1: MIL-STD-461F CS101 test set-up

Given that the return line is generally above ground, the monitoring device, traditionally an oscilloscope, cannot artificially ground it via the oscilloscope probe ground connection. That is why Figure 1 floats the oscilloscope via an isolation transformer. In modern set-ups, with the monitoring device often connected to computer automation, this floating set-up is complicated by the interface with the automation. Better approaches are inherently floated oscilloscopes, such as those offered by Fluke and Tektronix that are "wall-wart" powered, with optically isolated computer interfaces and thus completely isolated from safety ground.

Finally, when the test sample is powered from an ac bus, it is quite difficult to monitor the injected ripple riding on the ac power waveform due to the large ratio of potential involved. The maximum ripple limit is 6.3 Vrms in MIL-STD-461 CS101, and that is riding on 115 Vrms. A still shot of the injected ripple at 800 Hz riding on a 400 Hz bus is shown in Figure 2. In the digital edition of this issue, the picture is a video and the difficulty in measuring the audio ripple is more obvious.

Prior to 1993, a "phase-shift network," Model 7021-1 by Solar Electronics, was available to ease this problem. It worked on the principle that the phase of the ac power waveform was 180 degrees reversed between the power source and the test sample, so that if one used transformer action to sum the potentials across the power source and load, the result would be only the injected ripple, which would be in phase across power source and load. This works well if all the injected ripple drops across the test sample, but if any has dropped across the power source it gets added to the ripple across the test sample, and the technique then overestimates the ripple level across the test sample alone. It is as if the injected ripple were simply measured at the point of injection, which would be much simpler. For this reason, the phase shift network technique of monitoring the test sample ripple was proscribed in MIL-STD-462D in 1993, and ever since.

With the loss of the phase shift network, the ability to monitor injected potentials at frequencies below that of the ac power waveform was likewise lost. The lower frequency modulation appears as a rolling change in amplitude that is impossible to gauge because its full value appears only across many cycles of the ac power waveform. So in 1993, MIL-STD-461D (and all subsequent revisions) began the CS101 limit for ac-powered equipment at twice the line frequency, omitting the formerly required spectrum down to 30 Hz.

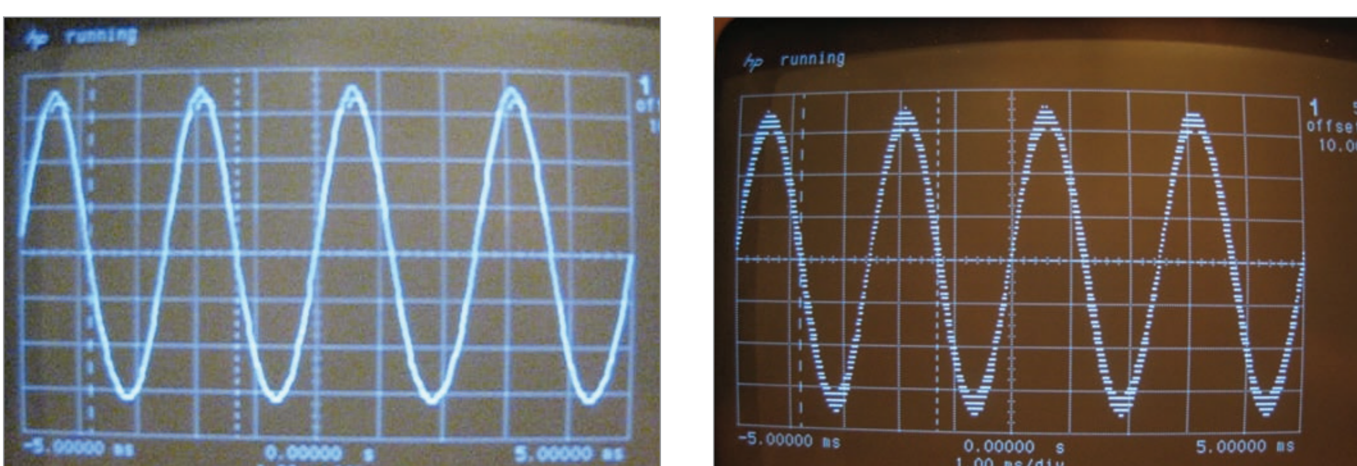


Figure 2: 800 Hz ripple superimposed on 400 Hz power (snapshot left, envelope right)

See our digital edition for actual video footage of this figure: http://www.incompliancemag.com/DigEd/inc1206

Figure 3: Commercial dynamic signal analyzers

OTHER APPROACHES

A useful but expensive approach is to use a dynamic signal analyzer (DSA) to view injected ripple in the frequency domain, allowing separation from the power frequency component. A DSA is an oscilloscope (1 Megohm input resistance) with a built-in fast Fourier transform (FFT) capability (see Figure 3). With this technique, the ac bus potential has to be attenuated, but the attenuation factor is 3 or 4, and that allows plenty of dynamic range to see the injected ripple potential. Two downsides are the cost ($10,000 – $20,000) and the fact that these devices operate to around 100 kHz, requiring a different technique to cover 100-150 kHz. This latter isn't a technical problem, but it does complicate and lengthen the test.

The author tried another technique using a distortion analyzer. The concept was to zero out the power waveform without any injected ripple, and then anything that would show up when ripple was injected would be the desired quantity to be measured. In practice, not enough of the power frequency waveform could be nulled out to enable reading the injected ripple accurately.

THE SOLUTION

The Figure 4 power-line ripple detector (PRD) network was developed by and for the EMC Compliance test facility as a CS101 test aid to overcome the problems described above. The PRD is an interface between the power bus and a low-level analyzer/receiver input, so the same analyzer/receiver presently

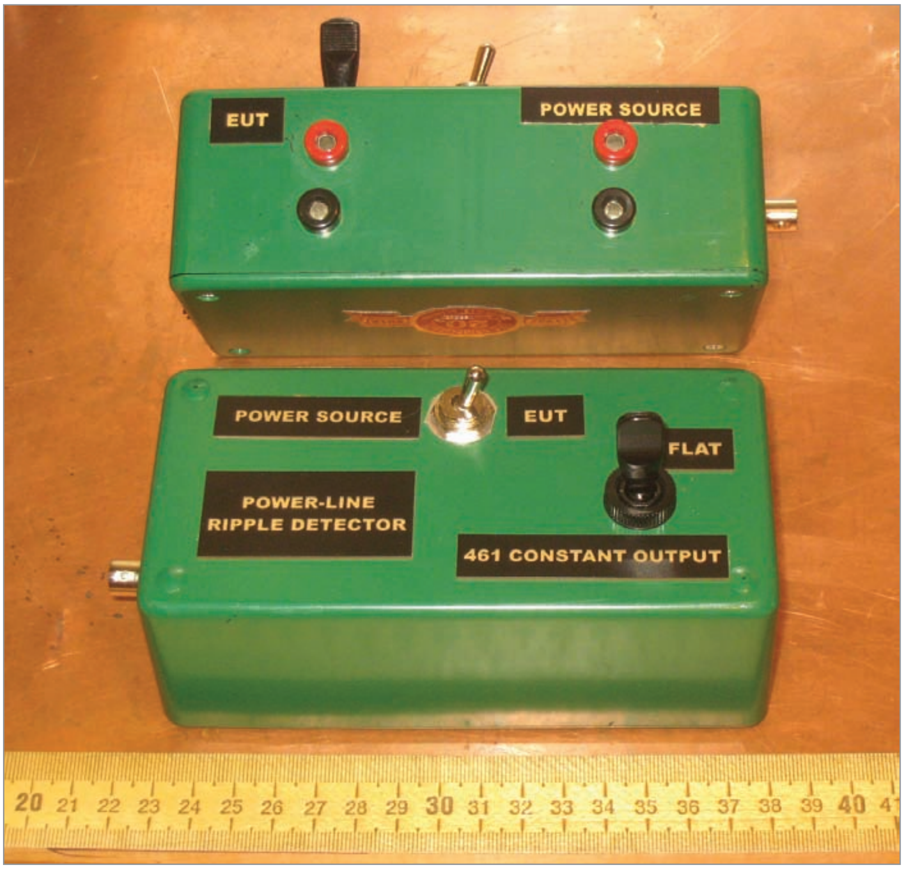


Figure 4: Power-line ripple detector

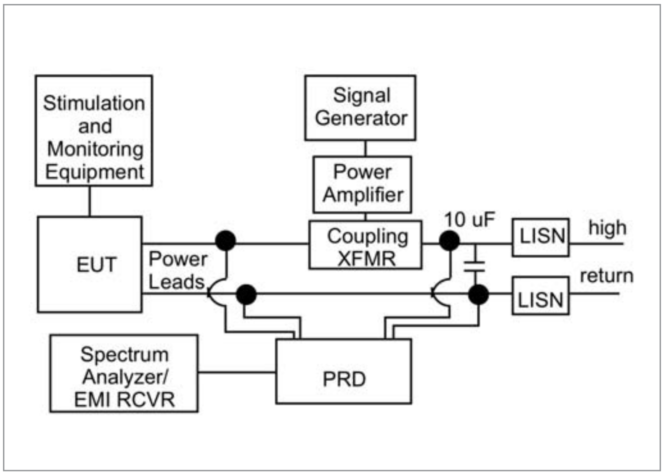


Figure 5a: Audio frequency ripple injection using PRD

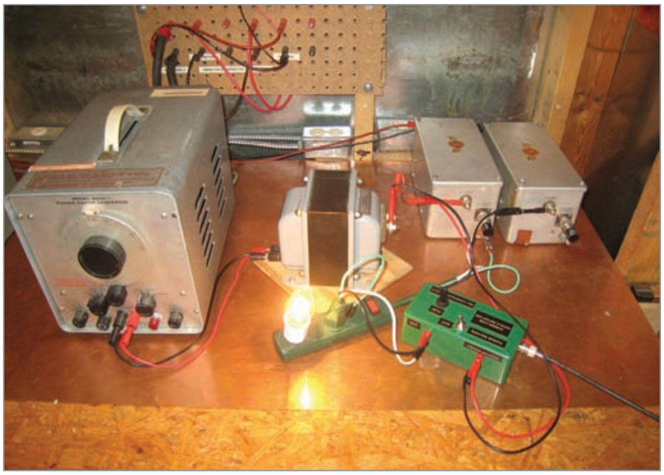


Figure 5b: Audio ripple injection using PRD (10 uF cap removed, analyzer not shown)

used for CE101 testing can now also be used for CS101 and RTCA/DO-160 section 18 testing as well. Figure 4 shows inputs for connections across the test sample power input and the power output (LISNs), a bnc connection to the spectrum analyzer/receiver, and two switches to control which input is monitored and the frequency response of the transducer.

The Figure 4 test aid will soon be available as a commercial piece of test equipment. The price of the PRD transducer is expected to be less than 10% that of a high-end dynamic signal analyzer instrument.

Figure 5 shows the PRD connected across the test sample (light bulb on power strip) power input, across the power output (LISNs) and with its bnc output connected to a 50 Ohm input spectrum analyzer or EMI receiver (not shown).

The PRD is a passive signal conditioner that acts as an attenuator, impedance match, and isolator. The latter property allows the spectrum analyzer/EMI receiver to operate with safety ground intact, while maintaining the isolation of the test sample power return above ground. Attenuation can be either frequency independent, nominally 66 dB[1], individually calibrated, or, at the flip of the right-hand switch (Figure 4), the attenuation above 5 kHz rolls off at 20 dB/decade to match the slope of the MIL-STD-461D/E/F CS101 limit. With this switch position selection, the output of the PRD into the spectrum analyzer/EMI receiver is independent of frequency across the entire CS101 test frequency range at a nominal 70 dBuV, or 3 mV. This allows for very easy testing, even in manual mode, with a cursor or threshold set at the 70 dBuV target.

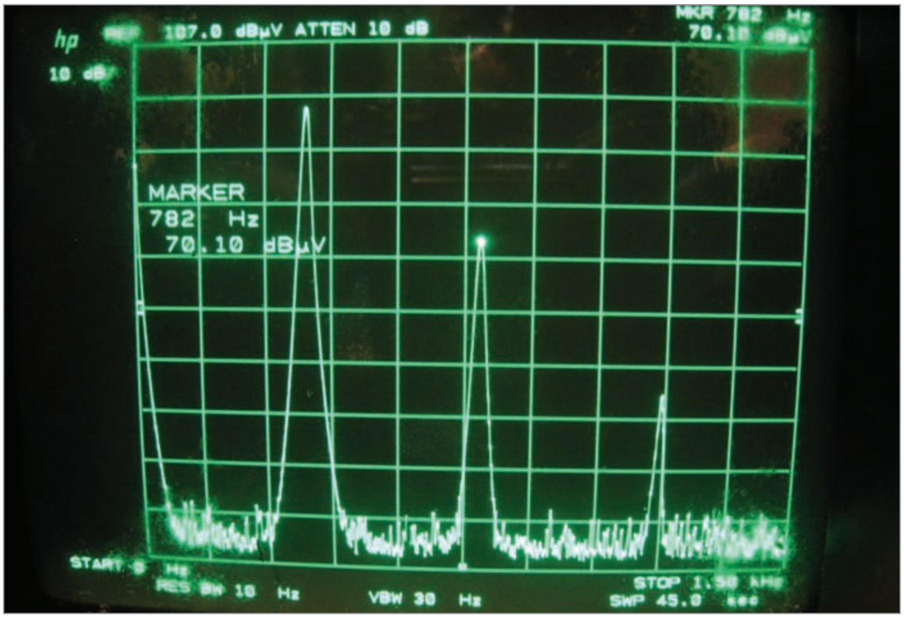


Figure 6: 800 Hz ripple in span containing 400 Hz power bus fundamental and third harmonic

The other switch in Figure 4 selects between the test sample power input and the power source (LISN) end of the test set-up. If the required limit cannot be established across the test sample power input, and the 80 watt limit has been reached, a flip of the switch allows a quick reading of the ripple potential dropped across the power source.

1 The nominal 66 dB factor is for a PRD that works with all power bus potentials up to and including 120 volts, ac (rms) or dc. Another model works on buses from 120 volts to 270 volts, again ac (rms) or dc.

If that level is enough that, added to the ripple across the test sample the sum meets the required limit, then action must be taken to reduce the power source impedance so that the missing ripple potential moves from the power source to the test sample power input. Test methods CS101, RTCA/DO-160 section 18, and similar should require this as a matter of course. Absent this requirement, the test is not well-controlled and repeatable.

In order to interpret Figure 6, the transducer factor of 66 dB must be added to the signal levels shown. The 400 Hz power waveform, thus adjusted, represents (95 dBuV + 66 dB = 161 dBuV) 112 volts, and the 800 Hz ripple at 70.4 dBuV is 136.4 dBuV, right at the limit. Comparison of the Figure 6 frequency domain sweep to the ripple superimposed on the ac bus potential in Figure 2 should say everything that needs to be said if the reader has performed this test before and can envision trying to assess the ripple modulating the peaks of the ac power waveform. For those lacking the experience, the video in the digital edition is instructive.

The ability to measure ripple injected below the power bus frequency is demonstrated by comparing Figures 7 and 8. Again, Figure 8 in the digital edition is a video clip of the low frequency modulation rolling through the 400 Hz waveform. Careful inspection of the snapshot picture reveals that the amplitude is changing from cycle to cycle; the envelope is on the right.

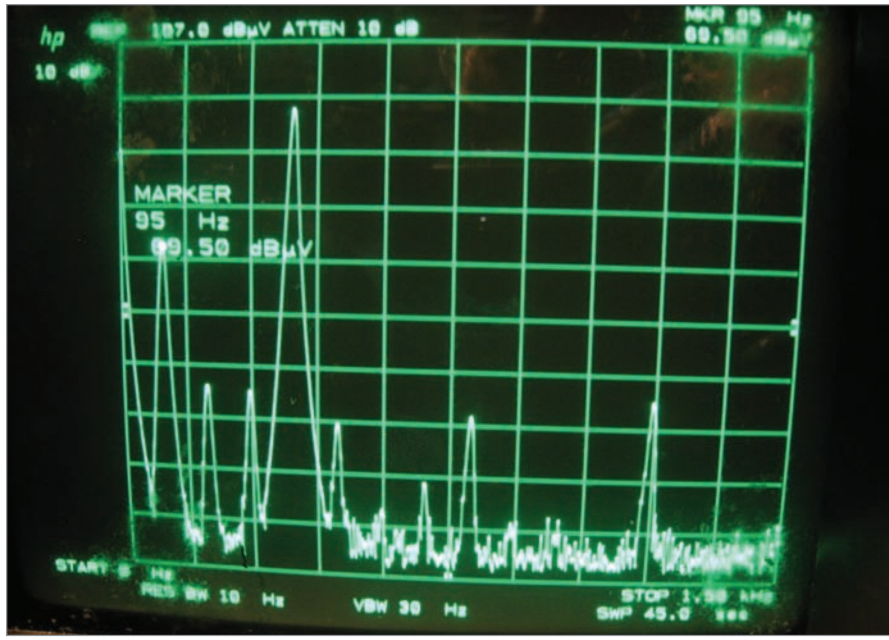


Figure 7: 100 Hz ripple in span from dc to 1 kHz

Absent the proscribed phase shift network, injected 100 Hz ripple on a 400 Hz bus is at best difficult to measure in the time domain because the modulation peaks are separated across many cycles of the ac bus. However, when using the PRD to facilitate a frequency domain measurement, measuring below the power bus frequency is no different than measuring above it.

Injection below the power frequency would be an added benefit for MIL-STD-461G, recovering the spectrum lost since 1993, but injecting ripple below the power frequency is already required in MIL-HDBK-704-2 through -6 (400 cycle, wild frequency and 60 Hz buses). Adoption of the use of the

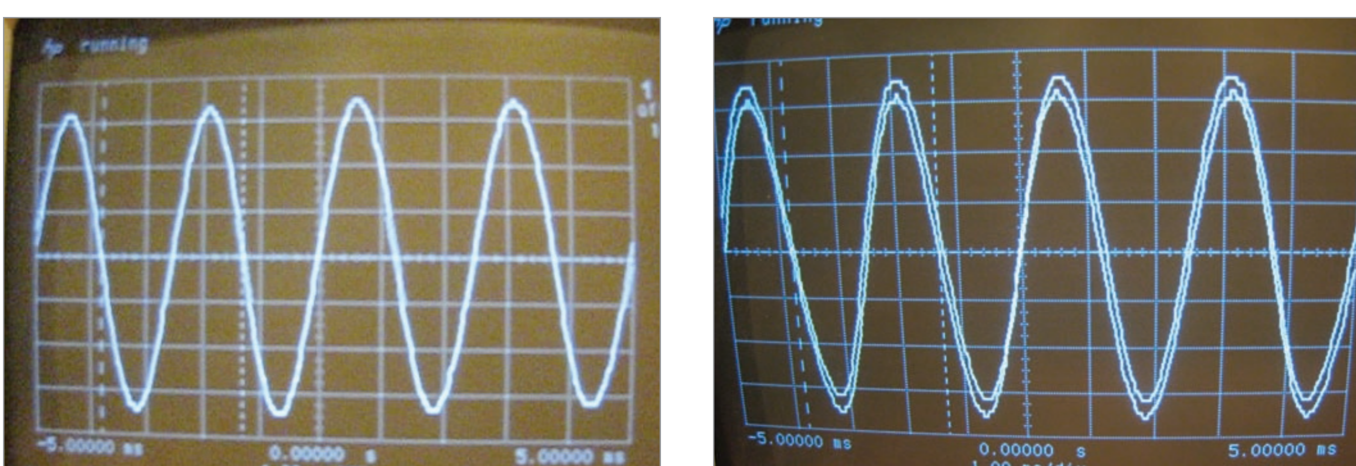


Figure 8: 100 Hz ripple superimposed on 400 Hz power (snapshot left, envelope right)

See our digital edition for actual video footage of this figure: http://www.incompliancemag.com/DigEd/inc1206

PRD's functionality could thus enhance MIL-STD-461, and service existing test methods in MIL-HDBK-704.

Figure 9 shows 6.3 Vrms ripple at 1 kHz using a sweep from 300 Hz to 1.3 kHz. The power frequency and second and third harmonics are visible in addition to the injected ripple. If the span is modified to be centered on the ripple frequency, and just wide enough to display the injected waveform, as in Figure 10, then the same test automation routine that is used with MIL-STD-461 requirement CS114, or RTCA/DO-160 section 20 conducted rf susceptibility, may be applied when automating audio frequency ripple injection. The routine commands both signal source and spectrum analyzer/EMI receiver to the desired frequency, with a specified and fixed span for the analyzer/receiver. With only the injected frequency visible, the analyzer/receiver "marker-to-peak" function is invoked, and then the leveling feedback loop adjusts until the marker is at the desired level. This is how existing automation for rf conducted susceptibility testing is made available for audio frequency conducted susceptibility testing via use of the PRD.

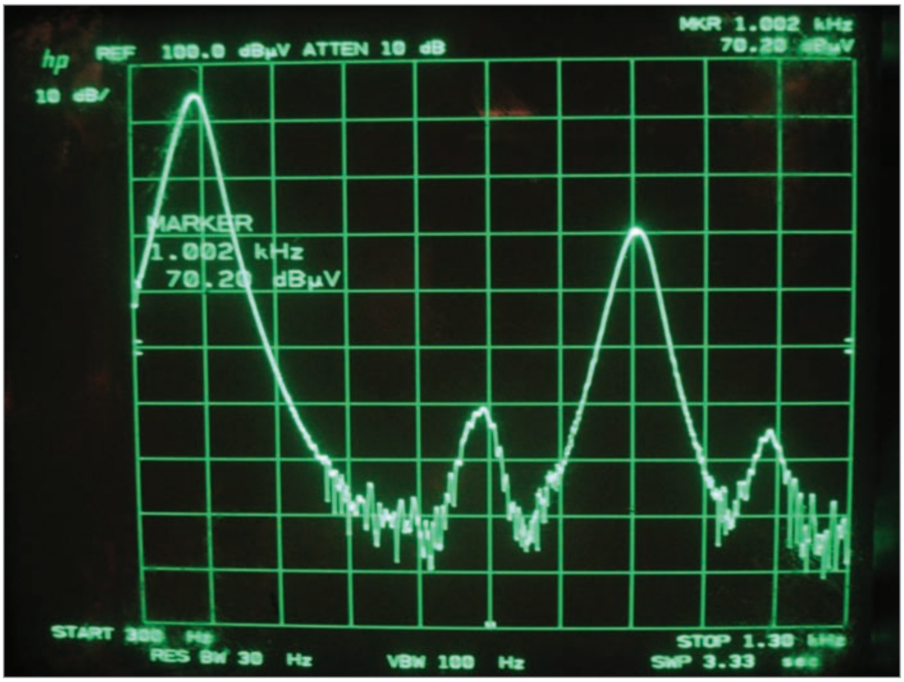


Figure 9: 1 kHz ripple in span to 1300 Hz

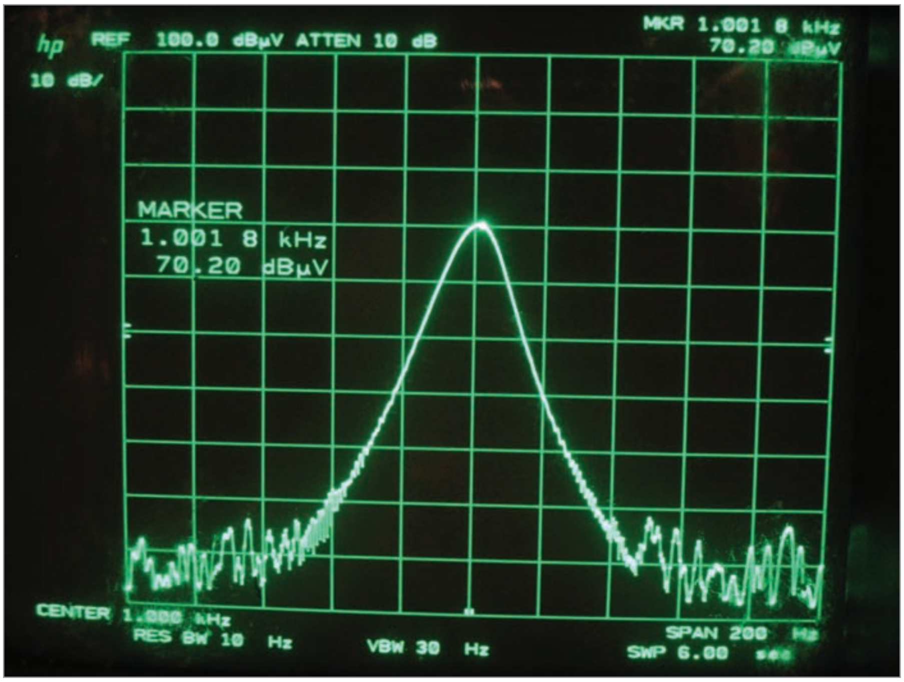


Figure 10: 1 kHz ripple at center of 100 Hz span

The only place this doesn't work well is very close to the power frequency. Prior to 1993, MIL-STD-462 CS01 had an exclusion zone within 10% of the power frequency. Using the MIL-STD-461E/F 6 dB bandwidth of 10 Hz, the closest "approach" to the power frequency at a level 25 dB below the bus potential is 15 Hz away. For 400 cycle or wild frequency power, that is well within the 10% window cited above.[2] Also, any span that includes the power frequency won't be able to use the marker-to-peak function to level on the test signal, because marker-to-peak will seek out the power frequency. If it is possible to have the injected signal at the span center frequency, a "marker-to-center-frequency" command could be used. If that isn't available at very low frequencies, a zero-span command could tune the receiver to the test signal frequency, and excludes all else. This however relies on extremely accurate and stable tuning so that the peak of the test signal is captured.

2 Using a 3 Hz 6 dB BW allows injection within 5 Hz of the power frequency, which meets the 10% window for 50/60 Hz power. A 3 Hz BW is available on many modern EMI receivers, but is not a requirement in MIL-STD-461.

For the record, the PRD's function allowing frequency domain viewing of injected ripple isn't necessary for dc-powered test samples. The device works just as well on a dc as an ac bus and, by providing isolation, removes the need for an isolation transformer on the monitoring device. While the PRD isn't necessary to monitor audio ripple injected on a dc bus, the fact that it can be used simplifies testing in that the set-up, software, and bookkeeping is identical between ac and dc-powered test samples.

CONCLUSION

An inexpensive transducer (PRD) that solves several long-standing issues with audio frequency conducted susceptibility testing has been developed at the EMC Compliance test facility. The PRD facilitates the use of a spectrum analyzer/EMI receiver to monitor injected audio frequency ripple. By separating the injected ripple from the power waveform, the PRD allows accurate and very simple monitoring of the injected waveform, something that has been difficult or extremely expensive to do until now. The PRD inherently provides isolation, so the analyzer/receiver need not be transformer isolated. The PRD also provides a quick check to see if excess ripple is dropped across the power output if not enough is measured across the test sample power input.

The PRD is being commercialized by Pearson Electronics and will be demonstrated at the Pearson Electronics booth during the 2012 EMC Symposium in Pittsburgh.

(the author)

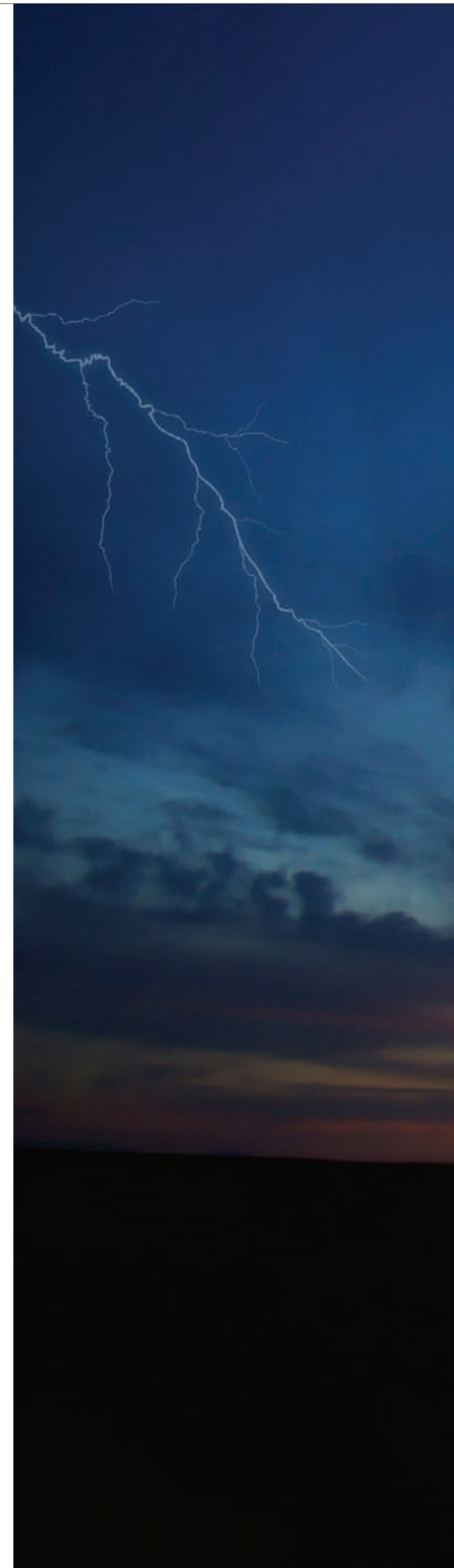
KEN JAVOR

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

Lightning Induced GPR

Why it's a problem, characteristics and simulation

BY AL MARTIN



"My fiber optic equipment is failing in the field. I don't understand why. It doesn't have a wired connection to the communications network, and furthermore it has passed testing to all the usual telecommunication standards, including GR-1089 Core [1], ITU-T K.20 [2], K.21 [3], and K.44 [4]" A previous article (*In Compliance*, September 2011) discussed why fiber optic equipment might fail even though it didn't have a wired connection to the communications network [5], as did a similar article by Rust [6]. Now recent field data have identified ground potential rise (GPR) due to lightning as a significant cause of failure of fiber optic communications equipment, e.g. [7], 0.

If GPR is the problem, what are its characteristics? In [5] the 30,000 A, 3 μsec surge used in the *IEEE Guide for Surge Protection of Equipment Connected to AC Power and Communication Circuits* [8] was assumed to be the one to use in calculating the effects of a GPR. But is it really? If not, what is the driving waveform for a GPR?

To sort out the general issue of what lightning is, a task force was set up under the auspices of the IEEE PES T&D committee to study the issue. This task force included experts from around the world. The task force wrote a summary of their work, which appeared in the January 2005 issue of the IEEE Transactions on Power Delivery [9]. In essence they said that no two lightning surges are the same, and that lightning has to be characterized in statistical rather than absolute terms. What they found is that the essential parameters of lightning – amplitude, rise time, fall time, and charge have a log-normal distribution. A log-normal distribution looks like:

It is necessary to note that lightning surges are of three types: Negative first stroke, positive first stroke, and subsequent [negative] strokes. The character of each is significantly different, and has different implications for protection.

$$f(x,\mu,\sigma)=\left[\frac{1}{x\sigma\sqrt{2\pi}}\right]\exp\left[-\frac{(\ln(x)-\mu)^2}{2\sigma^2}\right] \quad (1)$$

Where μ is the median value of the distribution and σ is its standard deviation.

To apply this distribution to lightning, it is necessary to note that lightning surges are of three types: Negative first stroke, positive first stroke, and subsequent [negative] strokes. The character of each is significantly different, and has different implications for protection. The first strokes typically have a relatively slow rise time, long duration, and higher current than subsequent strokes. The first strokes are generally responsible for damage due to heating, due to their high amplitude and long duration. Subsequent strokes are generally responsible for insulation breakdown, due to their fast rise time. The first stroke is most common and about 10% of first strokes have been classified as positive, although there has been some reclassification of positive strokes as upward lightning (see [10]).

RISE TIMES, FALL TIMES, AND AMPLITUDE

The paper by the task force has tables with the statistical parameters the three stroke types, for use in Equation 1. The parameters for a negative first stroke, excerpted from [9], are shown in Table 1. These values were measured at a tower, or derived from measurements of LEMP [lightning electromagnetic pulse]. This is actually an important point, as different observation points may be the root of some of the disagreement about what the lightning threat is. Anyhow it's useful to get an idea about what we're starting with.

Equation 1 is plotted for rise time in Figure 1, just to show what a log-normal distribution looks like. What is of more interest is the cumulative probability curve, which shows the probability being either greater or less than a chosen value. So for example you might want to know what the probability is of a first-stroke amplitude exceeding 50 kA.

The cumulative probability curve is obtained by integrating the probability distribution, which isn't easy to do. The result is something called an error function. Fortunately it isn't necessary to know anything about the error function – you can just look up its values in a table. That has been done for rise time, fall time and amplitude for a negative first stroke, and the results are shown in Figures 2 – 4.

Parameter	Median	Sigma
Peak amplitude (I_p), kA	31.1	0.48
10 - 90 rise time (T_{10}) μsec	4.5	0.58
Fall time (t_f) μsec	77.5	0.58

Table 1: Statistical parameters of a negative first stroke

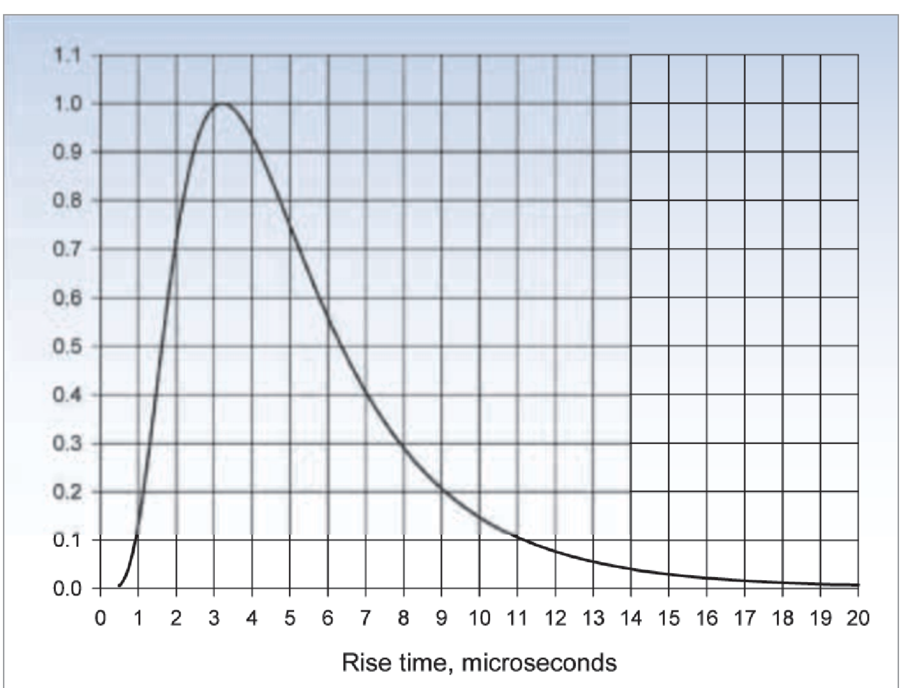


Figure 1: Log-normal distribution of rise time of first negative surge, median = 4.5, standard deviation = 0.58 (Table 1).

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It's important to note that the 3 parameters of rise time, fall time and amplitude are correlated, so they can't be chosen independently. Conditional probability analysis can be carried out to answer correlation questions like, "given a 1 μsec rise time, what is the probability that the amplitude will exceed 20 kA?" Conditional probability analysis is complex, and is better left for another discussion.

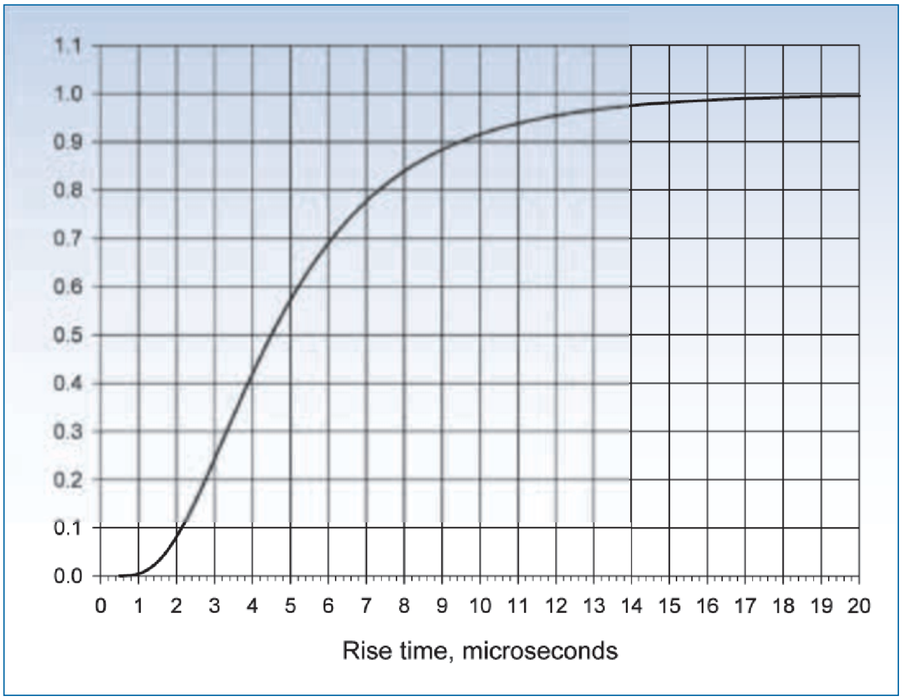

Figure 2: Probability the rise time of first negative surge < chosen value median = 4.5, standard deviation = 0.58 (Table 1)

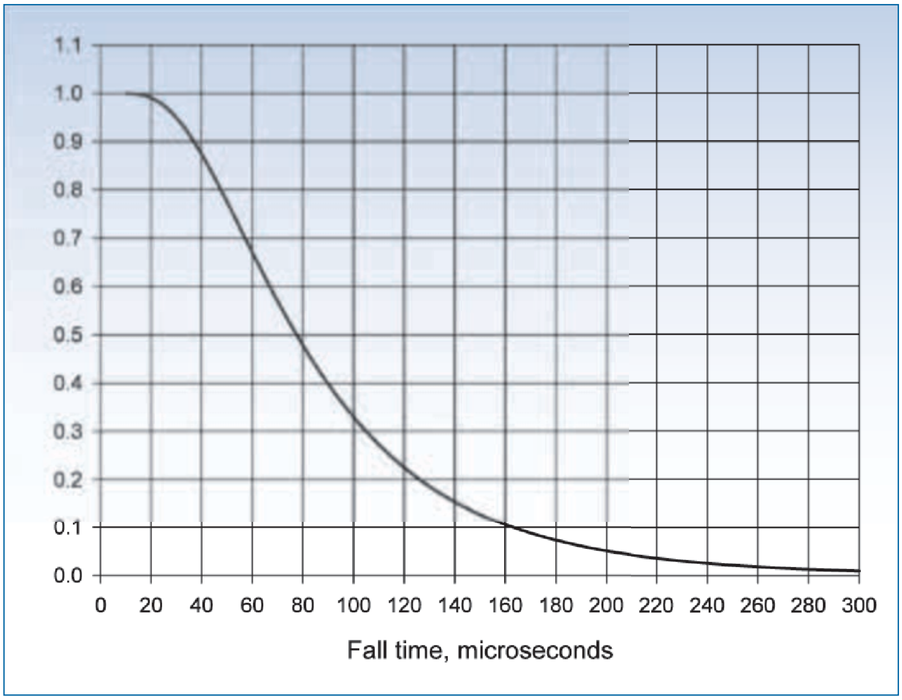

Figure 3: Probability the fall time of first negative surge > chosen value median = 77.5, standard deviation = 0.58 (Table 1)

Parameter	Median	Sigma
Peak amplitude (I_p), kA	12.3	0.53
10 - 90 rise time (T_{10}) μsec	0.6	0.92
Fall time (t_f) μsec	30.2	0.93

Table 2: Statistical parameters of a subsequent stroke

Similar to the negative first stroke, the parameters for a subsequent sroke are shown in Table 2.

Subsequent strokes are mainly of interest for the high di/dt of their rise time, which combined with circuit inductance can produce enough peak voltage to cause insulation breakdown. The cumulative distribution for a subsequent stroke is shown in Figure 5.

Cumulative plots are basically useful for estimating the probability that a chosen design parameter is inadequate. So for example suppose we are worried about L(di/dt) spikes, and are assuming a rise time ≥ 3 μs. What is the probability that the rise time is faster than we assumed? From Figure 2 the answer is that about 24% of the surges could rise in less than 3 μs. So if we are designing protection and assume a rise time ≥ 3 μs we may have inadequate protection 24% of the time. Characterizations of this sort are most accurate in the vicinity of the mean, and are less accurate out in the tails of the distributions.

COMMENTS

The telecom standards we have today were based on measurements made on wireline systems. As long as the subject is wireline equipment, these standards are appropriate. And indeed wireline equipment tested to these standards has proven reliable in the field. But fiber and wireless systems are different. They are not connected to the external network with wires, so the damage to these systems could be caused by the surges that are quite different from those defined in the existing wireline standards. In fact there is some evidence that fiber systems that have been successfully tested to the wireline standards have had a significant failure rate in the field. A possibility for this result is that damage was caused by a GPR which had a significantly different waveform from those defined in wireline standards. So the waveforms discussed here are probably more appropriate for testing.

APPROPRIATE SURGE GENERATORS

Supposing you wanted to create a standard for testing equipment for resistibility to a GPR surge; or maybe a surge to use for failure analysis testing. Which waveform would you choose? Considering the statistics discussed earlier, there is a wide range to choose from. In absence of other guidance, the 4.4/ 78 median surge waveshape defined in Table 1 would be a place to start. Now there is a problem – we don't have a generator that does a 4.5/ 78 waveshape. But maybe an 8/20 combination generator would suffice.

The 8/20 generator waveshape varies with the external resistance connected to it, so that needs to be taken into account. Mick Maytum has calculated the rise time of an 8/20 combination generator as a function of external circuit resistance [11]. These range from 1.59 µs for a 20 ohm load on the generator to 8 µs for a short circuit. We can use these values and values from the probability curve for a negative first stroke to make a plot of the probability that an 8/20 generator would simulate the rise time of a GPR surge vs the external resistance. The result is shown in Figure 6.

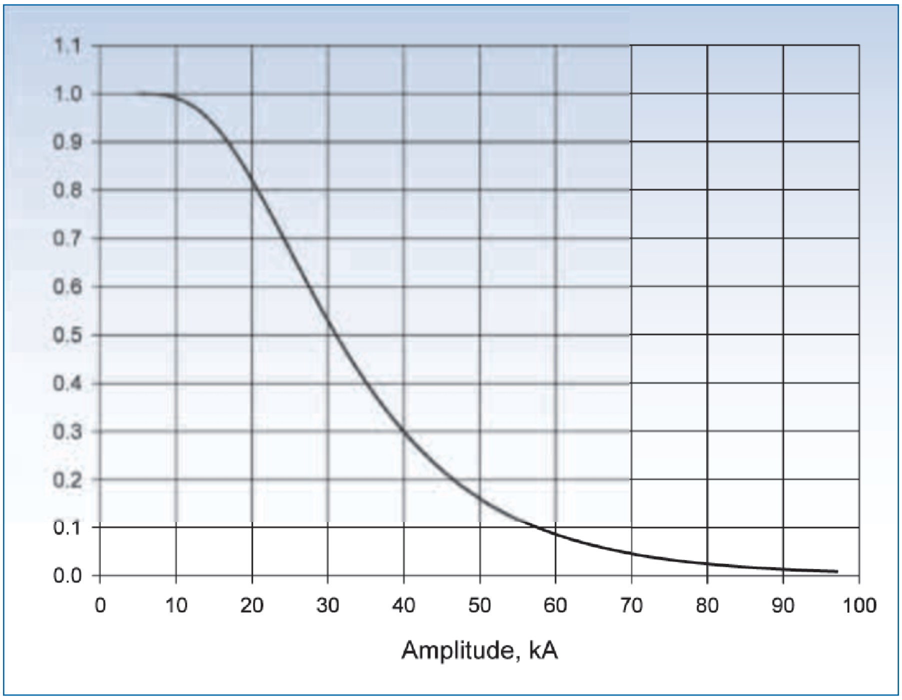

Figure 4: Probability the amplitude of first negative surge > chosen value median = 31.1, standard deviation = 0.48 (Table 1)

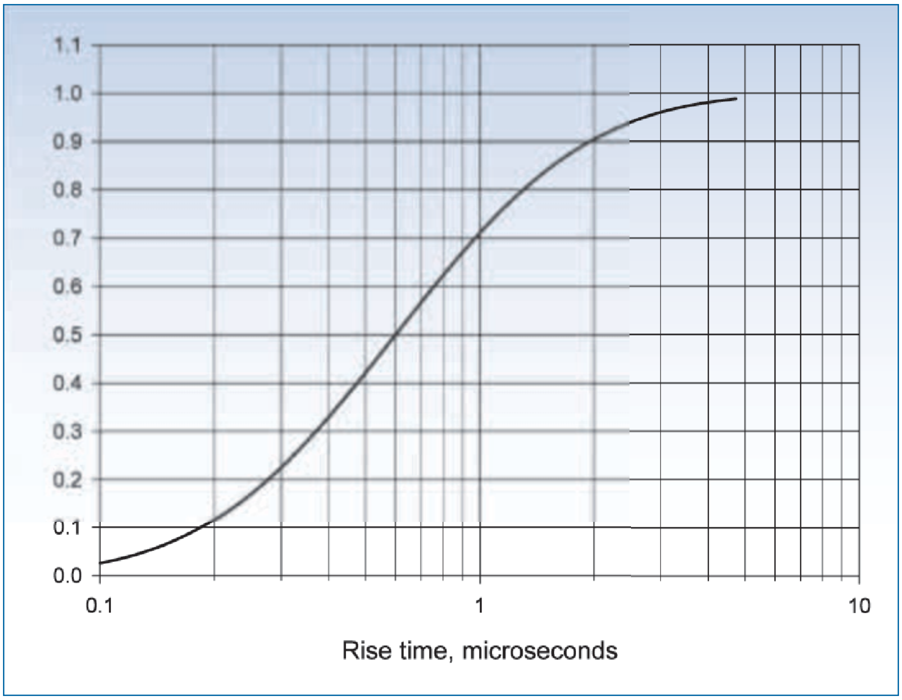

Figure 5: Probability the rise time of subsequent surge < chosen value median = 0.6, standard deviation = 0.92 (Table 2).

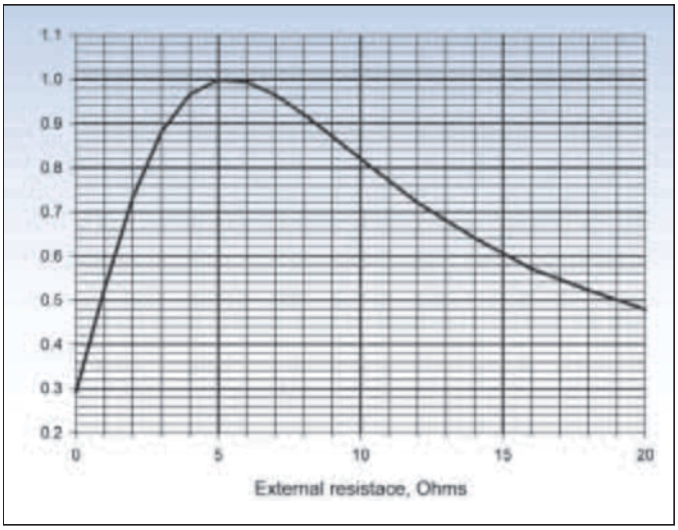

Figure 6: Probability that the rise-time of an 8/20 generator approximates the most-likely rise time of a 4.5/78 negative first stroke

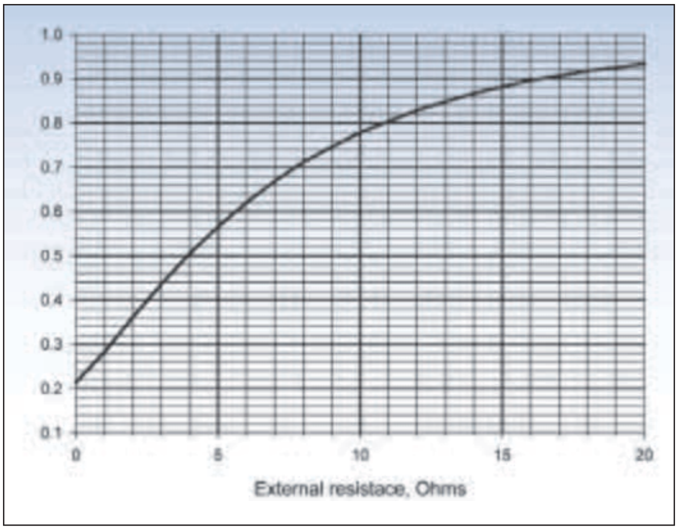

Figure 7: Probability that the fall-time of an 8/20 generator approximates the most likely fall time of a 4.5/78 negative first stroke

What this plot says is that an 8/20 combination wave generator with 5 ohms external resistance is most likely to simulate the rise time of a negative first surge with a median rise time of 4.5 µs. It also says that an 8/20 combination wave generator with an external resistance between about 1 and 19 ohms is at least a 50% as likely to simulate a negative first surge with a median rise time of 4.5 µs as the generator with a 5 ohm external resistance

Similarly we can use Maytum's values for fall time to make a plot of the probability that an 8/20 generator would simulate the fall time of a GPR surge vs the external resistance. The result is shown in Figure 7.

What this plot says is that an 8/20 combination wave generator with any external resistance is seldom likely to simulate the most probable fall time of a negative first surge with a median fall time of 78 µs. It also says that an 8/20 combination wave generator with an external resistance greater than 4 ohms has at least a 50% chance to simulate a negative first surge with a median fall time of 78 µs and a most-likely fall time of about 55 µs.

So the conclusion is that an 8/20 combination wave generator produces a reasonable simulation of a first negative stroke GPR. Positive first strokes are pretty rare, so we probably don't need to worry about those. What about subsequent strokes?

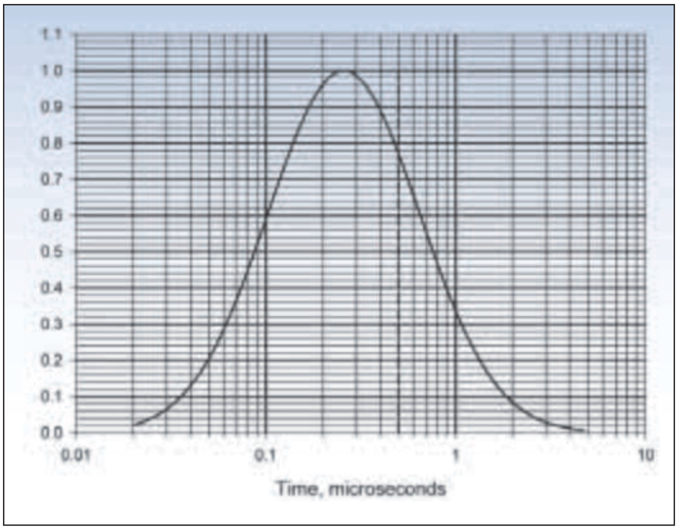

Figure 8: Log-normal distribution of rise time of a subsequent surge. Dashed line is ring-wave generator rise time

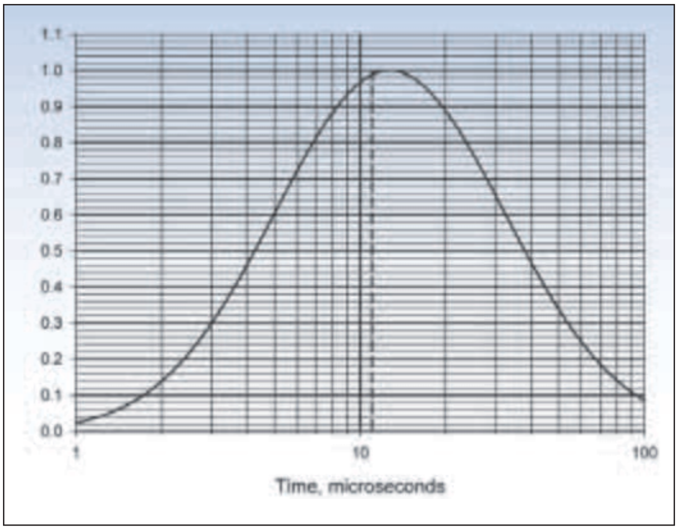

Figure 9: Log-normal distribution of fall time of a subsequent surge. Dashed line is ring-wave generator fall time

Many waveforms have been proposed to simulate the effects of lightning. The point of this discussion has been to select the most suitable ones for evaluating equipment resistibility to damage when a GPR is either the suspected source of the damage, or its effects are to be tested for.

To simulate a subsequent stroke, a generator with a faster rise time than the generally available double-exponential generators is needed. The best candidate appears to be the ring-wave generator defined in IEEE Std C62.41.2-2002™. It has a 0.5 µs rise time and a fall time of about 11 µs. Referring to Figure 8, the ring wave generator with a 0.5 µs rise time has a 76% probability of representing the most likely rise time of a subsequent surge with a median rise time of 0.6 µs.

Similarly, Figure 9 for the fall time of a subsequent surge shows that the ring wave generator has a 99% probability of representing the most likely fall time of a subsequent surge with a median fall time of 30.2 µs.

So the conclusion is that a ring-wave generator produces a reasonable simulation of a subsequent stroke GPR.

CONCLUSIONS

Both in standards and in the general literature many waveforms have been proposed to simulate the effects of lightning. The point of this discussion has been to select the most suitable ones for evaluating equipment resistibility to damage when a GPR is either the suspected source of the damage, or its effects are to be tested for. With that in mind:

- An 8/20 combination generator can be used to simulate the heating and the insulation breakdown effects of a negative first strike.
- A ring-wave generator can be used to simulate the insulation breakdown effects of a subsequent surge. It could also be used to simulate the heating effects of a subsequent strike, but that is generally not an issue.

REFERENCES

1. *Electromagnetic Compatibility (EMC) and Electrical Safety – Generic Criteria for Network Telecommunications Equipment.* Telcordia Technologies, Piscataway, N.J.
2. "Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents", *Recommendation K.20,* ITU Telecommunication Standardization Sector (ITU-T), Geneva, Switzerland
3. "Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents", *Recommendation K.21,* ITU Telecommunication Standardization Sector (ITU-T), Geneva, Switzerland
4. "Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation, *Recommendation K.44,* ITU Telecommunication Standardization Sector (ITU-T), Geneva, Switzerland
5. A. Martin, "Lightning Damage to Equipment without a Metallic Connection to an External Communications Service", *In Compliance Magazine*, September, 2011, pp40-47.
6. R. Rust, "Do it the Right Way", *OSP Magazine*, Aug 9, 2011
7. T. Miyazaki, T. Ishii, and S. Okabe, "A Field Study of Lightning Surges Propagating Into Residences", IEEE Trans. ON EMC, Vol. 52, NO. 4, Nov. 2010
8. M. J. Maytum, "Lightning Damage of Home Network Ports", *ATIS PEG Conference 2011 Presentations.* Alliance for Telecommunications Industry Solutions (ATIS) www.atis.org
9. R. L. Cohen, D. Dorr, J. Funke, C. Jensen and S. F. Waterer. *How To Protect Your House and Its Contents From Lightning: IEEE Guide for Surge Protection of Equipment Connected to AC Power and Communication Circuits.* 2005, ISBN: 0-7381-4634-X
10. "Parameters of Lightning Strokes: A Review". *IEEE Trans. On Power Delivery, Vol 20, No. 1, January 2005.*
11. B. Glushakow, "10/350 Lightning Test Waveform in Focus", *XI International Symposium on Lightning Protection,* 3rd-7th October, 2011Fortaleza, Brazil
12. M. J. Maytum, "The 2003 ITU-T Telecommunication Equipment Resistibility Recommendations," *Compliance Engineering 2004 Reference Guide,* Figure 5. Combination generator current waveshape variation with external load.

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We wish to thank our community of knowledgeable authors, indeed, experts in their field - who come together to bring you each issue of *In Compliance*. Their contributions of informative articles continue to move technology forward.

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