FEBRUARY 2012

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PLUS

The Early Pioneers of the EMC Society

Today's Pioneers of EMC

A Historical Look Back
The 1977 CBEMA Paper on Electromagnetic Emanations Part 3

Letter from the editor

The Pioneer of Spread Spectrum Technology

In this issue we pay tribute to the Pioneers of EMC, past and present. Dan Hoolihan and Gene Taylor introduce us to some of the dedicated engineers who set the foundation of today's EMC community.

There are many brilliant engineers who have made significant contributions to the field of electrical engineering. As a woman-owned business ourselves, it seemed fitting to mention a female pioneer. Better known for her beauty and acting talent than her engineering talent, Hollywood actress Hedy Lamarr, born Hedwig Eva Maria Kiesler (1914), was also a co-inventor (with George Antheil) of a secret communication system.

Filed June 10, 1941, Patent No. 2,292,387 was issued to Hedy Kiesler Markey (LaMarr) and George Antheil on August 11, 1942 for their "Secret Communication System." Original drawings and patent information can be viewed online www.google.com/patents/US2292387.

LaMarr's secret communication system was based on radio frequencies changing at irregular periods that were synchronized between transmitter and receiver. The purpose of the invention was to provide a simple, reliable method of secret communication that was difficult to decipher and would be useful in the remote control of dirigible craft, such as torpedoes. The two donated their patent as their contribution to the war effort, but the invention was deemed impractical to implement and not used during World War II. However, twenty years later, during the Cuban Missile Crisis, the secret communication system was installed on naval ships and subsequently extensively used in other military applications. The spread spectrum technology Lamarr helped to invent would become the foundation of digital communications evolving into today's cell technology and wireless applications.

Lamarr was recognized for her significant contribution to technology in 1997, when she and Anthiel were honored with the Electronic Frontier Foundation Pioneer Award and the BULBIE™ Gnass Spirit of Achievement Award, "The Oscar™" of inventing.

Until next time,

Lorie Nichols
Editor
editor@incompliancemag.com

IN COMPLIANCE

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Volume 4 • Number 2

Electromagnetic Compatibility Engineering

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

Henry Ott

April 17-19, 2012
Wyndham Peachtree Conference Center
Peachtree City, GA

Presented by Henry Ott Consultants
in partnership with
IN COMPLIANCE Magazine

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

COURSE CONTENT

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

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

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

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

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

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

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

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

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

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

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

EMC EXHIBITS AND EVENING RECEPTION: WEDNESDAY, APRIL 18, 2012
Exhibitors:for information contact Sharon Smith - e-mail: sharon.smith@incompliancemag.com or call (978) 873-7722

REGISTRATION

COURSE DATES/TIME: April 17-19, 2012
Tuesday and Thursday 8:30 a.m. to 4:30 p.m.
Wednesday 8:30 a.m. to 5:00 p.m.

COURSE LOCATION: Wyndham Peachtree Conference Center, 2443 Highway 54 West, Peachtree City, GA 30269

COURSE FEE: $1,495 ($1,295 until 3/2/2012). Fee includes notes, textbook*, breakfast, luncheon and beverage breaks. Payment required prior to course. Hotel accommodations are NOT included.

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

TO REGISTER: Call 973-992-1793, fax 973-533-1442 or mail the registration form.

HOTEL RESERVATIONS: Call the Wyndham Peachtree Conference Center toll free at 877-999-3223 or 770-487-2000. Room rates are $129 per night. Government rate is $79 (must have proper ID). Room rates are good until 10 days prior to the conference and based on availability. You must mention In Compliance Magazine when making reservations to get this special rate. The hotel is holding a limited block of rooms.

*Electromagnetic Compatibility Engineering, by Henry W. Ott

Who Should Attend

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

Feedback from recent participants

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

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

"Henry is the best in EMC."

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

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

"Really happy I flew all the way here."

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

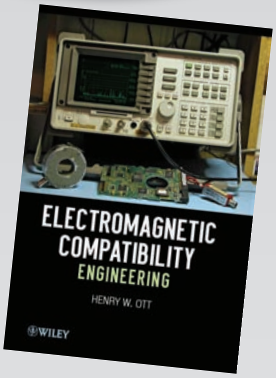
"Should be required training for all engineers."

"This is the best practical course available."

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

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

Includes Henry Ott's latest book!



HENRY OTT

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

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

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

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

REGISTRATION FORM

Register by 3/2/12 and save $200!

ELECTROMAGNETIC COMPATIBILITY ENGINEERING
April 17-19, 2012 Wyndham Peachtree Conference Center, Peachtree City, GA
Fee: $1,495
Payment required prior to start of course.

Name: ______________________________

Title: ______________________________

Company: ______________________________

Address: ______________________________

City: ____________ **State:** ______ **Zip:** ________

PAYMENT METHOD

❍ Check ❍ P.O. ❍ AMEX

❍ Discover ❍ Visa ❍ MC

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

News in Compliance

FCC News

FCC Allocates Spectrum for New Medical Technologies

The U.S. Federal Communications Commission (FCC) has adopted rules aimed at speeding the development of wireless medical devices that could help to restore the functioning of paralyzed human limbs.

The Commission's action came in response to a petition from the Alfred Mann Foundation to allow so-call medical micropower networks (MNNs) to utilize parts of the electromagnetic spectrum. MNNs are ultra-low power wideband networks consisting of multiple transmitters implanted in the body that use electric currents to activate and monitor nerves and muscles. The Mann Foundation had reportedly built prototype MNN systems and sought FCC approval that would allow for the actual use of the systems in patients.

In a Report and Order issued in November 2011, the Commission moved to expand the Medical Device Radiocommunications (MedRadio) Service under Part 95 of its rules to permit the use of MNNs in selected portions of the spectrum. The FCC noted that its action advances its broadband healthcare agenda and will improve the quality of life for individuals who have suffered spinal cord injuries, traumatic brain injuries, strokes and other neuromusculoskeletal disorders. The complete text of the Commission's Report and Order is available at www.incompliancemag.com/news/1202_01.

FCC Regulates TV Commercial Sound Levels

The U.S. Federal Communications Commission (FCC) has addressed one of the most vexing problems facing consumers; that is, the sound level of television commercials.

In a Report and Order issued in December 2011, the Commission implemented the provisions of the Commercial Advertisement Loudness Mitigation (CALM) Act, passed by the U.S. Congress in 2010. Under the Commission's new rules, commercials must have the same average volume as the television programs they accompany. Compliance with the requirement is specifically demonstrated by a broadcaster's application of the guidance detailed in the Recommended Practice developed by the Advanced Television Systems Committee in 2009 and the use of Recommendation BS 1770 measurement algorithm developed by the International Telecommunication Union.

The new commercial sound level rules apply to digital TV broadcasters, digital cable operators and other digital multichannel video programming distributors and become effective in December 2012.

The complete text of the Commission's Report and Order on its implementation of the CALM Act is available at www.incompliancemag.com/news/1202_02.

FCC Releases Latest Telephone Subscribership Report

The Federal Communications Commission (FCC) has released its most recent report on telephone subscriber levels in the United States.
The report, which is based on July 2011 statistics from the Census Bureau, provides subscriber penetration statistics by state, income level, race, age, household size and employment status. Among the report's highlights are the following key findings:

- The telephone subscriber penetration rate actually decreased from the penetration rate achieved in July 2010, from 96.0% to 95.6%. The Commission says that the decrease is not considered statistically significant.

FCC News

- The penetration rate for households with incomes below $20,000 was at or below 94.7%, while the rate for households in income categories over $75,000 was at least 98.9%.
- Penetration rates by state range from a high of 98.5% in Connecticut and North Dakota, to a low of 91.4% in Tennessee.
- The penetration rate was 96.7% for employed adults, and 95.1% for unemployed adults.

The Commission says that its continuing analysis of telephone service penetration statistics allows it to examine the aggregate effects of its actions and industry changes on consumers' decisions to maintain, acquire or drop telephone service.

The complete text of the Commission's latest report on telephone subscribership in the United States is available at www.incompliancemag.com/news/1202_03.

FCC Announces "Apps for Communities" Awards

The U.S. Federal Communications Commission (FCC) has announced the winners of its first Apps for Communities Challenge, which fosters the development of applications to connect those with limited Internet access to online information.

A total of $100,000 was awarded to 13 different entrants, who submitted applications that offer help to people looking for jobs, connect the homeless with needed services, and advise public transportation riders of the arrival time of the next bus. The awards were announced by FCC Chairman Julius Genachowski in December 2011.

The Apps for Communities Challenge is a joint effort of the FCC and the John S. and James L. Knight Foundation. Additional information is available at http://appsforcommunities.challenge.gov.

News in Compliance

UL Standards Updates

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

Standards

UL 209: Standard for Cellular Metal Floor Raceways and Fittings
New Edition dated December 20, 2011

UL 541: Standard for Refrigerated Vending Machines
New Edition dated December 30, 2011

UL 1557: Standard for Electrically Isolated Semiconductor Devices
New Edition dated December 29, 2011

UL 60745-2-13: Hand-Held Motor-Operated Electric Tools - Safety - Part 2-13: Particular Requirements for Chain Saws
New Edition dated December 8, 2011

Revisions

UL 94: Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
Revision dated December 7, 2011

UL 96A: Standard for Installation Requirements for Lightning Protection Systems
Revision dated December 5, 2011

UL 515: Standard for Electrical Resistance Heat Tracing for Commercial and Industrial Applications
Revision dated November 30, 2011

UL 783: Standard for Electric Flashlights and Lanterns for Use in Hazardous (Classified) Locations
Revision dated November 30, 2011

UL 857: Busways
Revision dated December 9, 2011

UL 1439: Standard for Tests for Sharpness of Edges on Equipment
Revision dated December 9, 2011

UL 1446: Standard for Systems of Insulating Materials - General
Revision dated December 6, 2011

UL 1703: Standard for Flat-Plate Photovoltaic Modules and Panels
Revision dated December 6, 2011

UL 2167: Standard for Water Mist Nozzles for Fire Protection Service
Revision dated November 30, 2011

UL 2785: Standard for Sustainability for Printing Cartridges
Revision dated December 7, 2011

UL 110: Interim Sustainability Requirements for Mobile Phones
Revision dated December 22, 2011

UL 880: Standard for Sustainability for Manufacturing Organizations
Revision dated December 21, 2011

UL 1821: Standard for Thermoplastic Sprinkler Pipe and Fittings for Fire Protection Service
Revision dated December 15, 2011

UL 2267: Standard for Fuel Cell Power Systems for Installation in Industrial Electric Trucks
Revision dated December 20, 2011

UL 60950-1: Information Technology Equipment - Safety - Part 1: General Requirements
Revision dated December 19, 2011

UL 60950-22: Information Technology Equipment - Safety - Part 22: Equipment to be Installed Outdoors
Revision dated December 19, 2011

Correction

In the January 2012 issue, in the article "Furthering Your Professional Development in 2012" (page 53) we erroneously listed the IEEE EMC Society Regional Event being held in September 2012 under the heading Milwaukee, WI. Please note, this event is held by the Minneapolis, MN Chapter in Bloomington, MN.

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

Send news items to the editor:

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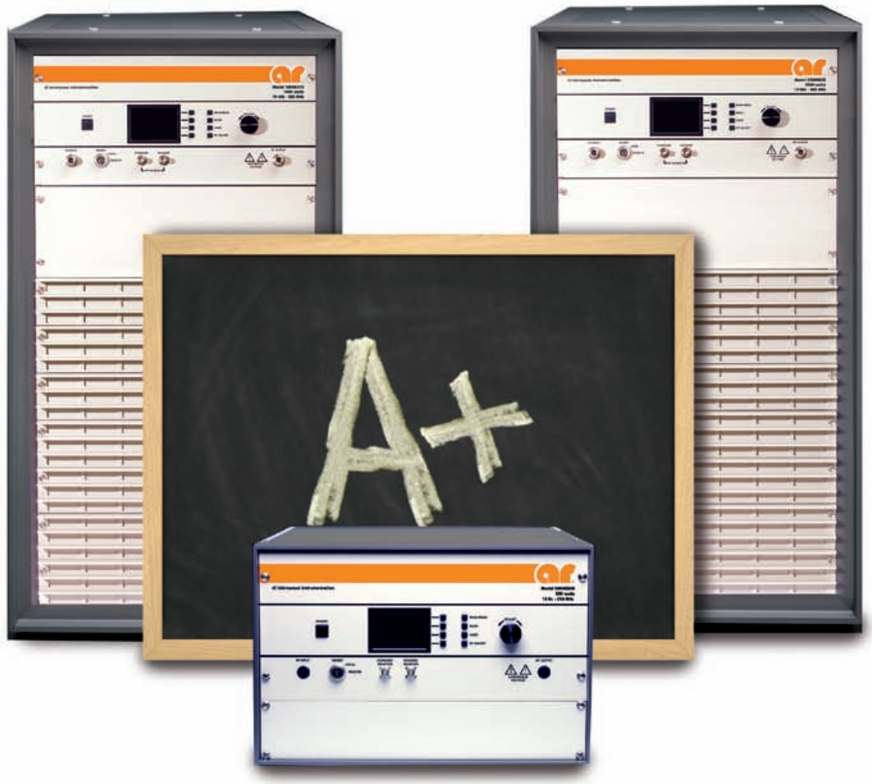
Maybe We Should Have Called It The A+ Series.



Our New "A" Series uses less energy, delivers more power, is lighter, smaller, and delivers a better price performance ratio.

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They feature the latest FET technology, and can be controlled remotely with IEEE, RS-232, USB and Ethernet interfaces. And with all these innovative features, our "A" Series amps use less energy, that's good for you and good for the environment. Our new "A" series also comes with enhanced cooling technology.

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News in Compliance

CPSC News

CPSC Launches Registry for Small Batch Children's Manufacturers

The U.S. Consumer Product Safety Commission (CPSC) has launched a new online registry for certain manufacturers of children's products.

According to the CPSC, the new small batch manufacturers' registry is intended for manufacturers who earned $1 million of less in total gross revenues from the sale of consumer products in 2011, and who produced in total no more than 7500 units of at least one consumer product.

Under current CPSC regulations, manufacturers who meet these criteria are except from having certain categories of products evaluated by outside testing laboratories during 2012. However, they are still required to meet all applicable safety standards related to their products, and provide a certificate of conformity attesting to the product's compliance with those requirements.

The new registry provides a mechanism for qualifying manufacturers to formally demonstrate to retailers and other interested parties their exemption from the third-party testing requirement.

Additional information about the CPSC small batch manufacturers' registry and the third-party testing exemption is available at www.cpsc.gov/smallbatch.

Replacement Battery Packs Present Explosion Hazard

BatteriesPlus of Hartland, WI is recalling nearly 112,000 Rayovac NI-CD cordless tool battery packs manufactured in China.

According to BatteriesPlus, the replacement battery pack can explode unexpectedly, posing a risk of serious injury to consumers. The company has received five reports of explosions related to the recalled battery packs, but no reports of injuries.

The recall battery packs were sold through BatteriesPlus retail stores nationwide and online at the company's website between June 2008 and October 2011 for about $60.

Additional details about this recall are available at www.incompliancemag.com/news/1202_04.

Hamilton Beach Recalls Toasters Due to Fire Hazard

Hamilton Beach Brands of Glen Allen, VA has announced the recall of about 14,000 of its Hamilton Beach-brand classic chrome 2-slice toaster manufactured in China.

The company says that, when the toasters are first plugged into the outlets, the heating element can be energized even though the toaster lifter is in the up or off position. This condition can pose a fire hazard if the toaster is near flammable items. Hamilton Beach says that it has receive five reports of toasters being energized when first plugged into an outlet, but no reports of injuries or property damage.

The recalled toasters were sold through mass merchandisers and department, grocery and home center stores nationwide from August 2011 through November 2011 for between $19 and $34. In addition, some of these toasters were sent to consumers as replacements for a different toaster model originally recalled in June 2011.

More information about this recall is available at www.incompliancemag.com/news/1202_05.

You Can't Make This Stuff Up

California's Pacific Gas and Electric Company (PG&E) probably can't be blamed for the timing of this coincidence. But there are no doubt some red faces at the company's offices as a result of a recent natural gas explosion that destroyed a Cupertino condominium.

In the immediate aftermath of the explosion which took place last September 1st, PG&E crews needed nearly 90 minutes to shut off the gas to the pipeline that exploded. Further investigation at the scene determined that there were no fewer than seven separate leaks in the gas lines running into and out of the building, and that there was no central shutoff valve nearby that could have quickly stopped the flow of natural gas.

Ironically, the day before the Cupertino gas explosion, PG&E was excoriated in a report released by the U.S. National Transportation Safety Board (NTSB) which documented the causes of a September 2010 natural gas explosion in a residential neighborhood in San Bruno, CA, in which eight people were killed and dozens more injured.

In the report, the NTSB cited PG&E for its "lax approach to pipeline safety" and stated that "PG&E's inadequate pipeline integrity management program failed to identify, detect, and remove the substandard pipe segments before they ruptured."

European Union News

New U.S./EU Conformity Assessment Bodies for EMC, Telecom Equipment

The United States and the European Union (EU) have expanded the list of conformity assessment bodies (CABs) authorized to conduct testing to electromagnetic compatibility and telecommunications equipment requirements.

Published in the *Official Journal of the European Union* in December 2011, the action adds MiCOM Labs of Pleasanton, CA and Nemko, USA, Inc. of Lewisville, TX to the list of U.S.-based CABs authorized to conduct testing to EU requirements. In addition, Intertek Semko AB of Krista, Sweden has been added to the list of EU-based CABs authorized to conduct testing to U.S. requirements.

Under the terms of a mutual recognition agreement (MRA) originally implemented in 1998, the United States and the EU recognize the results of conformity assessment activities performed in the exporting country conducted by authorized CABs. Testing to the requirements related to EMC and telecommunications equipment fall under the scope of the MRA.

The complete text of the action is available at www.incompliancemag.com/news/1202_06.

EU Commission Amends InVitro Medical Devices Directive

The Commission of the European Union (EU) has amended its Directive 98/79/EC on in-vitro medical devices. Published in December 2011 in the *Official Journal of the European Union*, the Commission's action adds assays for blood screening, diagnosis and confirmation of "Variant Creutzfeldt-Jakob disease" (vCJD) to List A of Annex II of the Directive. The change was made at the request of the United Kingdom, and the complete text of the Commission's action is available at www.incompliancemag.com/news/1202_07.

The Commission of the European Union New has expanded its list of CABs authorized to conduct testing to electromagnetic compatibility and telecommunications equipment requirements. It has also amended the InVitro Medical Devices Directive.

iNARTE Informer

What's New in 2012

As many readers will have already noticed, iNARTE fees for most certification applications and renewals have had to be increased this year. The last time we increased fees was back in January 2007, since which time we have been able to maintain a balanced budget by supplementing certification revenue with other activities, such as FCC Licencensure, workshop administration, book sales and royalties.

Finally in 2011 the economy and other circumstances have caught up with us. The FCC now issues lifetime licenses, so no renewal income there. Companies are no longer funding workshop attendance and tutorials as once they did, and today it seems that engineers are being asked to do more and more with less and less, so hardly any time is left for these activities, however valuable they might be in the long run. As a result our certification activities have to become self supporting in 2012. Our revised fee structure, together with the introduction of some new and exciting certification opportunities, is forecast to allow growth without further fee changes in the foreseeable future.

WHAT IS NEW IN 2012?

The fees for the **EMC Design Engineer Certification** program, launched in 2011, will not be changed and it is off to a great start. The Grandfather period in the USA for **Master EMC Design Engineers** closed on December 31st, 2011 with over 80 applications. Grandfathering for overseas residents is still active. The first examinations for the Engineer level applicant were conducted in Japan last October with almost 40 applicants. In 2012 the next level of this program for **Senior EMC Design Engineers** will be available. Here is a brief review of the program:

- This certification is intended for Engineers having the responsibility to apply EMC principles to ensure conformity in electronic design. Our traditional EMC Certification program was more geared towards EMC and EMI testing and mitigating engineering. Holding both credentials should be exceptionally valuable.
- The **EMC Design Engineer** certificate is intended for the graduate engineer just starting their career in design, or perhaps having just two or three years of practical work experience.
- The **Senior EMC Design Engineer** certificate is for the experienced engineer that has more than four or five years of design work experience.
- If there are any **Master EMC Design Engineers** out there who missed out on the Grandfather period, we can still accommodate you, but now there will be an examination involved.
- All certificates are lifetime awards, so no annual renewal requirements. However engineers and senior engineers can apply for upgrades after two years at their current levels.
- You can apply now for examination at any of our Authorized Test Centers. There is no need to wait for the EMCS 2012 Symposium. But remember, most test centers also require a

The lapel pin

Certified Master EMC Design Engineer

Certified Senior EMC Design Engineer

Certified EMC Design Engineer

proctoring fee that you can avoid by examining at any of the iNARTE supported special events; the EMCS symposium, the PSES symposium or the ESDA symposium.

Design artwork for the Lapel Pins and logos that Certified Design will be eligible to use are shown on page 14.

In addition, iNARTE will also be introducing new certification opportunities in 2012 for engineers and technicians having certain specialized knowledge and experience:

MIL-STD EMC Specialist, the details of which are already published on our web site at http://www.narte.org/h/milstdemcspecialist.asp.

Spectrum Management Specialist, the purpose of which is to create a credential that ensures a uniform level of expertise and quality for engineers having spectrum management and frequency coordination responsibilities.

Wireless Regulatory Compliance Specialist, the purpose of which is to ensure the correct interpretation of regulatory requirements for this complex family of equipment, and a uniform application of the rules for compliance.

REGISTER FOR CERTIFICATION EXAMS

A visit to the iNARTE web site at www.narte.org will enable you to get all the details of our current programs. If you have any questions about your qualifications for a particular program, or to find which program may best suit your career goals, please call or email us directly.

When you are ready for the iNARTE examination phase of your program, visit our web site at http://www.narte.org/h/testcenters.asp to find a convenient iNARTE Authorized Test Center. If none of our centers are suitably located, we can make alternative arrangements for you.

Also remember that we will be offering examination for any of our programs at several technical conferences and symposia this year. Watch our web site for Coming Events Information and then book your examination at one of these special events. Arrangements like this could save you and your company additional travel and proctoring expenses.

Here are the major events in 2012 where we will be offering these services:

- IEEE EMCS Symposium: August 5-10, Pittsburgh, PA
- EOS/ESD Symposium: September 9-14, Tucson, AZ
- IEEE PSES Symposium: November 5-7, Portland OR

QUESTION OF THE MONTH

Last month we asked:

A product being evaluated for product safety is provided with an interface port that has plain old telephone set (POTS) features and connects directly to a network interface unit (NIU). What is the acceptable working voltage for the TNV circuit that can be used for evaluating creepage and clearance distances required for separation within the product?

A. 90 V ac

B. 60 V dc

C. 127 V dc

D. 120 V dc

The correct answer is D. 120 V dc.

Since the interface port connects to a Network Interface Unit (NIU) and is a port with POTS type features that port circuit must be considered as TNV-3. Section 2.10.4 specifies that the normal operating voltage shall be assumed to be 120 V dc for either TNV-2 or TNV-3 circuits if the Telecommunication Network characteristics are not known. Note: This is generally the case since ringing voltage can be 90 to 105 V ac, 20 or 30 Hz and varies with Central Office ringing sources and loop length.

This month's question is:

During a site survey, a meter reading of 97 dBµV/m is recorded. The cable loss is 2.5 dB, attenuation is 10 dB and the antenna gain is –20 dBi. What is the corrected value in V/m?

A. 0.07 V/m

B. 2.99 V/m

C. 29.9 V/m

D. 7.0 V/m

(the author)

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

MR. Static

Charges Are Forever

BY NIELS JONASSEN, sponsored by the ESD Association

In 1795, Charles-Augustin de Coulomb observed that an insulated charged body exposed to atmospheric air would gradually lose its charge.

INTRODUCTION

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

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

~ The ESD Association

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Compliance Engineering Magazine,
Mr. Static Column

But because his contemporaries did not appreciate the importance of his observation, another hundred years passed before it was realized, with the discovery of atmospheric ions, that atmospheric air has a certain conductivity.

Although Coulomb's observation was very important, his formulation was wrong. In fact, charges don't disappear. Like Ian Fleming's diamonds, they are forever. Once you've placed a charge on a body, there's no way you can remove it again.

Admittedly, I have, for the sake of the argument, made this statement slightly too strong. There is one exception: If you have a conductor, negatively charged, and the conductor is connected to ground by a metallic wire, then the excess of electrons will bleed away through the wire. But that's the only exception.

In all other cases, what we call electro-static decay or discharge, where charges seem to disappear from a charged body, are processes where charge carriers with opposite charges are attracted through the surrounding medium.

EXAMPLES

Let's clarify this complex explanation by looking at an example in more detail. Suppose you have a positively charged plastic box. This means that, one way or another, you have removed electrons from some of the molecules on the surface of the box. We assume that the box is made of an insulative material and that, consequently, no charge-movement is possible along the surface or through the bulk of the box material. If now the surrounding medium—normally air—contains ions, the negative ones will be attracted to the box and plate out on the surface as long as there is a net field directed away from the surface.

But what happens to the ions once they have plated out on the surface? Well, we don't know. First of all, it's rather unlikely that each ion lands directly on top of a molecule that has lost one or more electrons. And even if it does, why should the electronegative oxygen molecule in the core of the negative ion cluster give up its extra electron to the apparently electropositive plastic molecule of the box material?

But let me describe a little experiment that demonstrates my point. In Figure 1 is shown a sheet of plastic placed on an

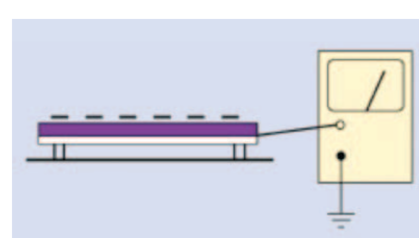
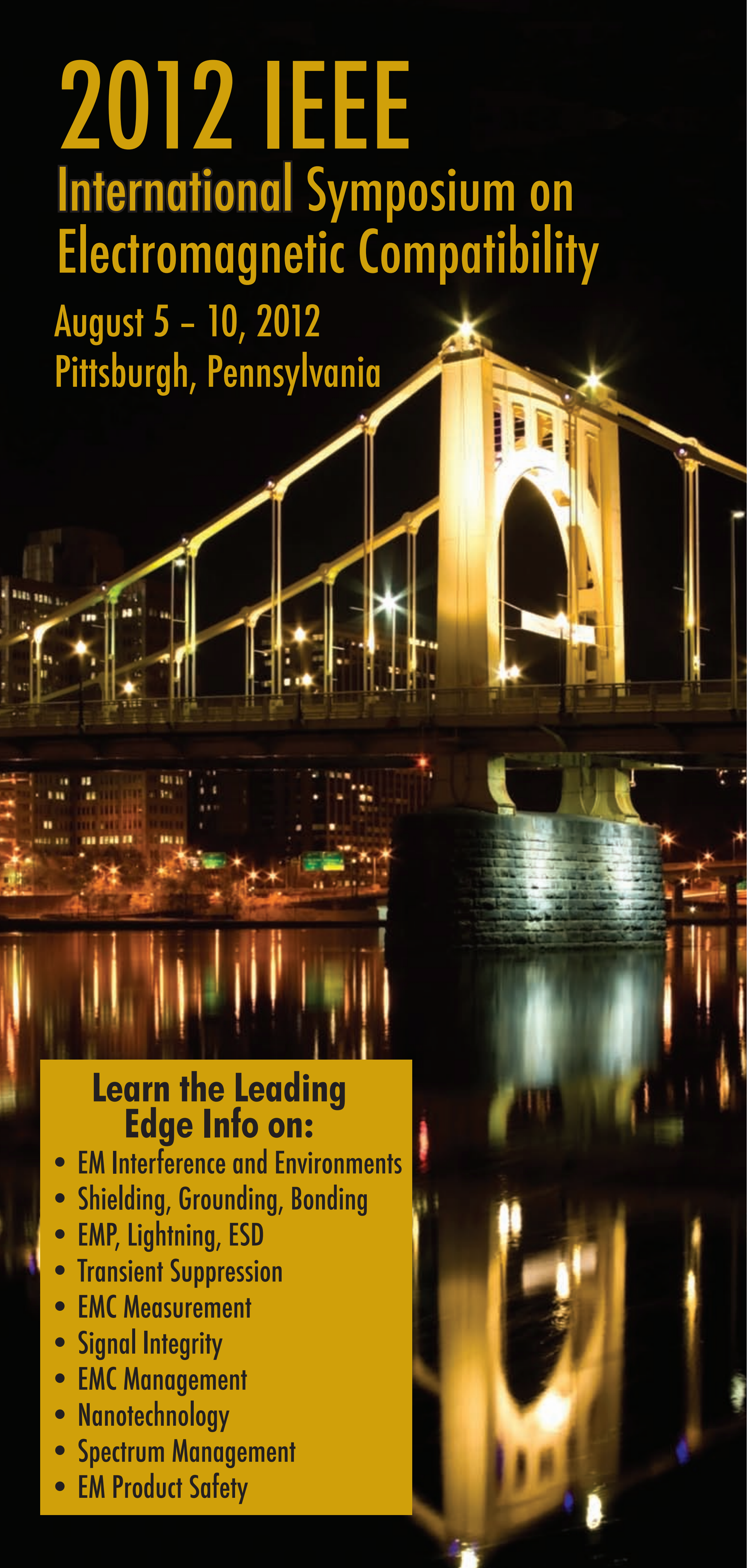


Figure 1: A plastic sheet placed on an insulated metal plate is connected to an electrometer in charge-measuring mode.



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insulated metal plate connected to an electrometer in the charge-measuring mode. The plastic was charged negatively by being rubbed by my remaining piece of Kratzenstein's cat (see "Ben Was Not Alone," *Compliance Engineering*, January/February 1998). The sheet was placed on the metal plate with the charged side in contact with the metal; a total charge of -4.5×10^{-7} C was read on the electrometer. (The negative signs of the charges are shown on the top of the plastic to make the figure clearer, but it actually doesn't matter.) After 24 hours the sheet was removed from the metal plate, and the charge was remeasured to -4.4×10^{-7} C.

Here was a plastic surface where a number of molecules had received one or more extra electrons, in close contact with a metal in which electrons are (almost) free to move, and still hardly any of the charged molecules had been neutralized. The electrons were not able to cross the border between the plastic and the metal, even over a prolonged period. What little neutralization that did happen was probably due to positive air ions plating out on the back side of the plastic.

But let's carry a similar experiment a little further. In Figure 2 is shown a sheet of plastic, again charged to a total of -4.5×10^{-7} C. (In this and the following experiments, the charge on the plastic sheets was measured by lowering the sheets in a Faraday pail connected to an electrometer in the charge-measuring mode.

When the plastic sheet is brought near a sharp corona electrode connected to an electrometer, as shown in Figure 3, the electrometer displays a charge of -3.7×10^{-7} C and the plastic, a remaining charge of -0.8×10^{-7} C. It thus appears as though a charge has been transferred from the plastic to the electrometer.

But this is only an illusion. What happens is that the charge on the plastic creates a field at the corona electrode exceeding the breakdown field strength, and ionization takes place in the immediate vicinity of the electrode. Thus, positive and negative ions are formed in equal numbers, and negative ions are moved in the field to the electrode, where they are being neutralized and are charging the electrometer. Positive ions are moved to the plastic, where they plate out and partly neutralize the field from the negative charge. This process stops when the field from the net charge on the plastic at the tip of the corona electrode is too low to cause ionization.

In order to show that this is what happens, the experiment just described was repeated in a slightly different manner. In Figure 4 is shown again a sheet of plastic charged to -4.5×10^{-7} C. In front of this charged sheet is a similar sheet of uncharged plastic. After the two sheets are moved toward a corona electrode connected to an electrometer, the negatively charged sheet still shows the original charge, -4.5×10^{-7} C.

The electrometer has received a charge of -2.7×10^{-7} C (Figure 5), but obviously not from the negatively charged sheet, since it kept its original charge. The uncharged sheet now carries a positive charge of 2.6×10^{-7} C. Therefore, the field at the corona electrode, caused by the negatively charged sheet, has created negative and positive ions moving in opposite directions.

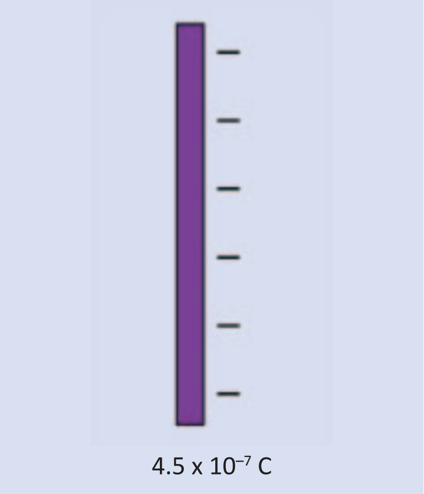

Figure 2: A sheet of plastic negatively charged.

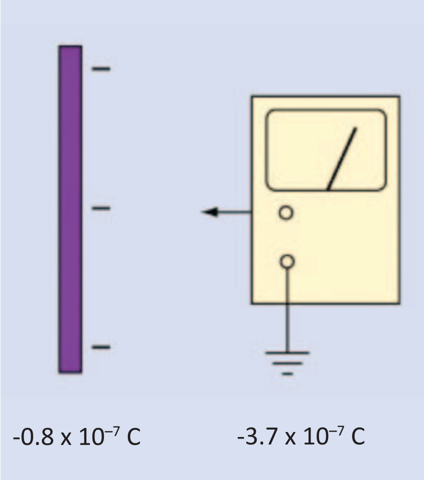

Figure 3: The plastic sheet is placed near a sharp corona electrode, ultimately causing ionization to occur in the electrode's immediate vicinity.

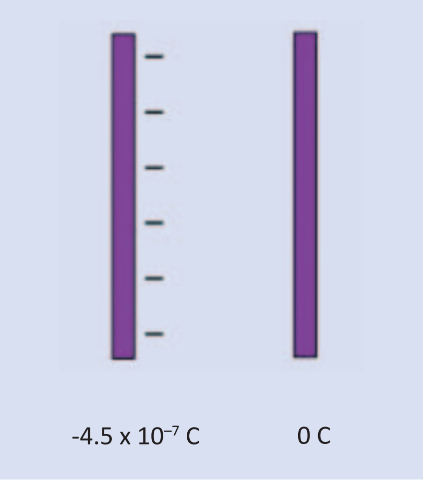

Figure 4: A charged plastic sheet placed behind an uncharged one and moved toward the corona electrode retains its charge.

Isn't it fascinating that a Teflon molecular structure, which once, perhaps accidentally, was impregnated with a few extra electrons, may never again attain its original, virginal state?

If the originally uncharged sheet had not been present, the positive ions would have moved to the negative sheet, reducing its total charge. And since the electrometer received a negative charge close to what is "missing" on the negative sheet, we might have concluded, that (negative) charges were being transferred from the negative sheet to the electrometer.

Obviously, this would be a wrong conclusion. The neutral sheet and the electrometer simply shared the negative and positive ions formed in the air.

The process described above is typical for all processes where an apparent loss of charge is connected with an ionization process, i.e., a process where the charge distribution creates high-enough fields to create mobile charge carriers—ions. In many cases such a process stops before total neutralization has taken place, because the field strength becomes too low.

It is a different situation if the medium surrounding the charge already contains mobile charge carriers, i.e., if it has a certain conductivity. This could be, for instance, a surface treated with an antistatic agent, i.e., a material containing positive and negative electrolytic ions. If a part of the surface is, say, positively charged, the field from the charge will attract negative ions from the surface layer to neutralize the field from the positive charge, and in this case the neutralization may be almost total.

But again, the charge itself does not move. All that happens is that the field changes and maybe becomes zero.

CONCLUSION

Charges (normally) don't disappear from a charged body. But they may appear to do so. All that actually happens, however, is that the field from oppositely charged charge carriers is superimposing the field from the original charges. What the originally charged molecules do when the oppositely charged carriers arrive (because of their mutual attraction), we don't know.

I leave you with this: Isn't it fascinating that a Teflon molecular structure, which once, perhaps accidentally, was impregnated with a few extra electrons, may never again attain its original, virginal state?

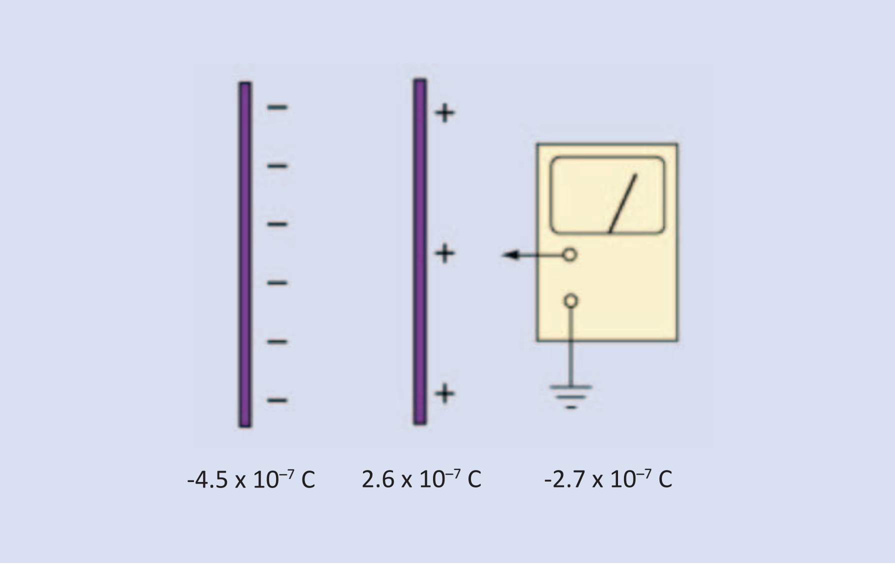

Figure 5: The uncharged sheet (Figure 4) now carries a positive charge.

(the author)

NIELS JONASSEN, MSC, DSC,

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

On Your Mark

BY GEOFFREY PECKHAM

As a product manufacturer, your duty to warn in the United States revolves around your ability to successfully inform people of the residual risks left over after you have done your best to design out or guard hazards that are associated with your product's entire lifecycle.

By "lifecycle" I mean your product's shipment, storage, installation, use, service, decommissioning and disposal. A classic problem, especially with machinery, is that there can be lots of safety information you need to communicate, yet the last thing you want is apply so many labels on your product that it looks like an Indy 500 racecar. Too many warnings can be as ineffective as too few as the situation raises the risk of having all the warnings ignored – too much information can lead to the "crying wolf" situation.

An often overlooked but very effective solution to this issue of information overload is to include the symbol standardized in ISO 7010 for "Refer to manual" (as shown in Figure 1) on a safety label that is applied to your product.

To make this work, use a risk assessment process to determine which safety information belongs on the product and which safety information goes in the manual. Then a "Read and understand manual" safety label, like the one shown in Figure 2, can be used to effectively tie together the on-product warnings and manual.

Figure 1: ISO "Refer to Manual" safety symbol

By following this process, you've essentially built a three-part system for communicating safety. Use of the internationally standardized "Refer to manual" safety symbol tells even non-English reading viewers that they need to read the manual to stay safe from harm. Creating such a system is important because U.S. courts acknowledge that, as a product manufacturer, your two primary vehicles for communicating safety information are your product's warnings and instructions. The "Read manual" label reinforces this tie-in and puts you in a position of being able to say, "What more could we have done?"

Yet there is a problem with this safety communication system: will your intended audience have ready access to the manual? In the old days, this was an issue because the manual was often lost or stuck in a file drawer. But in the last year or so, a solution has presented itself: the QR (quick response) code. More and more manufacturers are adding a QR code to the "Read manual" labels we supply to them. Again, see Figure 2. By scanning the QR code with a smart phone, the viewer is immediately taken to the product manufacturer's website where they can choose to either download a manual or read a specific instruction. This puts that critical information directly into the palm of the hand, right there on the spot. With the smartphone market now accounting for more than 40% of the mobile phones in use in the U.S. and growing at double digit rates each quarter, you now have an even stronger case for saying, "What more could we have done to communicate safety?" When used in conjunction with the specific hazard-related safety labels on your product, your new high tech

Figure 2: "Read and understand manual" ANSI Z535 product safety label with QR code in the symbol panel on right

"Refer to manual" labels will better help you fulfill your legal duty to warn.

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

(the author)

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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.

FUTURE of EMC Engineering

Obsolescence of Technology

BY MARK MONTROSE

In our continuing series on what the future of engineering may be like, we examine our environment and the needs or desires of humanity. Advances in technology are outpacing the ability of users to integrate new products into their lifestyle, many of which may become becomes obsolete within a short period of time.

Many engineers do not understand where technology is taking us and how it relates to their future. Their creative engineering skills must help humanity since customers worldwide buy products and services. Advances in technology are outpacing the ability of users to integrate new products into their lifestyle, many of which may become becomes obsolete within a short period of time.

An example is wireless communication. We now have 4G networks. There are many portable products still in use using 2G and 3G technology. In today's wireless environment, 2G and 3G systems still work fine, yet some manufacturers, service providers, and marketing professional believe they are a burden on our infrastructure and that everyone must upgrade to 4G. Support for legacy products is being discontinued in lieu of driving the current customer base to a higher level of functionality, generating significant revenue for companies that support this technology.

Let's assume for purpose of discussion, that 5G becomes available late 2012, and 6G is released 6 months later (2013). By the reasoning above, our dependence on 2G, 3G and 4G should be phased out quickly in lieu of 5G, which is then quickly followed by 6G. Customer support for what is considered outdated technology will be discontinued although millions of wireless devices are still in use. In the future we can expect xG to be developed. Those who must have the latest in technology may spend a night sleeping in front a store to be the first to own a new product that may only bring incremental improvement in performance over their current device. Others will also update their interactive systems at the same time (i.e., iPads, and wrist watch size high-definition television with 3D capabilities) because they too must have the latest in technology. What new technological advanced can we expect in the future if only incremental increase in performance is being achieved with today's level of engineering?

The most widely used aspect of technology is delivery of content. Delivery of content means the ability to have instant access to information anywhere in the world. I am amazed to see how many must upgrade their phones yearly to get the latest in super high-speed technology so they can text each other at finger typing speeds or use social networking site which requires minimal processing power.

Engineers of the future will know that having a faster processor gives only incremental improvement yet users still demand more content delivery, such as high-speed streaming video on a small screen. To give users what they want based on market demand, engineers must focus more on content deliver along with an easy to use interface. At the same time, product safety and EMC engineers must become involved during the design cycle.

Imagine the technology that we will use 25 or 50 years from now. Engineers of the future must look forward to an exciting career of creating products that provide a quantum leap in functionality and performance instead of incremental increases that we see with current technology.

(the author)

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

REALITY Engineering

Clash of the Titans

BY KEN JAVOR

Engineering, like physics, involves solving problems using algorithms subject to boundary conditions. In electromagnetics, equations are evaluated subject to boundary conditions such as conductive surfaces, insulators, etc. In product development, designs are subject to the boundary conditions of cost, schedule, and the all pervasive human element…

In industry, engineers quickly realize that technical issues are but a part of any engineering problem. Making a profit at a price that the market will accept is the overriding concern. There are always compromises to be made, and ideally, the compromises are made in such a way as to yield the best possible product. But not always…

BACKGROUND

One of the processes with which all EMC engineers become familiar is product modification during or soon after EMI qualification.

If a product fails an EMI test, whatever fix is implemented must be properly documented and entered into the product drawing package so that the production line builds perfect clones of the "golden unit". Experienced engineers realize this is a process with significant nuances.

A variation on this process problem occurs when the product installation changes from that originally specified during qualification. Ideally, the product is (1) electrically bonded to ground using the same technique during test as installed, (2) each connected cable cross-section (shield and wire configuration) is identical between qualification and production cables, and (3) cable shield terminations are the same between qualification and production, e.g., EMI backshells, length of pigtails, etc.

Sometimes even the best plans just don't pan out, and the installation changes after product qualification. Then engineering must decide whether the change is significant or not. "Significant" means the qualification design has been compromised and is no longer representative of production. Hence, qualification must be repeated using the new configuration. Needless to say, the engineer making this pronouncement is *not* popular with those tasked to keep the program on schedule and under budget. The path of least resistance is to pronounce the change insignificant ... at least in the short term. If the change is such that the product's compromised performance could cause customer dissatisfaction down the line, and a recall, then it will be the engineer who pronounced the change insignificant upon whom all responsibility (blame) will fall. Those who exerted pressure upon that engineer, either implicitly or explicitly, will all have moved on to other programs and projects and will have zero memory of the affair … which was technical in nature anyway and the proper province of engineering, not management.

As a specific example, a product was EMI qualified with a particular cable set. Down the road, end-user instructions for installation were reviewed by engineering, and one or more of the attached cables was found to have a break allowing installation of instrumentation mounted on small, open boards a few inches across. Cable shields at the break were tied to local ground using pigtails a few inches long. During qualification, these cables had *no* breaks.

So the question was whether this change was significant, or not. Here's where the plot thickens, because the question was posed to two different engineers, each unaware that the other engineer was working the same problem.

In general, this is *not* a good situation, because engineers will all have unique opinions and experiences. If the problem were sufficiently straightforward that all engineers would answer similarly, multiple engineers wouldn't have to be polled! It is often when people are shopping for a specific answer that they will ask until they hear the answer they like.

Engineer 1 said qualification had been compromised, and either the product would require requalification as installed, or the open boards would require metallic enclosures with connectors so that the shield terminations at the enclosures were of the same quality as the cable with no breaks.

Engineer 2 said the change was insignificant, and would not affect performance (i.e., radiated emissions or immunity).

A TEST IS WORTH (At Least) TWO EXPERT OPINIONS

This problem is not of the "how many angels can dance on the head of a pin" variety. It is real, tangible and readily subjected to analysis and testing. Figures 1a - c show a cable segmented so as to facilitate insertion of a cable break. The cable is RG-58 coax with a single shield, which is representative of the types of shields that are used in twisted, shielded pairs and the like. Cable connectors were PL-259s, which are threaded and don't leak. Threaded connectors were preferred over bayonet type (BNC) because those leak above roughly 10 MHz.

Radiated Emissions. Comparison between the continuous shield (Figure 1a) configuration and the simulated break (Figure 1b) configuration was made by taking coupling data over the biconical (30 – 200 MHz) and logperiodic (200 – 1000 MHz) ranges. Each antenna was sequentially oriented in vertical and horizontal polarizations. Instead of plotting limits, antenna port potentials induced by constant field intensity levels of 20, 40 and 60 dBuV/m were plotted as thick black curves over the data. Field intensities were adjusted to dBuV to allow juxtaposition with raw data from the measurement system.

It is intuitively gratifying that the effect of the break increases with increasing frequency. Figures 2a and 2b compare field intensities measured between 30 and 200 MHz using a vertical biconical. Near 30 MHz, degradation due to the break is minor but increases up to 30 dB at higher frequencies. The cable is driven with a conservative 67 dBuV, or about 2 mV, which is commensurate with experience.

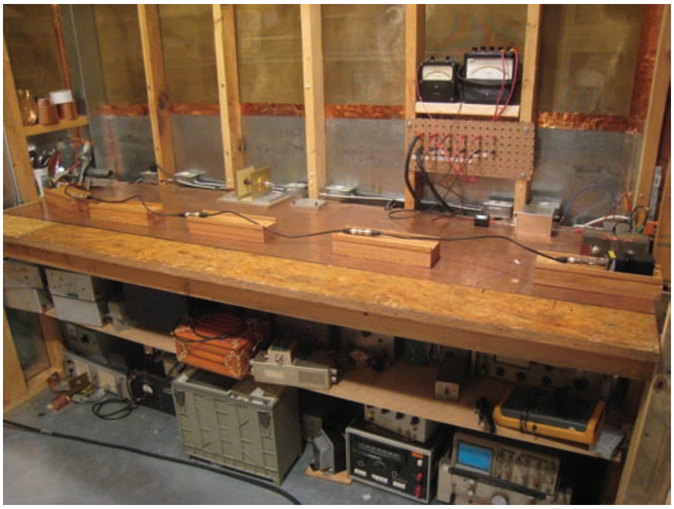

Figure 1a: Cable laid out over ground plane per standards such as CISPR 25, RTCA/DO-160, and MIL-STD-461

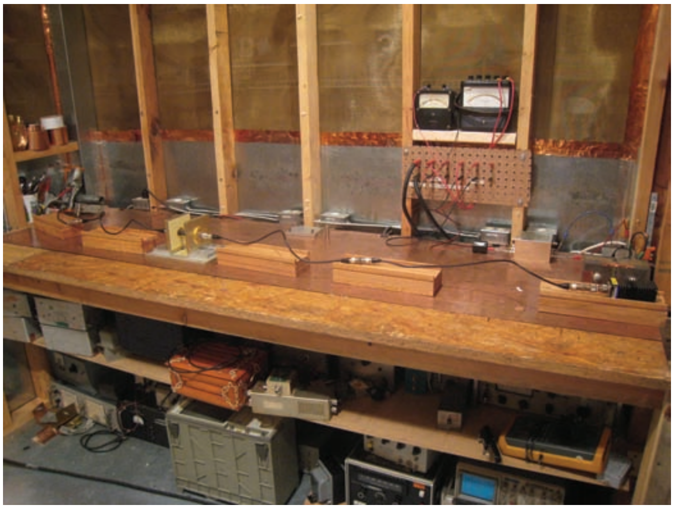

Figure 1b: Same set-up as Figure 1a, but with cable break installed at center.

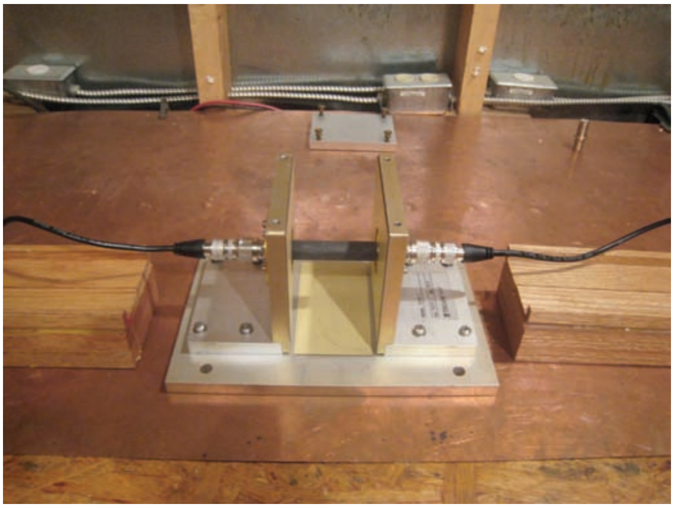

Figure 1c: Close-up of cable break implementation, showing it to be a current probe or injection clamp calibration fixture, with lid removed.

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Figures 3a and 3b compare field intensities measured between 30 and 200 MHz using a horizontal biconical. Emissions increase up to 20 dB.

Figures 4a and 4b compare emissions from 200 to 1000 MHz using a vertically polarized logperiodic antenna. Emission levels increase from 30 to 40 dB. Horizontally polarized performance (Figures 5a and 5b) shows similar increases.

At higher frequencies, a little break makes a big difference!

A few points must be emphasized, for completeness. First, field intensities in Figures 2 through 5 were measured at one meter because a small screen room was conveniently available. Even had the small screen room been fully anechoic, measured field intensities would not scale predictably to three or ten meters, but the measured differences would be very close to the differences which would be observed on an OATS, or an OATS-equivalent enclosed absorber-lined chamber. Since an unlined chamber was used, actual degradation will frequently vary from that measured, but it is clear that the magnitude of the overall degradation is such that the signature below the limit with intact cabling will be above the limit when the cable shield is broken.

Next, the presence of a table-top ground plane reduces measured field

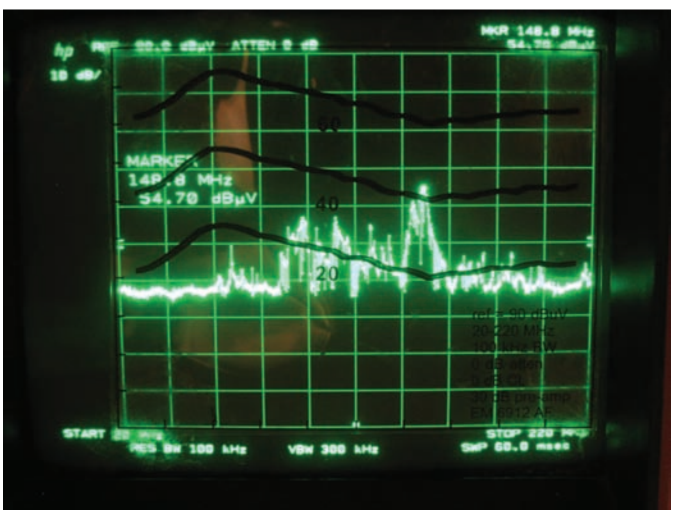

Figure 2a: Vertical radiated emissions from 20 – 200 MHz, with no break in the cable. Sweep was run at -40 dBm.

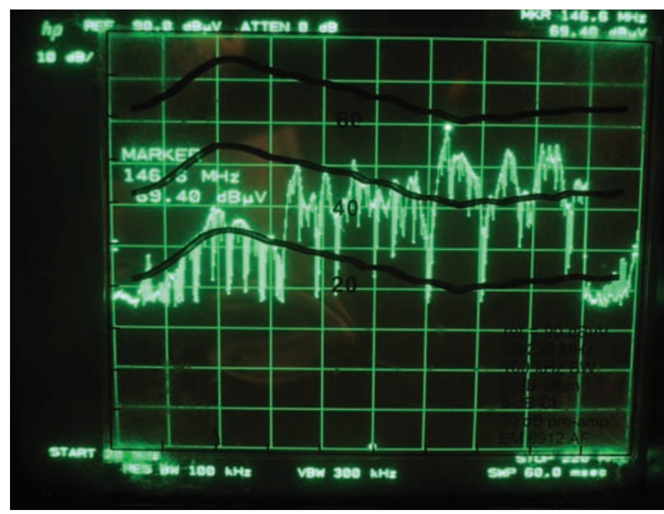

Figure 2b: Vertical radiated emissions from 20 – 200 MHz, with a break in the cable. Sweep was run at -40 dBm.

Figure 3a: Horizontal radiated emissions from 20 – 200 MHz, with no break in the cable. Sweep was run at -40 dBm.

Figure 3b: Horizontal radiated emissions from 20 – 200 MHz, with a break in the cable. Sweep was run at -40 dBm.

intensity relative to when the ground plane is the floor. But it shouldn't affect the *relative* levels of degradation from the shield break.

Lastly, degradation in shielding effectiveness (SE) alone is no guarantee the modification will cause a failure. The radio frequency signals have to be present within the shield before degrading the shield will result in a radiated emissions (RE) issue. It is quite possible that some or most or all of the frequencies between 30 and 1000 MHz won't be on the wires contained in the shield. But that is unknown *apriori*. When making a change like this, the burden-of-proof lies with those who claim the modification won't cause a problem. Engineers cannot, in the general case, analytically prove that the degradation will cause a problem. That isn't their responsibility.

Radiated Immunity. As in the case of emissions, a shield break can degrade immunity performance. To simplify testing, the EN61000-4-6 conducted injection (CI) technique was applied over its 150 kHz to 80 MHz range. CI immunity degradation will be conservative relative to actual radiated immunity (RI) degradation, because the conducted technique does not illuminate the break. Even so, the degradation is quite clearly *significant*, as the data sweeps in Figures 8 through 10 show. The exact same cable was used for emissions measurements,

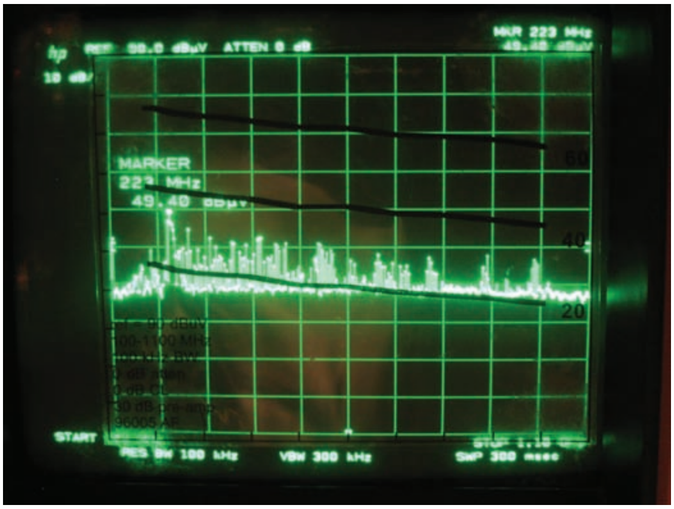

Figure 4a: Vertical radiated emissions from 200 – 1000 MHz, with no break in the cable. Sweep was run at -40 dBm

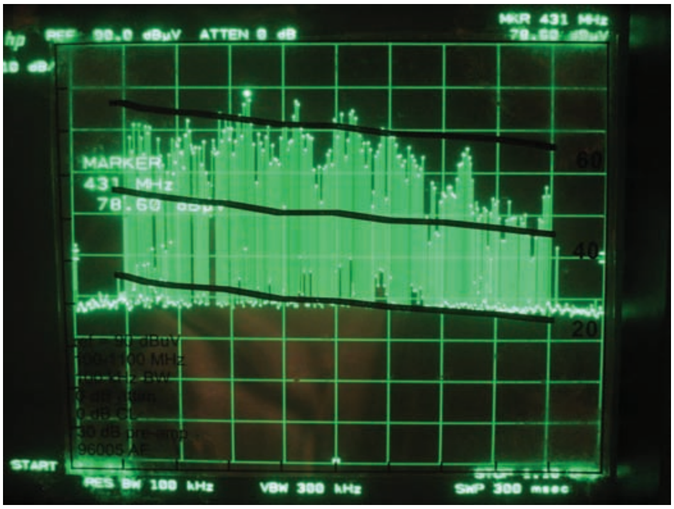

Figure 4b: Vertical radiated emissions from 200 – 1000 MHz, with a break in the cable. Sweep was run at -40 dBm.

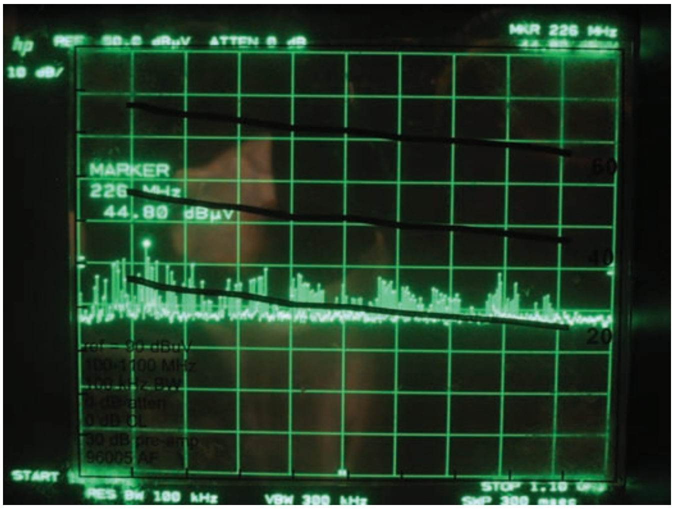

Figure 5a: Horizontal radiated emissions from 200 – 1000 MHz, with no break in the cable. Sweep was run at -40 dBm.

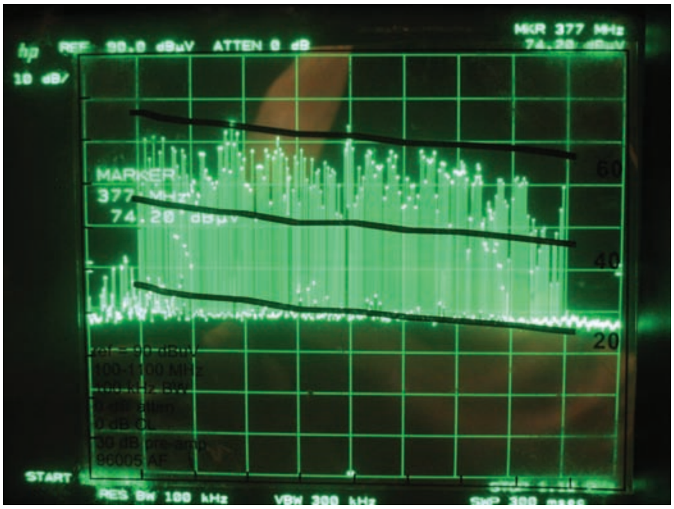

Figure 5b: Horizontal radiated emissions from 200 – 1000 MHz, with a break in the cable. Sweep was run at -40 dBm

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with some changes to configuration. Instead of driving the cable and measuring resultant RE, the cable was connected to a spectrum analyzer, and a CI technique injected current onto the cable shield which then coupled to the center conductor via the cable's transfer impedance. The cable's far end, previously floating, was now grounded as per EN61000-4-6, so that at low frequencies current would flow. Figure 6 shows the far end of the cable.

As in the case of RE, SE degradation alone didn't prove the modification would cause an RI failure. But given the degradation, the burden-of-proof is on those who claim the modification will not cause a problem.

Instead of maintaining a particular current or rf potential on the cable, a simpler method drove the injection device at 0 dBm constantly over frequency. Direct comparison is then possible between the cable with no break and with break.

Finally, CI testing using the current probe calibration fixture to simulate a break actually improved (decreased) coupling in the cable versus no break, because the wall and base of the fixture served as an excellent termination for the shield and the length of cable with rf current on it was less than with no break, and hence lower transfer impedance. So a better simulation of the actual installation drawing using simulated pigtails was created as in Figure 7.

Note in Figures 10a and 10b that, while there is evident degradation, there are standing waves that perturb a strict "A versus B" comparison on a frequency-by-frequency basis. This is in fact the reason for cutting off the EN61000-4-6 CI method at 80 MHz, where the RI test begins.

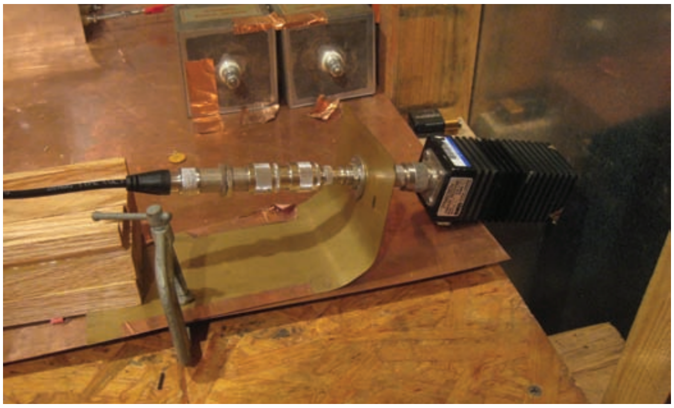


Figure 6: Close-up of far end of cable bonded to ground plane to get 61000-4-6 injected current to flow at low frequencies

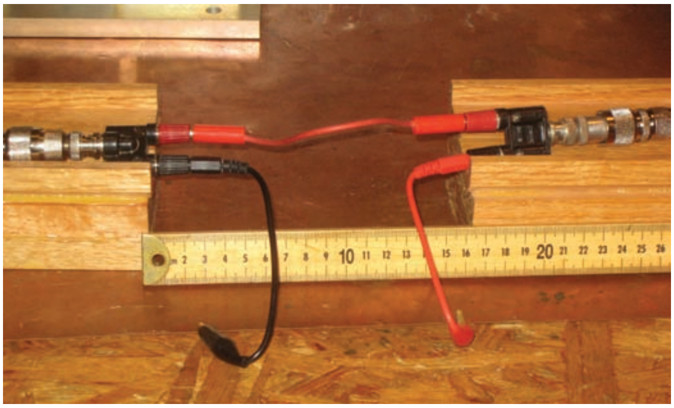


Figure 7: Close-up of simulated break for purposes of conducted immunity testing.

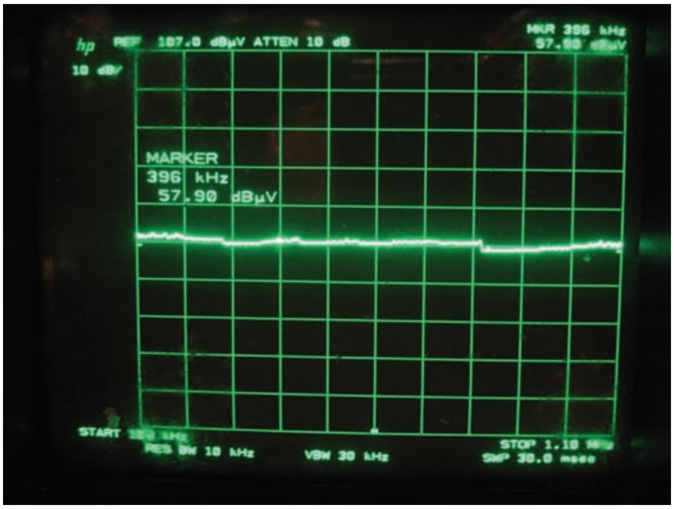


Figure 8a: Sweep from 100 kHz to 1.1 MHz with no break in cable. Injection device driven with 0 dBm.

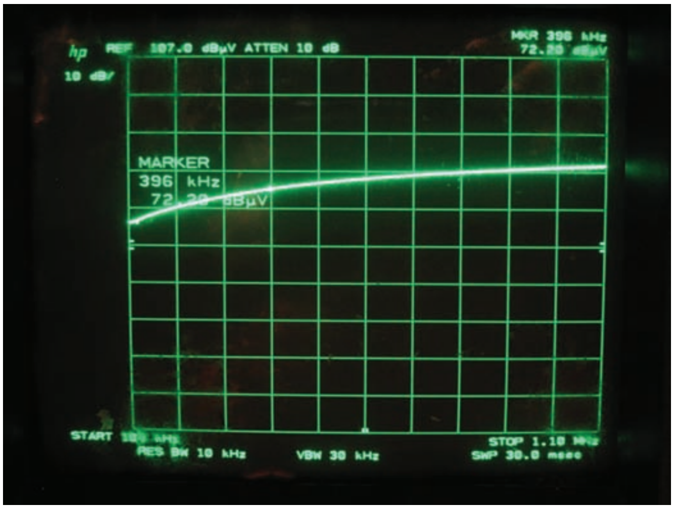


Figure 8b: Sweep from 100 kHz to 1.1 MHz with break in cable. Injection device driven with 0 dBm.

CONCLUSION

The story painted by the data should come as no surprise to the experienced EMC engineer. Likewise, it should not be surprising that the recommendation accepted was that the change was insignificant and merited no further attention.

There are important (professional) life lessons here, the least significant of which is the technical backdrop.

(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.

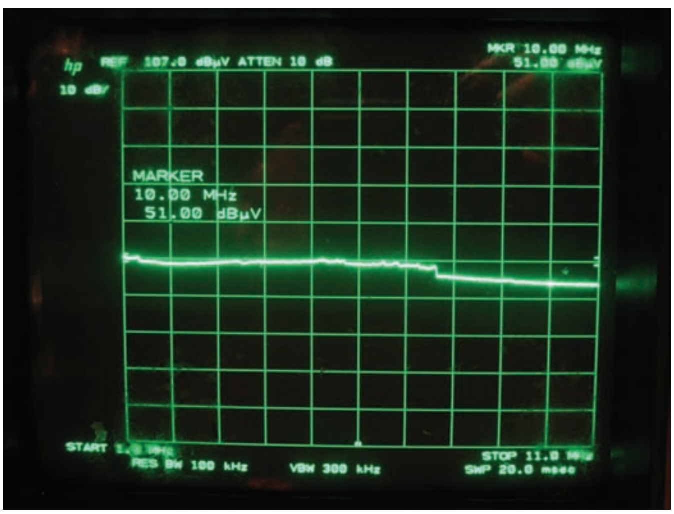


Figure 9a: Sweep from 1 MHz to 11 MHz with no break in cable. Injection device driven with 0 dBm

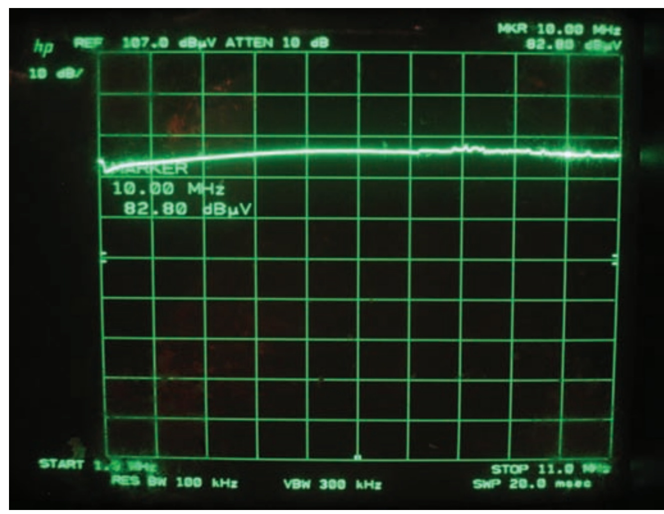


Figure 9b: Sweep from 1 MHz to 11 MHz with break in cable. Injection device driven with 0 dBm.

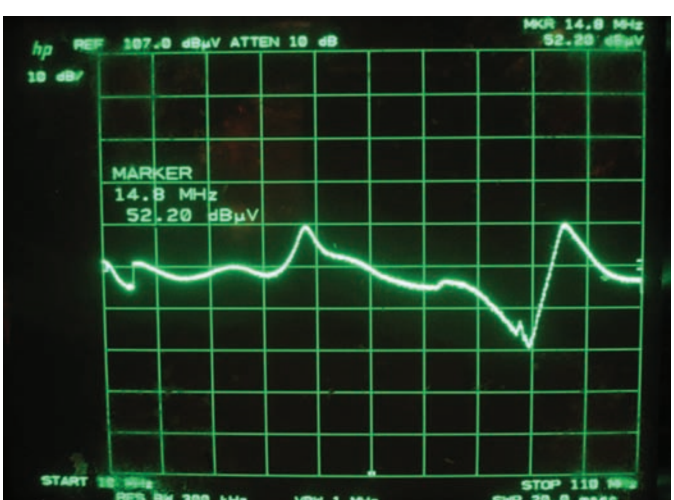


Figure 10a: Sweep from 10 MHz to 110 MHz with no break in cable. Injection device driven with 0 dBm. Discontinuity at 10 MHz compared to Figure 9a is because a different injection device was used for this band.

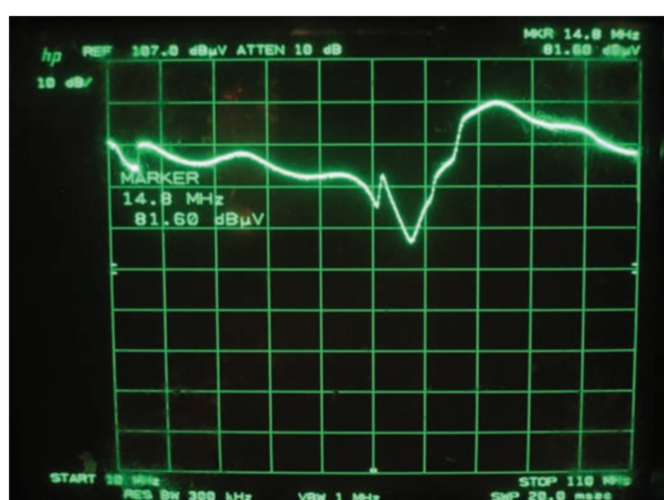
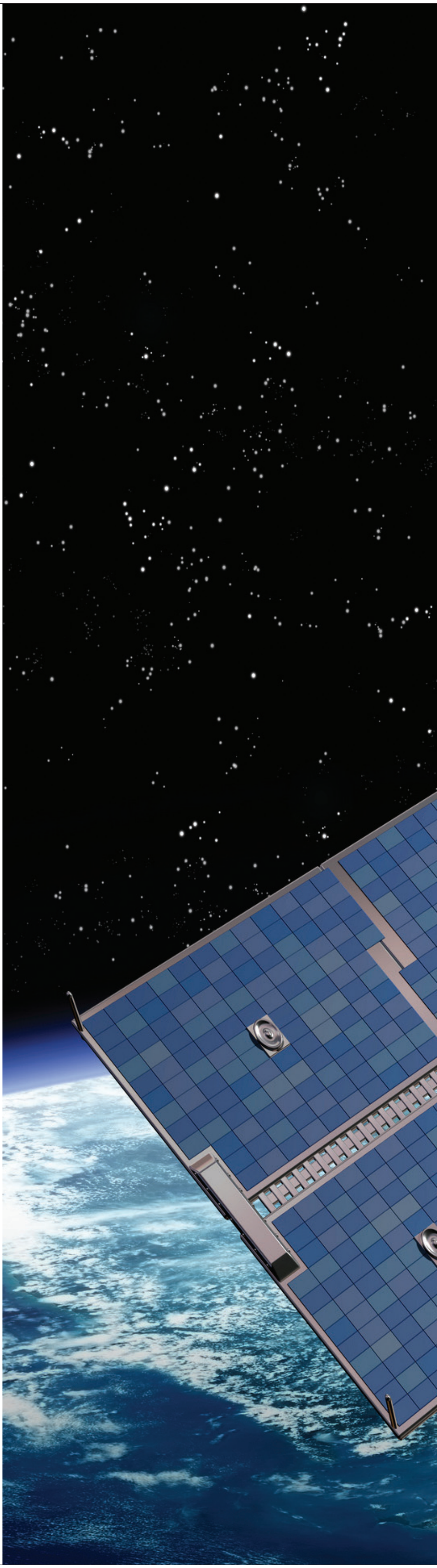


Figure 10b: Sweep from 10 MHz to 110 MHz with break in cable. Injection device driven with 0 dBm.



Low-level, Audio Frequency Conducted Emission Measurements: Motivation and Method

Control of low audio frequency magnetic fields from cables, as required by some spacecraft EMI control standards, is best implemented as a conducted emission measurement, but these may require exceptionally efficient transducers and techniques, which are discussed herein.

BY KEN JAVOR

Common-mode conducted emission (CMCE) limits and measurements are often specified within spacecraft EMI standards, such as the Space & Missile Command's *SMC-S-008, EMC Requirements for Space Equipment and Systems* [1], and the NASA Goddard Space Flight Center's *General Environmental Verification Standard (GEVS)* [2].

Above audio frequencies, the rationale for such control is generally either the control of cable-to-cable crosstalk, and/or indirect control of radiated emissions. Such control and measurement is much more accurate and repeatable than radiated measurements when the cable is electrically short.

At audio frequencies, effective cable design usually precludes interference from crosstalk. There is no need to control CMCE at audio frequencies unless an unusually low-level signal is carried by a cable, and/or there are restrictions on the quality of shielding available, or the ability to twist a signal with its return.

But there is a special case where the control of CMCE at frequencies down to the very low end of the audio

An optimally designed platform will separate magnetic sensors from localized magnetic hotspots, but it may be more difficult to separate sensors from any and all cables.

spectrum is desirable, and that is when a platform has a magnetic cleanliness requirement. Such platforms carry sensitive magnetometers. A sample derivation of such a limit is presented.

BACKGROUND

Consider the variable-mu magnetometer pictured in Figure 1. While this is earthbound test equipment, it will be shown that its sensitivity corresponds well with existing CMCE requirements in references [1] and [2].

The EMCO 6640 has 50 kHz bandwidth and 60 dep't wideband sensitivity. An EMI receiver connected to its analog output can tune in narrowband signals down to 13 dBpT (13 dBpT + 10 * log (50 kHz) = 60 dBpT).

An EMCO 6640 or similar device can measure the field from a test sample and its interconnecting cables by specifying a distance and configuration of the test set-up and sensor. In fact, this has been done in the 1967 vintage RE04 MIL-STD-461 requirement and MIL-STD-462 test method.

Such a control may be valuable for an equipment housing, but since such fields fall off with the cube of distance (at distances where the equipment dimensions are small relative to the separation distance), it is most likely cables will be the culprits. Also, an optimally designed platform will separate magnetic sensors from localized magnetic hotspots, but it may be more difficult to separate sensors from any and all cables. Finally, magnetic emissions from cables fall off directly with distance (or in the case of cables above a conductive ground plane, as the square of distance) so that cable CMCE, although nowhere near as "hot" as a motor or transformer, may appear so at a distance.

In order to derive a CMCE limit from a magnetic flux density limit such as 13 dBpT, it is helpful to convert from units of flux density to magnetic field, assuming free space permeability.

The basic relation $B = \mu H$ converts to dBpT = dBuA/m + 2 dB uH/m in log-space. Hence, 13 dBpT is 11 dBuA/m.

If a cable far from ground carries a current "I" causing a circulating magnetic field "H", that relationship is the familiar $H = I/2\pi r$.

Assuming a separation of one meter between cable and sensor and converting to log-space, an H-field of 11 dBuA/m implies a common mode current on the cable of 27 dBuA. However, the more common situation is that the cable is near a conductive ground plane, and if the height above ground "s" is small relative to the observation distance "r", then the relationship between the common mode current and resultant circulating magnetic field is $H = I\,(2s)/2\pi r^2$

For a typical case where "s" is 5 cm and "r" is 1 meter, the above equation introduces a 20 dB relaxation in the allowable cm current, which is then 47 dBuA rather than 27 dBuA.

Figure 1: Electro-Mechanics Company EMCO 6640 variable-mu magnetometer (circa 1964).

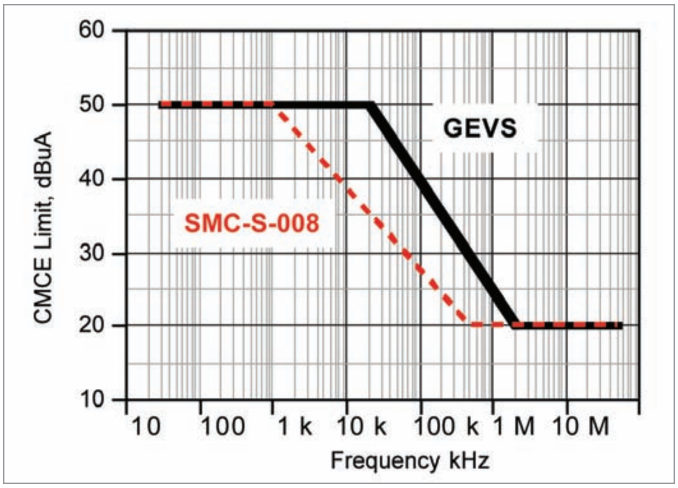


Figure 2: Existing spacecraft CMCE limits.

As this is written (late 2011), the existing GEVS CMCE requirement applies only to power lines. However, a revision currently in process will extend applicability to all cables.

The ground plane is our friend! Compare this computed value of 47 dBuA with the Figure 2 CMCE low frequency plateau limit in the two standards cited in the Introduction.

The previous derivation does not prove that the low frequency CMCE limits shown in Figure 2 are derived from magnetic cleanliness requirements; the actual origin of the GEVS limit is shrouded in the mists of time. The derivation only goes to show that such a CMCE limit can be very useful in controlling magnetic cleanliness. The SMC limit is a GEVS derivative: it has no separate lineage. It differs from the GEVS limit in that it applies to the total CMCE from a unit, as opposed to just the power interface or individual cables. The SMC limit is measured by lifting the unit off ground, reattaching it via a wire, and measuring the CMCE through that wire, or alternatively by clamping a current probe around all the cables emanating from the unit.

As this is written (late 2011), the existing GEVS CMCE requirement applies only to power lines. However, a revision currently in process will extend applicability to all cables. The new revision will also relegate the requirement below 150 kHz to those platforms with a specific need for magnetic cleanliness, with the generally applicable limit above 150 kHz being based on crosstalk control. The 30 Hz to 50 MHz SMC limit applies to all platforms and all cables, with possible extensions to both lower and higher frequencies on a platform-dependent basis.

Finally, before moving on to CMCE test methods, it should be noted that another common form of such control is through design requirements mandating balanced above-ground circuits, or single-ended circuits, with dc isolation between signal returns and ground. This is practical at audio frequencies where uncontrolled parasitics will not perturb basic circuit functions.

TEST EQUIPMENT – CURRENT PROBES

A preferred technique for making audio frequency CMCE measurements is the legacy current probe-based CE02 measurement of MIL-STD-462 (1967). However, current probes available in most EMI test facilities (Figure 3) are not efficient enough to measure accurately at a level 6 dB below 50 dBuA (the Honeywell 3892 being a possible candidate, but are long obsolescent and only available if the test facility already owns one). To assess how efficient a transducer must be, the noise floor of the EMI receiver or spectrum analyzer must be known. Published specifications for the Rohde & Schwarz EMI receivers and spectrum analyzers show a noise floor at 30 Hz above 20 dBuV. Obsolescent machines such as the HP8566, designed to be used above 100 Hz but often "pushed" down to 30 Hz with resultant degraded noise floor, show even higher noise levels at 30 Hz (Figure 4). If the goal is

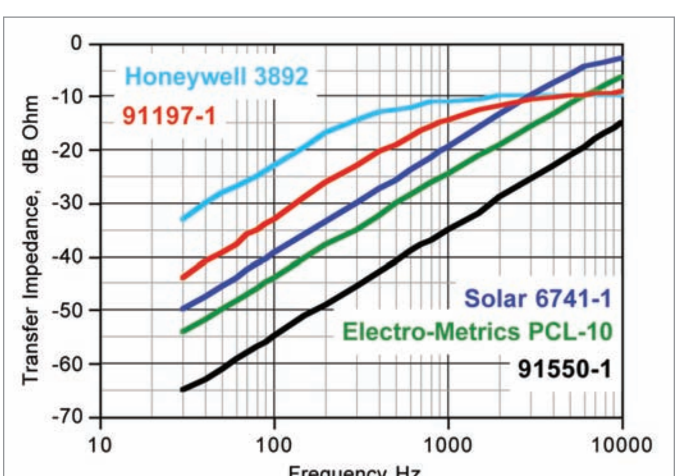


Figure 3: Transfer impedances of typical EMI current probes employed in the CE01/101 frequency range.

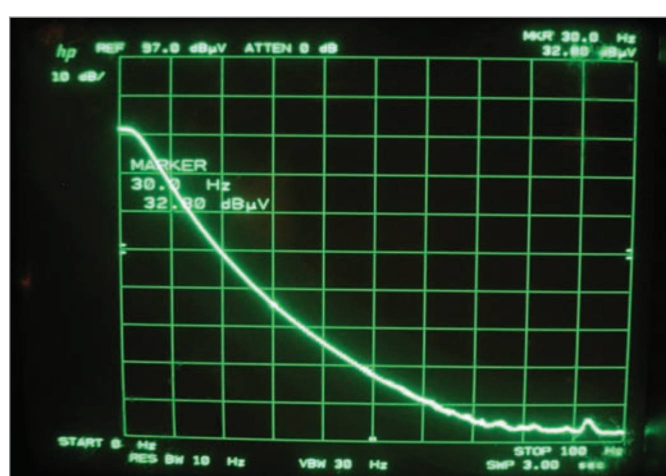


Figure 4: Degraded noise floor of HP 8566B spectrum analyzer below 100 Hz: about 33 dBuV at 30 Hz.

Traditional EMI test current probes are based on ferrite cores. Cores constructed of other available materials, similar to laminated transformer cores, have better low frequency response.

to accurately measure a 30 Hz signal at 50 dBuA with a noise floor at 20 dBuV, the current probe transfer impedance cannot be less than -24 dB Ohm. None of the current probe transfer impedances in Figure 3 are adequate for that task.

Traditional EMI test current probes are based on ferrite cores. Cores constructed of other available materials, similar to laminated transformer cores, have better low frequency response. Transfer impedances of three such commercially available low frequency probes are shown in Figure 5.

Comparison of Figures 3 and 5 reveals that the *least efficient* Pearson probe is about 20 dB more efficient than any of the Figure 4 probes except the obsolescent and very scarce Honeywell probe. Additionally, all the Pearson probes are more efficient than the Honeywell model below 60 Hz.

A current probe inserts impedance into the line around which it is clamped. Generally, the inserted impedance is the transfer impedance divided by the turns ratio. For the special case when a resistor shunts the probe output, the inserted impedance is the shunt

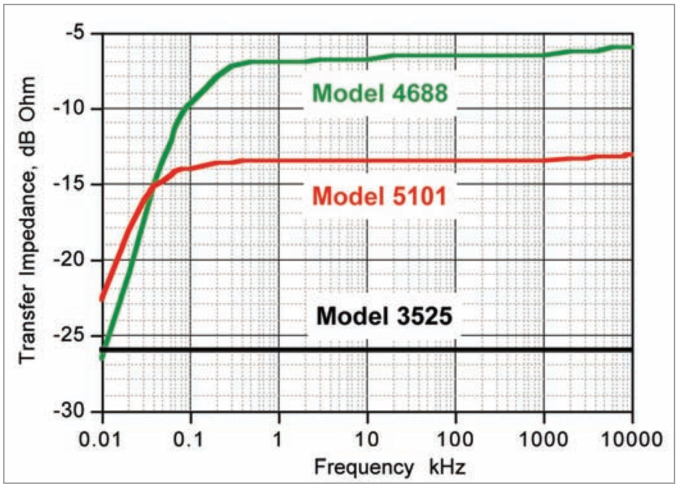


Figure 5: Transfer impedances of three Pearson Electronics wideband current probes. (Note: These probes are designed with 50 Ohm output impedances, and the plotted curves were made with a 50 Ohm network analyzer. If driving a 1 Megohm oscilloscope input, the plateau is 6 dB higher than shown. Thus, the Model 4688 is time domain spec'd as a 1 V/A probe with a lower 3 dB frequency of 600 Hz, the Model 5101 is spec'd as a 0.5 V/A probe with a lower 3 dB point at 150 Hz, and the Model 3525 is spec'd at 0.1 V/A, with a lower 3 dB point of 6 Hz. Source: the Pearson Electronics web site at http://pearsonelectronics.com.

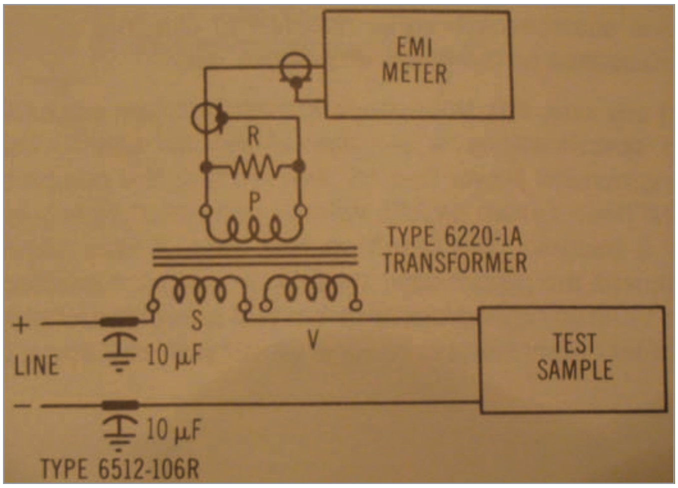


Figure 6: The Solar 6220-1 audio frequency coupling transformer used as a current probe (Source: Solar Electronics catalog application note).

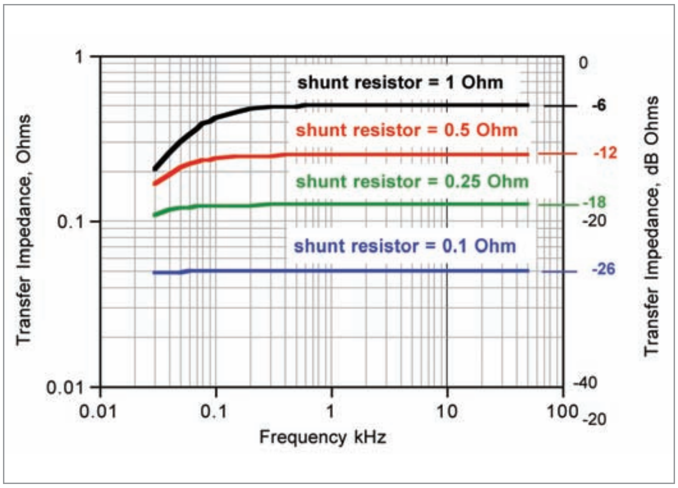


Figure 7: Solar 6220-1 transfer impedance using various shunt resistors on the primary side.

For measurements on power lines, or between a unit case and ground, the transformer method can be adapted to provide even more efficient low-level, low frequency measurements.

resistance divided by the square of the turns ratio. For the three Pearson probes discussed herein, the inserted impedances are negligible:

Model	Z_T, Ω	Inserted Impedance*, mΩ
3525	0.1	0.2
4688	1	20
5101	0.5	5

* Source: Pearson Electronics

TEST EQUIPMENT – CURRENT PROBE ALTERNATIVE

For measurements on power lines or between a unit case and ground, the transformer method pioneered by the Solar Electronics Company can be adapted to provide even more efficient low-level, low frequency measurements. If measurements on individual cable bundles are necessary, an efficient current probe such as those discussed previously, is necessary. Regardless, the transformer method may still be helpful under certain conditions.

The transformer method is based on Solar Application Note AN62201, which has been around long enough that it was adopted by the United States Army and included in the 1971 Notice 3 to MIL-STD-462 (the "pink notice"). The application note, found in any edition of the Solar Electronics Catalog relies on the fact that a current probe is a type of transformer; therefore, a different kind of transformer may be substituted. The connection into the circuit, shown in Figure 6, is the same as for MIL-STD-461 CS01 or CS101. But instead of driving the Model 6220-1 coupling transformer with a power amplifier, the transformer's primary side is connected to an EMI receiver or spectrum analyzer. A loading resistor shunts the primary side to reflect a resistance into the secondary. The resulting transfer impedance has a flat asymptotic plateau at frequencies where the transformer's reactance is higher than the shunt resistance.

The principle of operation is that the secondary, unloaded on the primary side, has about 1.2 mH inductance. The reactance of that inductance, shunted by different resistors, yields a family of curves as shown in Figure 7.

Because of the Model 6220-1 turns ratio of 2:1 primary to secondary, the transfer impedance plateaus in Figure 7 are equal to one-half the shunt resistor value in the circuit of Figure 6. [3] Given the 1.2 milliohm secondary inductance, the highest transfer impedance available at 30 Hz is about -13 dB Ohm. That value is obtained with no load, which is inadvisable since that would insert the entire 1.2 mH inductance into the power-line impedance. That is known to cause switched mode power supply instability. [4] The problem can be avoided using a 1 Ohm shunt, reflecting

A large increase in sensitivity is attained, acquired at the cost of inserting almost 0.5 Ohms in series with the circuit-under-test. Of course, the possibilities here are only limited by access to the power transformer of choice.

0.25 Ohm into the power-line. Transfer impedance degrades 1 dB to -14 dB Ohm, which is the maximum practical transfer impedance available with this technique. This is 8 - 12 dB better than the various Pearson probes achieve.

If even better low frequency sensitivity is needed, say if the custodians of SMC-S-008 extend their CMCE limit below 30 Hz, an ordinary 50 or 60 Hz power transformer can be of assistance. A 60 Hz 120 V transformer primary stepping down to 25.2 volts and 2 amp load current yielded the transfer impedance shown in Figure 8, when the primary was loaded by 10 Ohms and the secondary was used to carry the current. A large increase in sensitivity is attained, acquired at the cost of inserting almost 0.5 Ohms in series

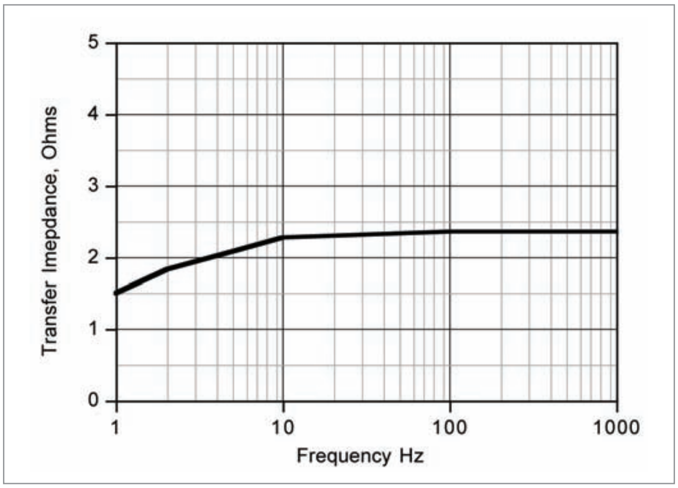


Figure 8: Transfer impedance of a step-down 60 Hz power transformer with primary shunted by 10 Ohms

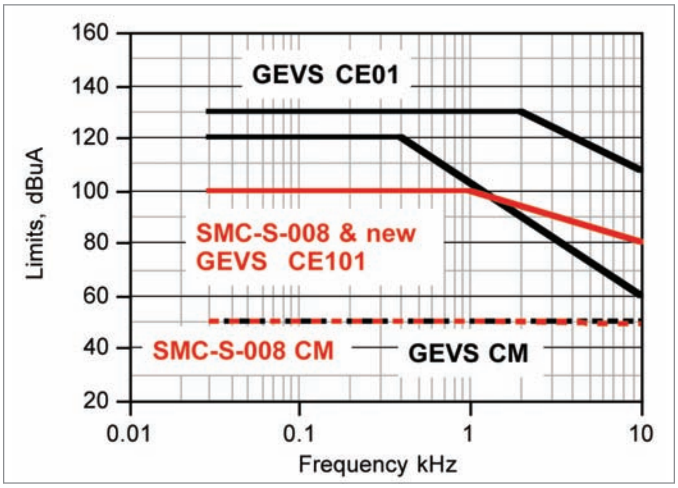


Figure 9: CE01 and CECM limits for GEVS and SMC-S-008

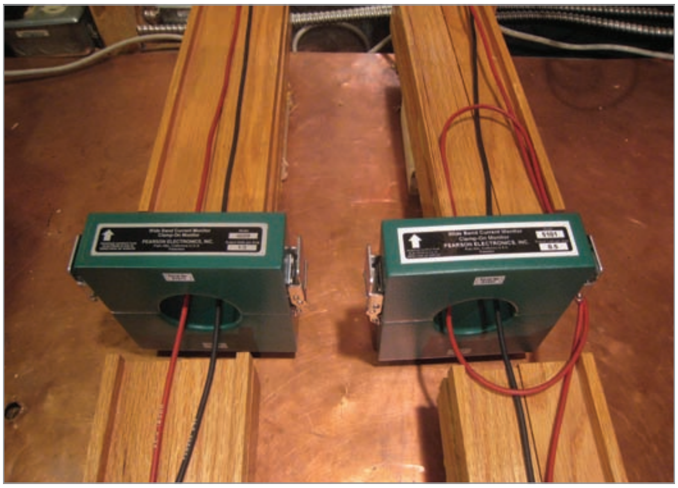


Figure 10: CM measurement on left; dm measurement on right.

Figure 11: CM/DM measurements made using a pair of Solar 6220-1 coupling transformers. The connection of the primaries (expanded on in Figures 12 and 13) determines which mode is measured and which rejected.

> A key property of a current probe to be used for making pure differential or pure common mode measurements (measurements that involve multiple conductors passing through its window) is adequate rejection of the undesired mode.

with the circuit-under-test. Of course, the possibilities here are only limited by access to the power transformer of choice. It should be noted that somewhere between 1 to 10 kHz the power transformer performance deteriorated, and at 1 Hz the measured current waveform was distorted. A 50 Hz transformer could be expected to work to a slightly lower frequency, and the upper limit issue is not a problem because the 6220-1 or a current probe with adequate sensitivity is available at and above 1 kHz.

COMMON MODE MEASUREMENTS

In addition to efficient transducer factors, a key property of a current probe to be used for making pure differential or pure common mode measurements (measurements that involve multiple conductors passing through its window) is adequate rejection of the undesired mode. The Pearson probes all provide at least 80 dB of differential mode rejection when used to measure common mode current up to 10 kHz. Brand new models 4688 and 5101 measured upwards of 90 dB rejection, but EMC Compliance's well-used Model 3525 measured just over 80 dB. The cases are identical in construction, so hard use accounts for the difference. Figure 9 is a plot of traditional CE01 limits superimposed on the CMCE limit of Figure 2. The dm rejection of the cm test method must exceed the difference between the CE01 limits and the CECM limits. The 80+ dB rejection of the Pearson probes more than suffices, except for the most relaxed GEVS CE01 limit. In the new GEVS, that limit is replaced by MIL-STD-461F CE101, with a low frequency plateau of 100 dBuA. For such a standard, the cited probes are a solution to making these sensitive cm measurements.

To achieve maximum rejection of the undesired mode with multiple wires penetrating the window, it is necessary that the wires be tightly coupled to each other and centered in the window, so that capacitive coupling between either wire and the grounded current probe case is nearly equal. This is normally achieved with a split nonconductive dowel drilled down the center to take the two wires. It must be long enough so that wires clearing it drape away from the current probe body, and its diameter is just less than the probe window.

Using a pair of Solar 6220-1s to implement the transformer method in lieu of current probes, Figure 10 transforms into Figures 11 through 13. An important difference between hinged current probes and transformers is that a current probe may be opened and closed and wires rearranged within it without disturbing the flow of current to the test sample. The same is not true for a transformer. However, because the primary side is isolated from the current carrying secondary,

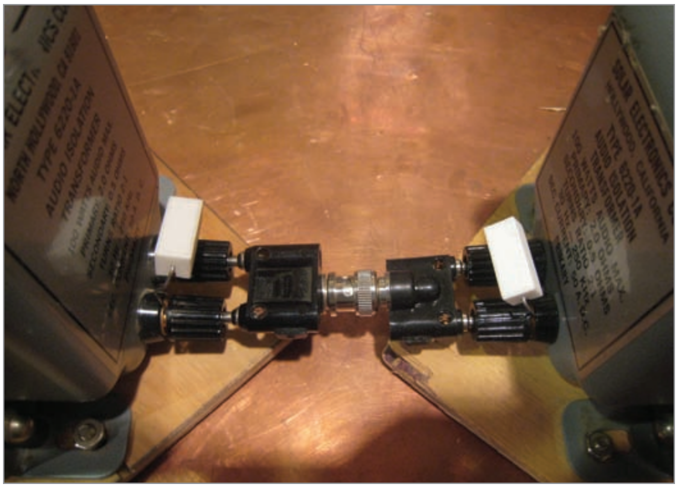


Figure 12: CM measurement connection close-up. The EMI receiver connection shown in Figure 10 has been removed for clarity.

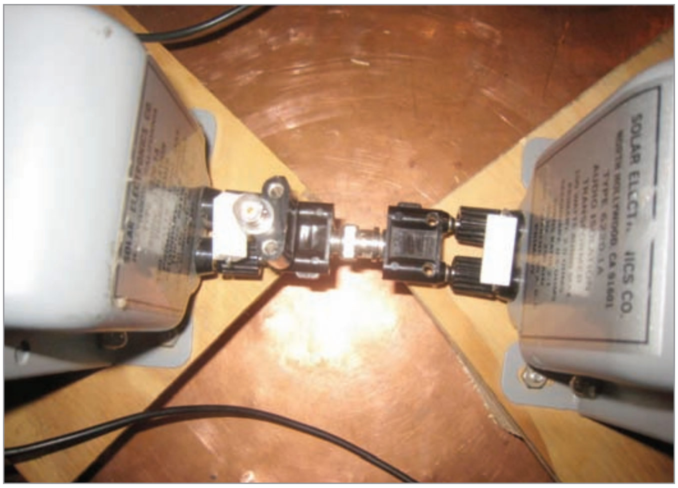


Figure 13: DM measurement connection close-up. The EMI receiver connection shown in Figure 10 is there, but the connecting coaxial cable has been removed for clarity.

the sense in which the primaries are connected to each other can be changed without disturbing the flow of current to the test sample, which is a blessing for any device which has to "boot" and requires significant time to reach proper operation subsequent to power cycling. The only difference between Figures 12 (cm measurement) and 13 (dm measurement) is how the bnc-to-banana adapters interconnect. Connections to the secondaries, shown in Figure 10, don't change.

For optimal rejection of the undesired mode, it is critical that the two transformers have *exactly* identical transfer impedances. Of course, this criterion is unachievable in practice, and although this technique produces more efficiency than the use of a current probe, the use of a single current probe to reject the undesired mode will always be superior. Undesired mode rejection is enhanced by using shunt resistors of lower resistance than the reactance of the transformers at the desired frequency. In this investigation, each transformer was shunted by 0.47 Ohms, for a net shunt resistance of about 0.235 Ohms. That compares favorably with the reactance of 1.2 mH at 30 Hz being 0.22 Ohms. Nevertheless, the maximum undesired mode rejection was about 40 dB.

Inspection of Figure 9 reveals that 40 dB differential mode rejection is insufficient to yield accurate cm measurements, because the dm limit is much more than 40 dB above the cm limit. However, the vast majority of electronic loads do not generate noise below the dc-dc converter frequency, and in that case the 40 dB value will be perfectly adequate. Low audio frequency conducted emissions are usually generated by rotating machinery of one kind or another, so if the test sample performs that sort of function, a current probe is a must.

There is a way around a low dm rejection ratio. This involves a modification to the cm measurement as per SMC-S-008, which requires measurement of total cm current, measured between test sample case and ground by raising the test sample case above ground and connecting it to ground with a wire, as shown in Figure 14.

The modification is to replace the current probe with the 6220-1 as per Figure 6, but instead of inserting a power wire, its secondary is inserted in series with the ground wire, effectively making the coupling transformer secondary as shunted by the primary, a series element in the ground connection (in Figure 15).

This technique measures only the common mode current driven into ground, and thus there is no need to reject the undesired mode. It is ideal for working to SMC-S-008, but it is overkill if working to GEVS or any similar requirement that controls CMCE on a per-cable basis. Nevertheless, in the case of the unit that doesn't generate frequencies below that of its electronic switching power supply, there won't be any significant CMCE. A total summation of nothing is still nothing.

CONCLUSION

For the test facility that finds itself rarely working to one of these spacecraft EMI requirements, if the requirement is to only test the power interface, or if an SMC-like total CMCE measurement is made and the test sample generates no noise at audio frequencies, the CS01 coupling transformer technique is a handy way to measure with existing assets and

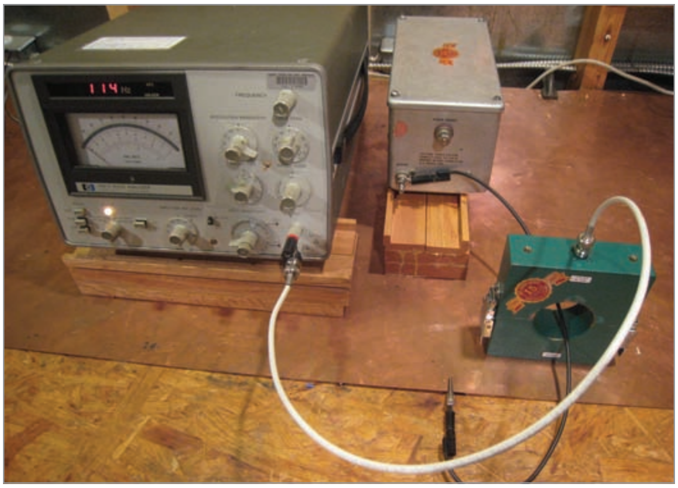


Figure 14: Total CMCE measurement per SMC-S-2008. The LISN represents a test sample whose metal case is raised above ground and then connected to ground via a wire.

Figure 15: Total CMCE measurement per SMC-S-2008, but using the CS01 coupling transformer in lieu of a current probe.

adequate sensitivity. If a test facility is going to be making such measurements routinely, or if the test sample has cable connections beyond power that require individual sampling and generates significant audio frequencies, then the Pearson probes or probes with similar performance are preferable.

ACKNOWLEDGMENT

Mark Nave's detailed review of the work contributed greatly to the overall effort and is deeply appreciated. The author would like to thank Pearson Electronics for the loan of Models 4688 and 5101 current probes in developing this article.

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3. This can be understood by recognizing that the resistance shunting the primary reflects across the windings by the square of the turns ratio. That reflected value, multiplied by the current flowing through it is converted on the primary side by the turns ratio, so the end result is that the effective shunted value is the primary resistance divided by the turns ratio.

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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.

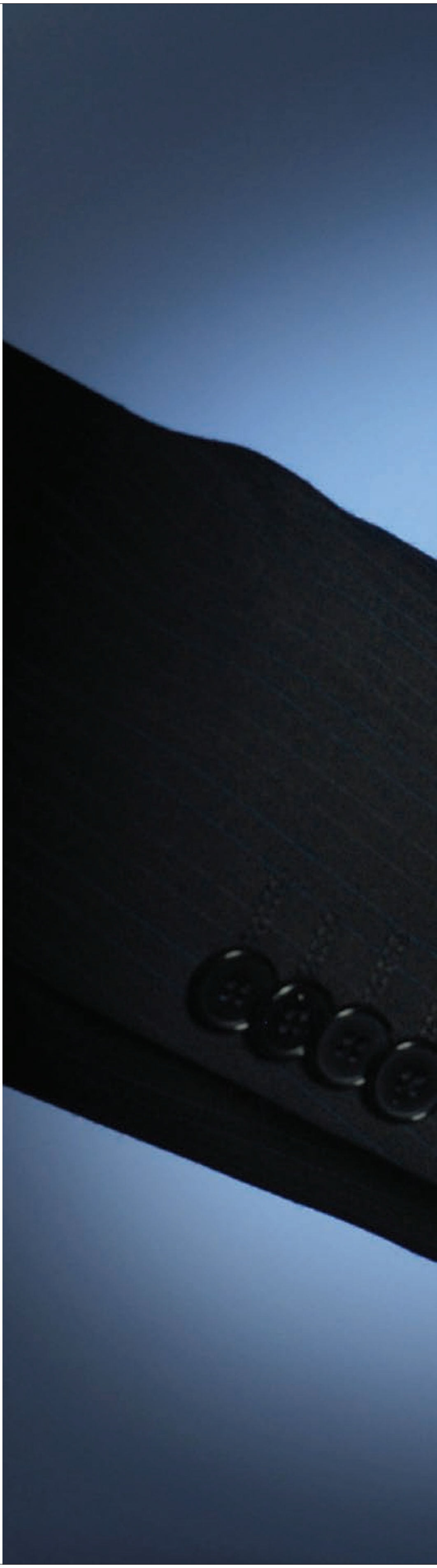
The Pioneers of EMC

DANIEL D. HOOLIHAN

In the mid-1950s, a group of professionals in the electrical engineering sector of radio frequency interference (RFI), began to formulate the idea of creating an organization devoted to their specialty.

These informal discussions came to a climax at a luncheon on February 27, 1957 during the Third Conference on RFI Reduction sponsored by the Armour Research Foundation in Chicago. In his speech, Mr. Fred Nichols, Vice-Chairman of the Radio Interference Technical Committee of the Los Angeles area, proposed starting a national professional group on RFI, and six individuals at the luncheon enthusiastically endorsed the idea and helped make it happen. Those individuals included Anthony Zimbalatti, Milton Kant, Harold Schwenk, John Lucyk, Albert Ruzgis, and S. Nellis. The six individuals from the East Coast, along with Mr. Nichols and other involved engineers, eventually gathered 325 signatures on a petition that was delivered to the New York Office of the Institute of Radio Engineers (IRE) in July of 1957. The petition to form a group devoted to radio frequency interference was approved by the IRE on October 10, 1957, and the first organizational meeting of the Professional Group on RFI was held on November 20, 1957 in Asbury Park, New Jersey.

This article addresses the pioneering work of Mr. Schwenk, Mr. Leonard Milton, Mr. Albert Kall, Mr. James McNaul, Mr. Milton Kant, Dr. Ralph Showers, Mr. Anthony Zimbalatti and Mr. Sam Burruano.



SOME EARLY PIONEERS OF THE EMC SOCIETY

The First Officers of the Professional Group on Radio Frequency Interference (PGRFI) and Involved Individuals: 1950 -1959

Harold R. Schwenk
(November 1, 1923 - March 2, 1988)

The first chairman of the Professional Group on RFI (PGRFI) was Harold Raymond Schwenk. (The PGRFI was the predecessor of the Electromagnetic Compatibility (EMC) Society of the Institute of Electrical and Electronic Engineers (IEEE)). Mr. Schwenk was known for his teaching capability, especially with his fellow engineers. He joined the Sperry Gyroscope Company in New York, where he was involved with analyzing, designing, testing and reworking electronics equipment to assure compliance with RFI/EMI/EMC requirements. In addition to founding the PGRFI, he also founded the Metropolitan New York EMC Society Chapter and served as chairman of that Chapter several times. In 1967, he took his EMC expertise to Grumman Corporation in Bethpage, New York. There, Mr. Schwenk used his education and experience to help design the EMC capabilities of the A-6B, EA-6B, E-2B/C, F-14 and EF-11 aircraft. Harold also performed EMC engineering experiments that led to advancements in the design of shielded structures, including protecting electronics in all-composite aircraft from lightning effects.

Electronic News

June 22, 1959

RF Interference Work Termed Urgent Need

Electronic News Photos

INTERFERENCE PANEL: Panel on interference prediction at a session sponsored last week by the IRE Professional Group on Radio Frequency Interference, in New York. Standing, left to right, are C. B. Plummer, Federal Communications Commission, Washington; Dr. R. M. Showers, University of Pennsylvania, Philadelphia; D. C. Ports, Jansky & Bailey, Inc., Washington; Andrew Massey, U. S. Navy Bureau of Ships, Washington; A. L. Fullerton, Jr., Melpar, Inc., Boston; H. R. Schwenk, PGRFI National Chairman; J. J. Egli, U. S. Army Signal Research & Development Laboratory, Ft. Monmouth, N. J., and S. J. Burruano, Filtron Co., Inc., New York.

Leonard Milton

Mr. Milton was the first vice-chairman of the PGRFI and also served a second term as vice-chair from 1 July 1960 to 30 June 1961. He served on the Constitution Committee of the PGRFI and was the first chairman of the Liaison Committee of the PGRFI. Mr. Milton was an executive vice-president of Filtron Company in 1959 and became president of Filtron Corporation in 1962.

Albert Kall

Mr. Kall was the first secretary of the PGRFI and served two other terms as secretary. He also chaired the Technical Advisory Committee of the Administrative Committee of the PGRFI. Mr. Kall chaired the Technical Papers Committee in 1960, and in 1961 and 1962, he was acting editor of the *Transactions* for the PGRFI. Finally, he was an associate editor for the *Transactions* from 1970-1974. Mr. Kahll had a long career in industry with the Ark Engineering Company.

James McNaul

Mr. McNaul was the first treasurer (1957-1959) and the second chairman (July 1, 1959 - June 30, 1960) of the Administrative Committee of the PGRFI. As a member of the Constitution Committee, he was also instrumental in drafting a constitution for the PGRFI. McNaul was a lieutenant in the Army Signal Corps R&D Labs at Fort Monmouth, New Jersey from 1956-1958. While at Fort Monmouth, he was assigned as Assistant Project Officer to Project MONMOUTH, a large scale investigation of communication systems in a future

European war, with particular emphasis on new communication technologies and the radio frequency

James McNaul

interference potential resulting from its introduction into the Army structure. It was a three-year study using civilian contractors in cooperation with Army professional engineers. In 1961, McNaul joined the Army Satellite Communications Agency, becoming Assistant Technical Director. In 1964, James returned to school at Stanford University and earned his Ph.D. in business. He then pursued a career in academia and business until his retirement in 1999. Dr. McNaul was a principal participant in the 50th Anniversary of the EMC Society in Hawaii in 2007.

Milton Kant

Mr. Kant was an original member of the Administrative Committee of the PGRFI and helped prepare a draft Constitution for the PGRFI. He was also the first editor of the PGRFI Newsletter, and published that issue on January 2, 1958. He then served on the Newsletter Committee of the PGRFI. Milton served as secretary of the Adminatrative Committee of the PGRFI in 1961. He also served as chairman of the Information Retrieval Committee (which led to the publication of EMCABS) and chaired the 1965 EMC Symposium Committee. Initially, Mr. Kant worked for the Civil Aeronautics Administration and then the U.S. Air Force, Rome Air Development Center. He became more involved with RFI when he moved to the Sperry Gyroscope Company in New York and then switched to RCA/GE to work on the Aegis destroyer radar system. After working on the Aegis system for 22 years, he retired. Milt was invited to the 50th Anniversary of the EMC Society in 2007 and showed up in Hawaii for the festivities.

Leonard Milton is seated in the center of the front row.

Ralph Showers

Dr. Showers was a member of the original Administrative Committee of the PGRFI and became the third chairman of the PGRFI from 1960 to 1961. He also chaired the Technical Papers Committee and initiated the Transactions of the PGRFI organization. He was a Professor at the Moore School of Electrical Engineering at the University of Pennsylvania in Philadelphia. Dr. Showers also chaired the United States Committee on EMC, C63, for 35 years. He is a past chair of the International Committee on EMC, CISPR.

Dr. Ralph Showers

He remains active in CISPR Technical Advisory Groups and IEC Technical Committee77 Technical Advisory Groups. Dr. Showers has won numerous awards for his EMC Standards activities, including the prestigious International Electrotechnical Commission's Charles Proteus Steinmetz Award in 1982 "for leadership in the development of standards for measurement of radio interference".

Anthony Zimbalatti

Mr. Zimbalatti was one of the six "drivers" of the organizational founding of the PGRFI and was present at the infamous February 27, 1957 luncheon which initiated the formation of the EMC Society. Mr. Zimbalatti was a member of the Newsletter Committee of the PGRFI in 1958. He had a very successful career at the Grumman Aircraft as an EMC engineer. He also wrote a thought-provoking column for the Newsletter called *Point and Counter Point*. Finally, Tony was honored at the 50th anniversary of the EMC Society in 2007 as one of the Society's Founders.

Samuel J. Burruano

Sam was an original member of the Administrative Committee of the PGRFI. He was chairman and co-organizer of the First RFI Symposium in 1959. In June of 1961, he formed Burruano Associates to provide military and civilian agencies with practical and theoretical consultation in the fields of interference analysis and control. He was present at the 50th Anniversary of the EMC Society in Hawaii in 2007.

(the author)

DANIEL D. HOOLIHAN

is the Founder and Principal of Hoolihan EMC Consulting. He is a Past-President of the EMC Society of the IEEE and is presently serving on the Board of Directors. He is presently an assessor for the NIST NVLAP EMC and Telecom Lab Accreditation program. As of the first of this year, he is the Chair of the ANSI ASC-C63R committee on EMC.

A War Story from Mr. Zimbalatti

(an incident of problem solving at Langley Air Base, edited by Dan Hoolihan from Tony Zimbalatti's War Stories told at the 50th Anniversary of the EMC Society)

We did early-flight development testing of the Grumman-built E2A U.S. Naval Aircraft. The range of the Low-Frequency Automatic Directional Finding (LFADF) system was being limited because it was an early development aircraft. Because it had no other low frequency receiver to use for navigation, the range was restricted to less than five miles. This hampered the developmental flights for many months. It was standard practice to have, for each aircraft, an avionics flight test engineer who reported his observations; one particular flight test engineer reported the failure of the aircraft radio to attain maximum range or sensitivity and claimed it was due to electromagnetic interference (EMI). He claimed, furthermore, that the EMI people didn't know how to solve the problem. In short and for whatever reason, he didn't like EMI engineers; they had done something to him.

Several months after hiring onto Grumman in the late 1960s, I was asked to evaluate the problem and to develop a solution. The flight was scheduled on Christmas (bonus) Day because, in general, it was less than a half a day at work. I appeared at the flight-ready room, met the avionics engineer and the flight test engineer, and asked, "What now?"

He said, "Harness Up." I said, "Well, show me how. And what do I do, if we have to use the parachute?" (which is part of the harness, for those who are not familiar).

He said, "You mean you haven't been to school and been certified to fly?" I said, "I just started at Grumman a couple months ago, what do I know?"

I noticed that he had a wry smile on his face, like "It's an EMI guy, I'm going to get him." So, he harnessed me up and we walked to the taxi strip where the plane was waiting with the pilot and the co-pilot.

He said, "This is how you use this. If we have to ditch (that's the technical term for getting out of the aircraft) stand on a seat, push out the plug, jump, count to ten, and you'll clear everything. Also, we'll be over water so you're going to have to get rid of that harness." I started to feel queasy.

The way the set-up is on an E2 aircraft is that you have a pilot and co-pilot, you have a left and a right engine, and then in the aft compartment you have three operators with three scopes. The capacity was such that they could monitor the whole East Coast corridor and control all the traffic at Philadelphia, New York, and Washington. We actually ran an experiment with that aircraft to show that we could do that in case the three terminals were down. That is the capability of that aircraft; the equivalent of the Boeing aircraft that did the same thing for the Air Force. The Boeing did it with maybe ten or twelve people, while the Navy did it with three.

We took off, successfully. I performed my test and was satisfied with the results that I got. Then, the pilot announced that, since we had time, he wanted to do a so-called "fish-tail experiment." As in "fish-tailing" with a car, the aircraft swings from side-to-side. He wanted me to observe and report. I was in the rearmost seat of this 60 foot long airplane, feeling most uncomfortable. He was going to measure fish-tailing!!

Stopping the engine on the right side, or stopping the propeller and feathering it (which turns it so it doesn't offer resistance), then replicating the procedure on the left side, causes the plane to swing from side to side. I was watching the engine and starting to feel queasy. I don't like flying in the first place and, with my inner-ear problems, balance is a big problem for me.

Fortunately, we didn't have to ditch. To this day, I still don't know if I would have gone down with the plane, because I don't think I would want to jump out. We came back and went into the debrief room. I debriefed and said that my test proved it wasn't an EMI problem; it was an antenna problem. The flight test engineer grabbed the microphone and he said that the test proved that it was an EMC problem. We were back to zero, again!

The controversy persisted until a special flight test was made. I got a call from the chief test pilot for the E2 program. He said, "You still have the controversy?"

I said, "Yes, but Tommy, there is really no controversy. If you fly that aircraft with a dummy rigged antenna, we can prove it."

Now, Tommy was known for a secret. And what was his secret? In one of his maneuvers of the airplane, he dived, fired his gun, came back up into the gun, and riddled his own airplane with bullets. That was the kind of guy Tommy was!

He said, "Tony, if you tell me you want me to fly a dummy rigged antenna, what are you going to do?" I said, "I am going to move the antenna out of the fuselage (outside of the aircraft) and drop it about six inches. Then we are going to fly."

He said, "It will be done in two days, The flight will happen Saturday. Want to come in and watch it?" I said, "Of course!"

So, Saturday comes and Tommy took off. We were watching him. He went out to five miles. He went out to ten miles. He continued flying and, finally, we got a message.

He says, "I am at a hundred and ten miles." I'm going, "Tommy we've got the flight restriction."

He said "Don't tell me, that's my business to fly." I said, "Sorry."

So he went out one-hundred and ten miles, which was well beyond the range that we needed to do our developmental flight testing. He came back and landed. You have to understand that at the Grumman Company at this time, the founders were there. The original aircraft people, including Leroy Grumman, were still alive. It was an engineering company. It was a company that had more engineers per worker than any other company in the US. In fact, its name was the Grumman Aircraft Engineering Company.

So Tommy says, "If anybody tries to take that antenna off, I will exercise my prerogative."

Everybody knew what that meant. He had a direct line to call the CEO. So the flight test continued with a jury rigged antenna.

Meanwhile, the antenna group and the avionics engineers were still arguing that it was not an antenna problem. Their basis was that I had moved the antenna away from the interference source by bringing it outside the airplane. I said, "Yes."

Meanwhile, I developed a test plan for the E2 for the EMC engineers that were assigned to the E2 because I was hired to work on another airplane. My section chief told me to write the plan.

I said, "I want you to collect the data to prove that it is an antenna problem".

They performed their test, basically dropping the antenna one inch at a time. I had math models to predict what would happen on the back of an envelope. You have an aperture; a small aperture and a large surface. Rensselaer published some aperture results and I used their quasi-static equations, because we were dealing with 95KC to 1 MC – not a big deal. They came back with the results, and still they insisted that it was the antenna group. In the hierarchy, the antenna group for some reason is considered in high esteem. The reason, I think, is because everyone looks at it as a mysterious device. But, it's nothing but a hunk of wire that gets tuned.

Meanwhile, nobody wanted to do anything. So, I grabbed the antenna installation manual that Collins had written. It said that the average aperture (I can't remember the exact dimension) was two foot square; the actual aperture was less than that, maybe one foot square. I looked to the antenna engineer and I said, "How did this happen?"

He said, "You know … structures. We are always concerned about cutting a big wall at that location on the aircraft." I said, "Yeah. I can understand that. So what did you do?"

He said, "I called Collins and told him about the problem." Collins said: "'Oh yeah, you could reduce the size of the aperture. "

I said, "You have this documented, of course. And did you ask him for the mathematics to justify this decision?" I knew the answer by his reaction. I said, "You've done a very poor thing." I showed him the results because my boss had seen them.

He said, "I certainly endorse it. I don't want to be in an argument with this section chief."

I said, "He doesn't have to know."

So, to this day, that antenna sits two inches below the fuselage with the radar, forty or fifty years later.

A War Story from Mr. Burruano

(an incident, edited by Dan Hoolihan from Sam Burruano's War Stories told at the 50th Anniversary of the EMC Society)

What I want to do is tell you a little bit about the early days, some of my war stories.

The technical stuff is great, but there are a lot of work stories to show you that EMC can be a fun job. My first run-in with Air Force One was in the 1950s. Eisenhower was president and Vice-President Nixon was on his way to Russia for the infamous Kitchen Debate. As Air Force One was flying over Poland, the navigation was via triangulation and something was jamming the entire navigation system. They couldn't hear any of the transmissions from the radio stations and required special help from the Russians to get into Russia. When the plane came back from Russia, they called and said: "We want to borrow Sam for three nights." They thought it was going to take that long to find out what the problem was. So, I went over to Wright-Patterson Air Force Base. They must have had about 15 or 20 guys out there making microscopic measurements on the body of the airplane. I went up to the Colonel who was running the thing and said, "Look, send these guys home. I'll solve the problem for you." You pray a lot when you do this, because that's gutsy. So, I sat down and started to do the logical things. What could be causing this? Is it on the airplane? What could it be? Could it be broadband or continuous wave? Could it be the electronic system or the electrical system? I listed all the parts of the electric system (like 449, which I was instrumental in doing something about during the time I was working on Project Llamas … but that's another story). There was no sense in listing all of the electronics sub-systems; I turned all of those on at once and it didn't do a thing to the navigational system. So, I started to go through the electrical sub-systems one by one. All of a sudden, BZZZZ!! Boy, I had found it. I looked down to see what it was, and it was the fluorescent lights.

So it was a very simple solution. I got some non-fluorescent lamps and installed one interference filter, and the interference was gone. They thought I was a real hero. (I know, I know … a hero is really an Italian sandwich!)

This picture from the 2007 IEEE International Symposium on EMC in Hawaii shows, from left to right, James McNaul, Vince Mancino, Milton Kant (in the "Hawaiian" shirt), Dr. Showers, Sam Burruano, and Tony Zimbalatti.

Today's Pioneers of EMC

Originally published in the IEEE EMC Newsletter, Issue 231, Fall 2011

Our 2011 symposium has disappeared into history, along with that one week of the year when EMC experts and friends from all over the world get together for the exchange of ideas and words. This year, the symposium committee tried a few new things on the exhibit floor that were intended to enhance the experience of all our attendees and exhibitors. Our symposium chair, Mr. Ray Adams from Boeing, was very supportive to all of the committee members as they explored a few changes from symposia of the past. One experiment that he encouraged me to try was a unique attempt to honor important members of our society. That is the background picture into which we were able to paint the stories of about a dozen *Pioneers Of EMC (POE)*. Readers who were there will surely recall the attitude of unusual excitement as we all got to meet and shake hands with engineers who are singularly responsible for what our industry looks like today.

Ray Adams approached me well over a year before our event took place to ask me if I would be willing to work with him on the exhibits side of the 2011 symposium. I can only guess that my long-time exposure to the entire Southern Californian EMC community was the primary qualification that he considered in proffering his invitation. Ray knew that, in my career as an independent Manufacturers Representative, I was constantly meeting and working with engineers and companies all over the SoCal territory. My job is to help them solve their EMC problems by matching their needs to the best products available. Since I work closely with many of our long-time EMC exhibitors in that manner, helping them on the exhibit floor was a natural fit.

Working on the exhibits floor with our symposium partners, Three Dimensions and GES Convention Services, was rewarding but difficult. Suffice it to say that I have a better appreciation of how much fun Mr. Boehner and Mr. Reid have on a daily basis! It literally did not matter what the topic was. On the exhibit floor there were always conflicting agendas and differing opinions! On everything from temperature to which fans were turned on to hours of operation to food, there were passionate advocates of various and sundry alternatives. The best news of all, however, was that in the end at the Exhibitors Breakfast on Thursday morning, there were no complaints and no angry exhibitors.

photo by the EMC 2011 Symposium Photography Team

Pioneers of EMC attending the EMC 2011 Symposium in Long Beach included (front row from left) Ray Klouda, Joyce Ware (daughter of Paul Bender), George Kunkel of Spira Manufacturing Corporation, Richard Parker of Fair-Rite Products Corp, Art Cohen of AH Systems, and Tom Klouda. Tom and Ray are the sons of Jim Klouda, founder of Elite Electronic Engineering.

(Back row from left) Richard Janiec of Retlif (representing Walter Poggi), Don Shepherd of AR RF/Microwave Instrumentation, Joe Fischer of Fischer Custom Communications, Brian Lawrence of iNARTE, Alwyn Broaddus of DNB Engineering, and Don Sweeney of DLS Electronic Systems rounded out the pioneers present in Long Beach.

That was my personal goal – to make sure the exhibitors at our annual symposia would come to Long Beach and feel that their participation in our event was respected, appreciated and valued.

There were quite a few new ideas reflected on the exhibit floor; but this is neither the time nor place to discuss all of them. However, one of our 'new ideas' had rather impressive results and is worthy of special mention. Our *Pioneers of EMC (POE)* event appears to have been thoroughly enjoyed and supported by the entire membership.

It may be of some interest to society members to better understand what the driving factors behind this event were. While I was driving between account calls one day sometime during the month of March, I had the bright idea of putting together our POE display, After attending dozens of IEEE/EMC Society events over the last decade, I was struck by the realization that there was a pretty important class of people that our society does not generally have a good track record of recognizing.

Any attendee at an EMC Symposium event can visit Dan Hoolihan's Historical display and discover when our society was founded and a host of other related information. We often put old EMC test and measurement equipment on display for educational purposes. It is pretty amazing what 'we' used to do with some pretty rudimentary hardware… and that was before 'software' was even a word, much less a reality! Well, there's another thing that new engineers and members of our profession can learn from visiting Dan's booth, but it is a bit on the subtle side… EMC Test Standards always drove test equipment development and there were usually easily identifiable market leaders who drove the standards and then designed the necessary test equipment or procedures.

It was those leaders who generally made hard decisions a long time ago. They took a gamble that paid off for all of us who now make our living in the world of EMC Technology.

Our rule of thumb in looking for POE nominations from Symposia committee members and others were the following:

- ✓ left the corporate world 30 to 40 years ago because they had a 'better idea'
- ✓ risked it all with no guarantees (at the time), but were successful
- ✓ focused on some specialty niche area within the EMC industry
- ✓ went back to their garage and developed that better idea into a marketable product or service
- ✓ turned that marketable product into a company that impacted our industry
- ✓ developed a product/expertise that has had significant impact on our industry
- ✓ created a company that still exists today (in some version) and is critical to our industry
- ✓ became (and remain to this day) a bit of a 'guru' both to their own company as well as to others
- ✓ remained true to our EMC industry throughout and still contribute to it today

I leave it to future symposia chair and exhibit floor chairpersons to decide whether our POE honoring exhibit of 2011 was a new tradition worth repeating or whether it was simply a one-time 'transient'. Regardless, it is with great pleasure that I take a moment to introduce the Pioneers Of EMC who were nominated for our 2011 EMC Symposium. The people that we honored and introduced on the exhibit floor at the 2011 Long Beach Symposia are, collectively, responsible for the gainful employment within our industry of at least 1000 people. They represent and/or support several hundred small businesses and have products in literally thousands of EMC test labs around the world. I am personally very proud to have been able to meet every one of them.

Arthur C. Cohen
AH Systems, Inc.

Art unofficially started his work long before he established AH Systems in 1974. However, once he graduated and moved beyond modifying *Pringles* cans in his basement, he developed a complete set of antennae that came to be depended upon by many people for whom EMC testing was 'the great unknown'. Now, his company manufactures a complete line of affordable, reliable EMC test equipment including test antennas, preamplifiers, current probes and low-loss cables that are used to satisfy almost every possible test standard.

Paul Bender
AR Receiver Systems

Paul started Carnel Labs in his garage in November, 1961, as a calibration laboratory. He quickly became the key West Coast service center for the servicing of receivers, spectrum analyzers and other EMI instruments ranging from DC to 40 GHz. Paul and his team put their hands on (and repaired or calibrated) equipment used by the US Navy and Air Force, NASA, JPL, Hughes, General Dynamics, Rockwell and Litton Data Systems, just to name a few. In 1992, Carnel began manufacturing its own EMI product offerings based on their purchase and consolidation of the old Eaton line. Carnel Labs became the Receiver Systems Division of AR in 2002. Paul likes to say that he is still an employee in the field after 50 years, and he continues to enjoy the many challenges that it brings to him. He adds that he is happy to have a nice head of hair in spite of pulling out many of them due to those many frustrating challenges!

Donald Shepherd
AR RF/Microwave Instrumentation

"Shep" started work in his garage. He and his partner began work in an era when RF amplifiers were expensive, unreliable, difficult to work with, very touchy in performance and hard to find. One of Shep's founding principles was to provide exceptional customer support. Over the last 40+ years, he has been persistent and has turned those dreams into a reality with worldwide reach. No EMC lab in the world is unfamiliar with the wide orange stripe and the quality and service that it represents.

Donald L. Sweeney
DLS Electronic Systems, Inc.

Today, Don is the president of DLS. However, his career has been varied and included stints at Extel, Teletype, Gates Radio and Collins Radio, along with specialized consulting contracts too numerous to list. He has devoted the last 40 years of his career to solving problems in electromagnetic engineering. Through his formal educational courses at various universities along with other teaching venue, there is hardly an EMC engineer anywhere today whose work has not been influenced by Brian (or new, up-and-coming ones who should not be similarly influenced).

Alwyn Broaddus
DNB Engineering, Inc.

DNB is a full service test lab, and world leader and expert provider of certification testing. We are honored to have Alwyn Broaddus, our founder, recognized as a Pioneer of EMC at the 2011 IEEE International Symposium on Electromagnetic Compatibility. Alwyn originally founded the company in 1979 to provide an electromagnetic compatibility (EMC) test facility with engineering support. Al was always noted for his interest in and willingness to solve unique or unusual EMC test problems, and DNB has retained that ability through the years. Today, DNB Engineering provides unrivaled EMC, Lightning, High Intensity Radiated Fields (HIRF), Environmental, Product Safety and Regulatory Testing to clients around the world, with a goal of providing a certified facility for customers where they will be able to obtain a qualified, unbiased, third-party product evaluation.

James Klouda
Elite Electronic Engineering Inc.

In many ways, Elite began aboard a USAF bomber sometime in the early 1950s. An on-board camera system started to interfere with the bomber's autopilot when it was turned on. An urgent call was placed to the camera manufacturer's new young engineer, Jim Klouda. With a little sleuthing, and a little shielding, Klouda fixed the problem and saved the day. Shortly after that experience, Jim founded Elite Labs. In 1954, Elite had two employees and a 2,500 sq ft storefront. By 1973, the company had grown 10-fold. Today, the company is three times larger yet, with 60 employees and more than 45K sq ft. Located in the heart of the country, the Illinois facility serves as both headquarters and the primary testing site with 27 RF test chambers in various configurations, sizes, absorber linings, power supplies and monitoring systems that can be tailored to meet exact testing needs. One thing hasn't changed in 50 years: Elite remains dedicated to serving its customers and ensuring their complete satisfaction

Richard Parker
Fair-Rite Products Corp

For over fifty years Fair-Rite has been the first choice in cost effective ferrite components. The history of ferrites (magnetic oxides) began centuries before the birth of Christ with the discovery of stones that would attract iron. However, Richard came sometime after that, and he focused his early efforts on using ferrites for EMI energy attenuation. He was a pioneer and a pathfinder in that area. The company he founded so many years ago now offers a comprehensive product line that includes a wide range of materials and geometries for EMI suppression, power applications and RFID antennas. It would be hard to find any other product on the market today that can offer such a fast, simple and effective way to suppress unwanted EMI energy.

Joseph Fischer
Fischer Custom Communications

FCC has been a stable background supplier to our industry for almost forty years now. During that entire time, FCC has consistently been a reliable source for specialized transient protection devices, RF test and measurement instruments and EMP test systems. Joe 'got the bug' many years ago and has never looked back. His indomitable partner Virginia (congratulations on a marriage of over 50 years!) has always been by his side providing just the right push of encouragement that he needed. He (and she) is still there at FCC providing innovative, high-technology products that meet the specialized needs of our industry.

Brian Lawrence
iNARTE, Inc.

Brian Lawrence began his EMC career designing stealth materials for the British armed services. In 1973 he moved to the USA and established a facility providing these materials to the US Navy. In 1980 he joined Rayproof to develop their anechoic chamber product line. Rayproof later merged into Lindgren RF Enclosures and then into ETS-Lindgren. Brian retired as Managing Director of ETS-Lindgren UK in 2006. He is now Executive Director at iNARTE, the International Association of Radio, Telecommunications and Electromagnetics. iNARTE has expanded its personnel credentialing programs and is today affiliated with RABQSA , a part of the American Society for Quality.

Walter Poggi
Retlif Testing Laboratories

Walter started Retlif over 30 years ago to provide a qualified, knowledgeable site for EMC compliance testing to FCC Parts 15 and 18. At the time, he was one of the first competent suppliers of these services on the east coast. He recognized a great need and rose to the occasion. In the years since, Retlif expanded their own test offerings, but Walter did a lot more than that for our industry. He was a key driver and contributor for the first EMC laboratory accreditation program through AVLAP and was similarly effective in working with the ACIL. Walters fingerprints are sprinkled throughout many of our Standards bodies and within many of our internationally recognized and accepted trade agreements.

George Kunkel
Spira Manufacturing Corporation

In his earlier years, George was a ubiquitous writer. He was always extremely active within the EMI/RFI and electromagnetic industry and has authored and presented over 100 papers internationally. His papers, inventions and products are invariably focused nicely around his own area of particular interest – EMI gasketing. The unique gasketing that Spira markets has had impact on many other manufacturers; both competitors as well as users. George has taught several courses on applied electromagnetic theory at UCLA and other sites. He held the position of chairman of the Technical Committee on Interference Control of the EMC Society of the IEEE for seventeen years. Unlike many, his listing in several “Who’s Who” publications was earned, not bought.

To close this article, I’d like to thank those pioneers listed above for their perseverance, individualism, entrepreneurial spirit and innovativeness through the years. Their work has impacted how all of us now do our jobs.

I’d also like to offer my thanks and recognition to the following people who played a key role in helping to make our POE event a success: Mark Frankfurth, Dan Hoolihan, Janet O’Neil and Ray Adams. Without their assist and able support, this event would not have occurred and those people shown above would, once again, have not been singled out for this recognition. My apologies to those we missed this first time around. Hopefully, the POE idea will be further refined and again presented to our community next year…

(the author)

GENE TAYLOR
is a Manufacturers Representative with Altamont Technical Services in Southern California. Gene and the entire ATS organization, are concentrated particularly on offering test and measurement solutions to their customers in CA and NV who have EMC/EMI testing requirements (and that’s just about everybody, nowadays!). He graduated from CSU in Northridge, CA with a BS in Physics/Physical Sciences then engaged in post-degree studies at UCLA in business and marketing. He made a particularly prophetic career decision in 1972 and has never looked back from a lifetime of technically-oriented, ‘top-o-the-pyramid’ type sales and marketing. He has been focused specifically in the ‘black magic’ world of EMC for about ten years. Gene can be reached through the company website at www.atsemc.com.

A Historical Look Back: The 1977 CBEMA Paper on Electromagnetic Emanations

Part 3

This third and final part looks at Section 6 (Interference Potential of EDP/OE), Section 7 (The Commercial EDP/OE Interference Models), Section 8 (Emanation Limits for EDP/OE Products), Section 9 (Comparisons of Recommended Limits with Others), Section 10 (Emanation Measurement), and Section 11 (Conclusions).

BY DANIEL D. HOOLIHAN

In the middle of the 1970s, the United States Federal Communications Commission (FCC) began to look seriously at electromagnetic emissions from electronic data processing (EDP) equipment and office equipment (OE). This growing awareness on the part of the United States telecommunications regulatory body was a result of the increasing number of computers being used by society and the heightened potential to licensed broadcast services due to the proliferation of small electronic-computer sources. The Computer and Business Equipment Manufacturers Association (CBEMA) formed a technical subcommittee to assist in preparing an industry response to the concerns of the FCC.

The first part of this series of articles reviewed the first one-third of the report, including the Title of the Paper, Background, Members of the CBEMA Subcommittee, Table of Contents, Scope, Definitions, Introduction and Section 4 (EDP and OE as a Source of Electromagnetic Emanations). The second part of this review looked at Section 5 (Susceptibility of Communications Receivers to Commercial EDP/OE Emanations) of the report.

> Section 6 of the report completes the investigation of the paper's interference model by examining the propagation of electromagnetic emanations from EDP/OE to communication receivers.

TITLE OF THE PAPER

The title of the published paper was *"Limits and Methods of Measurement of Electromagnetic Emanations from Electronic Data Processing and Office Equipment."* The report was prepared by CBEMA Subcommittee 5 on Electromagnetic Interference.

TABLE OF CONTENTS

The report was 183 pages in length. It included a Title page, Foreword, Table of Contents, Scope, Definitions, Introduction, seven major sections, Conclusion, and one Appendix.

SECTION 6 - INTERFERENCE POTENTIAL OF EDP/OE

This section of the report completes the investigation of the paper's interference model by examining the propagation of electromagnetic emanations from EDP/OE to communication receivers. *The examination is primarily empirical and considers the proximity of the EDP/OE to the population of receivers.* The report distinguished between commercial products and domestic (used in the home) products.

An analysis of the number of receivers quickly led to the conclusion that AM radio receivers and VHF/UHF Television were the most likely to have interference issues with EDP/OE. One of the report's footnotes says: 'There were 178 million AM receivers and 102 Million TV sets in the USA in 1971."

Because there were very few receivers in the frequency range below 450 kHz, the interference potential of the sub450 kHz receivers was considered to be minimal and the low end of the conducted emission limits was set at 450 kHz. Again, because there were very few receivers above 1000MHz and because, in 1977, the harmonics from clocks in the computer equipment were not prevalent above 300 MHz; it was decided to select 1000 MHz as the high-end limit of the radiated emission limits.

Thirty MHz (30 MHz) was selected as the "break point" between conducted and radiated emissions based on (1) propagation factors, (2) measurement practices, and (3) traditional limit setting. A study of the propagation factors of radiated electromagnetic fields *below 30 MHz* led the study to say: "Therefore, at typical receiver/ product separation distances, direct radiation is expected to be much lower than radiation from the receiver's power cord caused by conductor emanations."

The paper did a study of receiving antennas within 100 meters of computer system installations in the

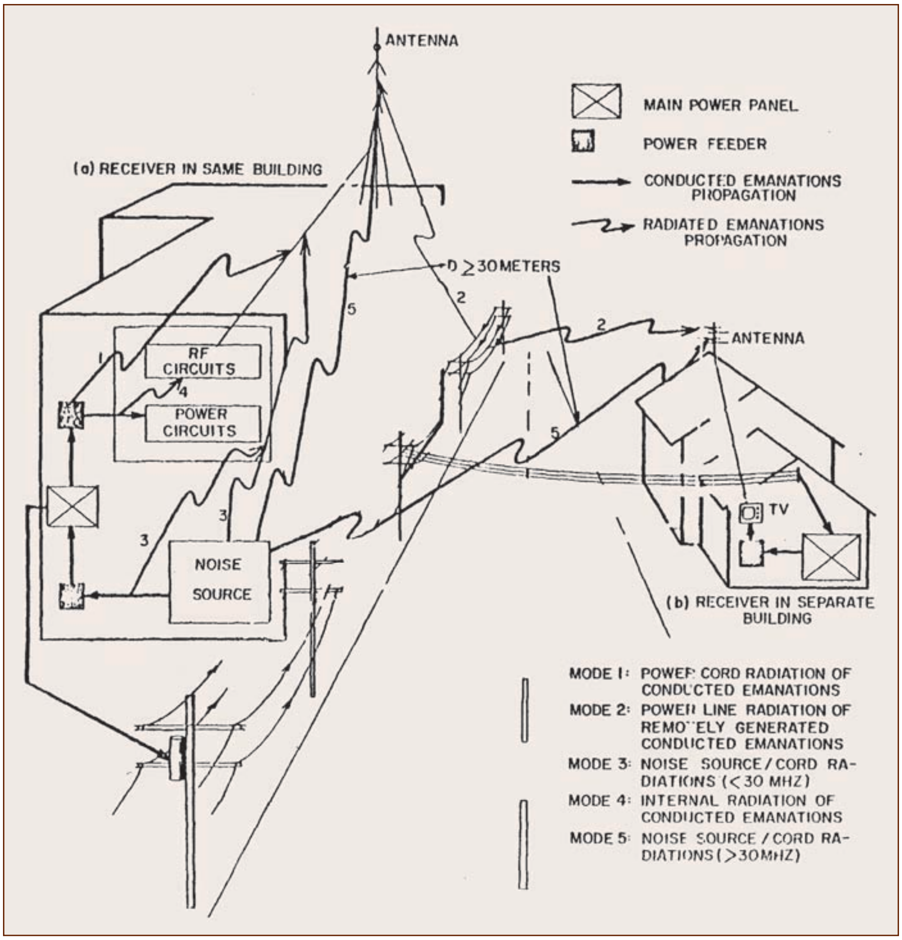


Figure 1: Five EMI propogation/coupling modes

Conducted propagation losses depend heavily on the source impedance, power line impedance, and receiver impedance.

USA and Canada. The study covered 243 commercial EDP/OE installations and it observed 826 functional antennas. Furthermore, it was concluded that *"89 percent of receiving antennas found within 100 meters of commercial EDP/OE installations can be expected to be 30 meters or more from the installation."* The study concluded **a** *30-meter horizontal distance* was a reasonable control distance. A 10-meter height for the antenna was picked as an "average" antenna height.

Five coupling modes were identified for the model.

Mode 1 Power Cord Radiation of Conducted Emanations

Mode 2 Power Line Radiation of Remotely Generated Conducted Emanations

Mode 3 Noise Source/Cord Radiations < 30 MHz

Mode 4 Internal Radiation or Conducted Emanations

Mode 5 Noise Source/Cord Radiations > 30 MHz

These modes are shown in Figure 1 (Figure 6-1 in Report).

The principal coupling mode in the 30 to 1000 MHz range for radiated emissions is Mode 5, where the emanations are transmitted to the receiving antenna through the air. Attenuation of the electromagnetic fields in the 30-300 MHz range was studied and found to be 23 dB per decade, which agreed closely with the theoretical value of 20 dB. Attenuation of the EM energy through building walls was selected to be 8 dB based on theory and experimental measurements.

Conducted propagation losses depend heavily on the source impedance, power line impedance, and receiver impedance. The model being developed by the study assumed the computer system and the "receiver" both were operating from different metered utility services. Theoretical investigations and field investigations led to a 25-55 dB loss for a common service entrance and 42-89 dB loss for separate service entrances. The minimum values of 25 dB (business/apartment) and 42 dB (business/house) were selected for the EMI model.

SECTION 7 - THE COMMERCIAL EDP/OE INTERFERENCE MODELS

The model for commercial EDP/OE interference is shown in Figure 2 (Figure 7-1 in Report).

The model shows (1) the separation distance for radiated emissions between the commercial source of EDP/OE and the receiving antennas is greater than 30 meters and (2) the conducted emanations have at least two sets of power panels/watt-hour meters

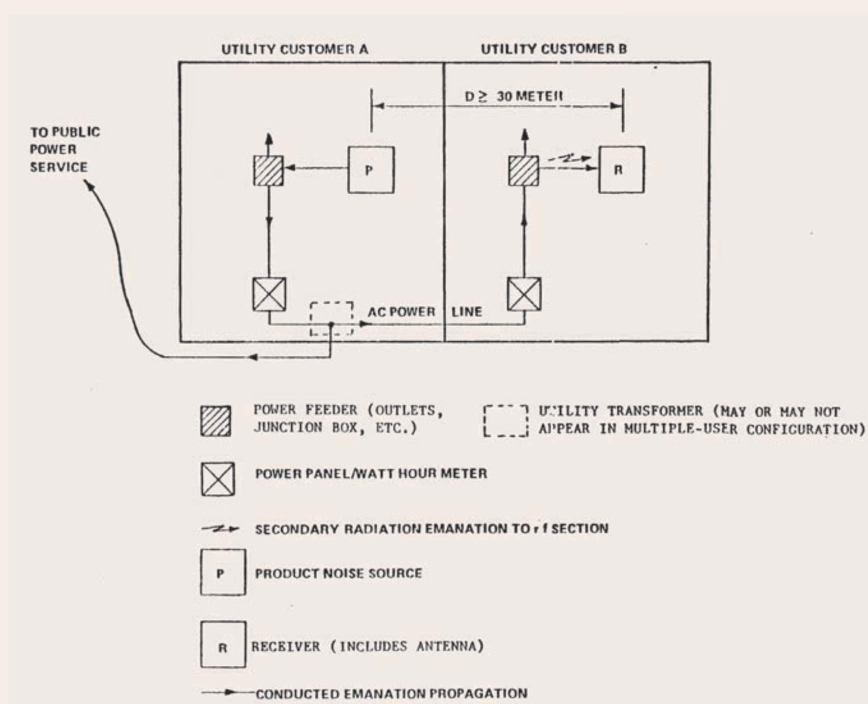


Figure 2: Commercial EDP/OE interference model

	City/Residential - Business/Apartment			Rural/Suburban - House-to-House		
	NB	BroadBand		NB	BroadBand	
	Average	Peak	QP	Average	Peak	QP
V''_{50}	16	79	37	16	79	37
A_L	25	25	25	42	42	42
E_S	65	65	65	48	48	48
E_T	-46	-46	-46	-46	-46	-46
V_{50}	60 dBuV	123 dBuV/MHz	81 dBuV	60 dBuV	123 dBuV/MHz	81 dBuV

Table 1: Calculation matrix for EDP/OE emanation limits (power line conducted) for the 450 kHz to 1.6 MHz range

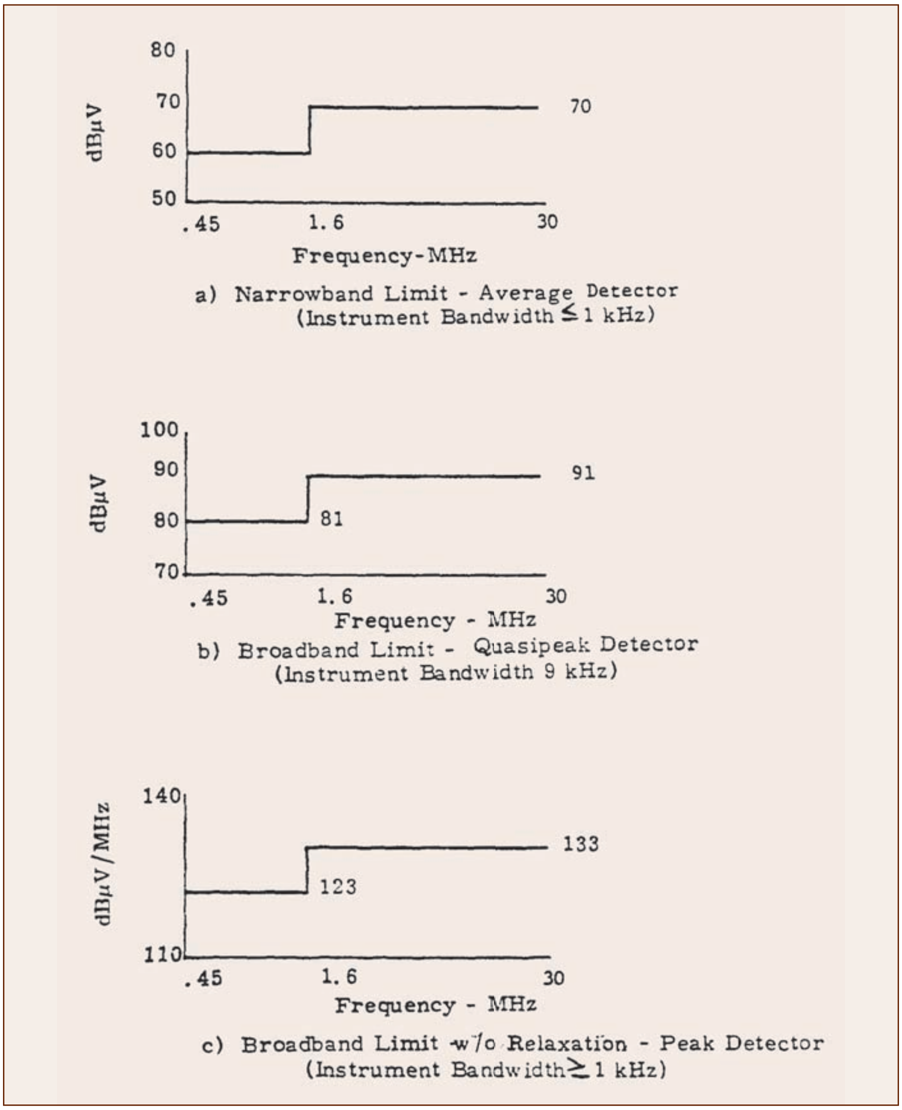


Figure 3: Calculated conducted limits for 50 ohm LISN

between the source and the receiver. Eleven assumptions were outlined in the paper and, in general, the assumptions were all worst case.

The maximum permissible field strength of radiated interference at a receiver located 30 meters from an EDP/OE is given by:

$E_{30} = E_S - S/N + A_B$

where:

E_{30} = radiated emanation limit for commercial EDP/OE separated by 30 meters or more from a receiver in the selected communication service band (dBuV/m or dBuV/MHz/m)

S/N = receiver signal-to-noise ratio for the selected communications service (dB)

A_B = building attenuation factor for the EDP/OE environment (dB)

E_S = expected receiver signal strength (dBuV/m).

The equation for computing the limit for conducted emissions from commercial computers is given as:

$V_{50} = V''_{50} + A_L + E_S - E_T$

where:

V_{50} = conducted emanation limit at desired field strength (dBuV) or (dBuV/MHz)

V''_{50} = equivalent audio threshold of detectable interference at test condition field strength (dBuV or dbuV/MHz)

A_L = propagation loss factor (dB)

E_S = desired field strength (dBuV/m)

E_T = test condition field strength (dBuV/m).

The conducted equation gives the maximum permissible power line terminal voltage across a fifty-ohm grounded impedance that would result from conducted emissions from commercial EDP/OE separated by two sets of power panels and associated utility hardware.

SECTION 8 – EMANATION LIMITS FOR EDP/OE PRODUCTS

This section concentrates on the calculation of maximum permissible amplitudes for both radiated and conducted emissions from computer and business equipment in the frequency range 450 kHz to 1000 MHz.

Table 1 (Table 8-1 in Report) shows the calculated narrowband and broadband conducted limits in the frequency range 450 kHz to 1.6 MHz (the AM radio band) based on the earlier models and the received field strength protection levels presented earlier in the paper.

Because of the lack of receivers in the 1.6 MHz to 30 MHz range and the fact that the limit developed for AM radios was conservative, the paper proposed a more relaxed limit of 10 dB in the higher conducted emission frequency range.

Figure 3 (Figure 8-1 in Report) shows the calculated conducted limits for a 50-ohm LISN.

For the calculation of radiated emission limits in the frequency range from 30MHz to 1000 MHz, a typical received field strength for a primary service was selected. Then this field strength was decreased by the mean S/N ratio and increased by the worst-case building attenuation factor. A basic limit was calculated for each major communication service for a 30-meter control distance using this technique. The results are summarized in Table 2 (Table 8-2 in Report).

Frequency Band	1	2	3	4	5	6	7	8	9	10
Frequency (MHz)	30-54	54-88	88-108	108-136	136-174	174-216	216-300	300-420	420-470	470-1000
Primary Service	Public Safety	TV	FM Radio	Aero	Public Safety	TV	Aero	Aero	Public Safety	TV
Primary Grade Signal Strength dBuV/m	31	68	60	15	37	71	20	20	39	74
S/N - NB - AVG dB	10	45	30	0	10	45	0	0	10	45
S/N - NB, BB QP - dB	5	53	21	2	8	42	2	2	8	42
S/N - BB - PK - dB	-12	37	4	-14	-10	31	-14	-14	-10	31
Building Attenuation	8	8	8	21	8	8	21	21	8	8
Limit - NB - QP, Ave - dBuV/m	29	31	38	36	35	34	41	41	37	37
Limit - BB - QP - dBuV/MHz	34	23	47	34	37	37	39	39	39	40
Limit - BB - Peak dBuV/MHz	51	39	64	50	55	48	55	55	57	51

Table 2: Calculation matrix for EDP/OE emanation limits (radiated 30 meters) for the 30–1000 MHz range

A study of existing emission limits was performed. With the exception of a European Computer Manufacturer's Association study, no requirements and/or limits were found which were specifically developed for computers and office equipment.

The above values were smoothed to (1) produce a regular-unified limit and (2) to allow a single quasi-peak limit for emissions expected to produce narrowband or broadband receiver response.

The "smoothed" limits are shown in Figure 4 (Figure 8-3 in Report).

The report went into additional details and discussion on the amount of "underprotection" and "overprotection" provided by the "smoothed" limits. Potential relaxation of limits relative to pulse repetition rates for broadband peak limits was also discussed in detail, and then the report concluded that "the most efficient method for obtaining relaxation with calculating PRR is to use a CISPR Quasi-Peak receiver."

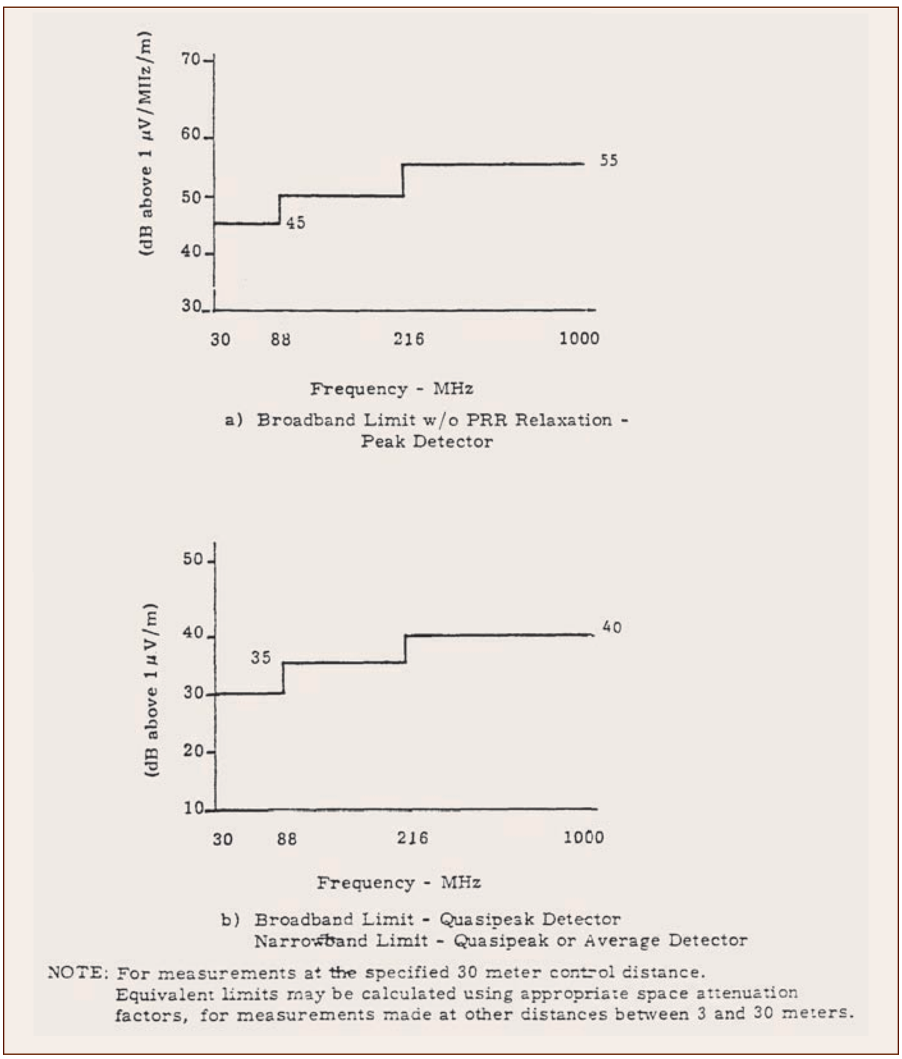


Figure 4: Recommended emanation limits (radiated) for EDP/OE in the 30-1000 MHz frequency range when measured at a 30-meter antenna distance

The probability for conducted EMI disturbance was found to be 0.004 for the business/apartment model and 0.0002 for the house/house model.

SECTION 9.0 – COMPARISON OF RECOMMENDED LIMITS WITH OTHERS

A study of existing emission limits was performed. With the exception of a European Computer Manufacturer's Association (ECMA) study published in March of 1976, no requirements and/or limits were found which were specifically developed for computers and office equipment. The technical derivations of national and foreign limits for equipment were not available to the developers of the CBEMA study. Also, the background on the degree of protection provided to communication services by meeting the existing foreign and national limits was not known.

Despite these weaknesses, the CBEMA limits were compared to the existing radiated emission limits and also to the typical NB emanations from existing EDP/OE products. In general, the proposed limits were at the same level as the German High Frequency Law in effect in 1977 and the proposed ECMA limits in the TV and FM tadio bands, and more conservative by approximately 20 dB in other ranges. *However, the proposed FCC limits for restricted radiation devices, as per FCC Docket 20780, were more stringent by 10 to 20 dB than the proposed CBEMA limits.*

This is illustrated in Figure 5 (Figure 9-1 in Report).

A similar analysis was done for broadband limits. The proposed

> The conducted emanation limits proposed by CBEMA were compared to the existing conducted emission limits from ECMA and the German VDE organization.

CBEMA limits are shown in the report to be (1) within 2 to 5 dB of the normalized German VDE limit, (2) within 3 dB of the ECMA proposed limits for the European TV and FM radio services, and (3) 3-27 dB more conservative in the other frequency bands.

The conducted emanation limits proposed by CBEMA were then compared to the existing conducted emission limits from ECMA and the German VDE organization. The VDE limit could be more than 12 dB more liberal to more than 25 dB more stringent. *The proposed FCC limit on commercial EDP/OE was 14 to 30 dB more stringent than the proposed CBEMA limits.* These comparisons are shown in Figure 6 (Figure 9-4 in Report).

Again, a similar analysis was done for broadband conducted emanations. Some difficulties were experienced in the BB comparison due to the use of a 150-ohm network by the VDE in Germany and because the BB Threshold of Detectable Interference (TDI) was 21 dB greater than the NB TDI. In general, the German VDE limits were more stringent than the proposed CBEMA BB limits.

A comparison of the proposed CBEMA limits and the existing emanation spectra from about 135 products representing the current line of EDP/OE products was performed. A comparison of the data showed that a significant number of installed products had exceeded the proposed limits, but there had been a negligible interference rate with the EDP/OE products. Also, it showed that many of the products far exceed the proposed FCC limits.

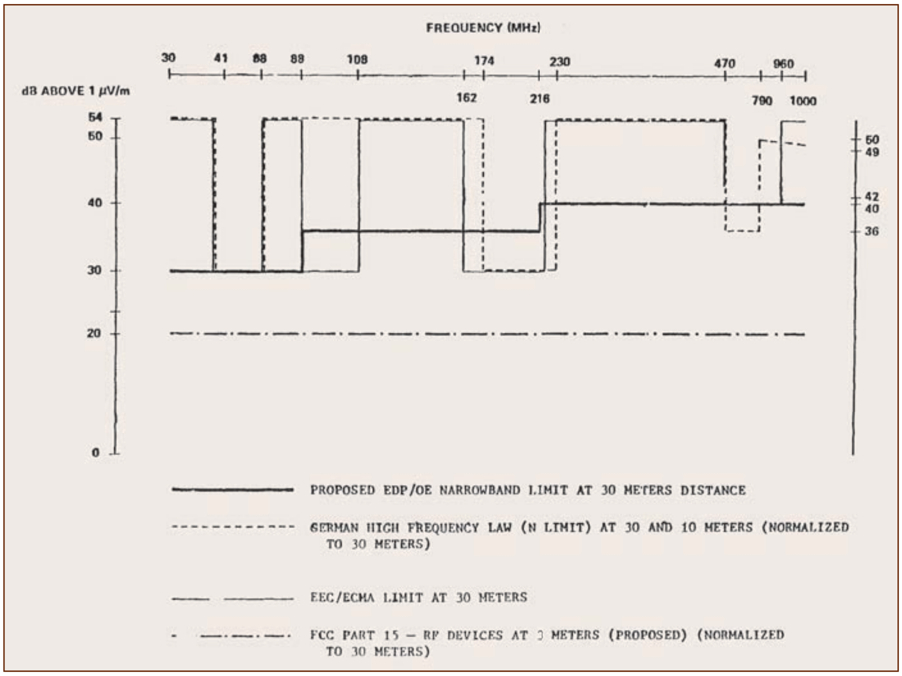


Figure 5: CBEMA recommended radiation emission limits compared to those existing in 1977

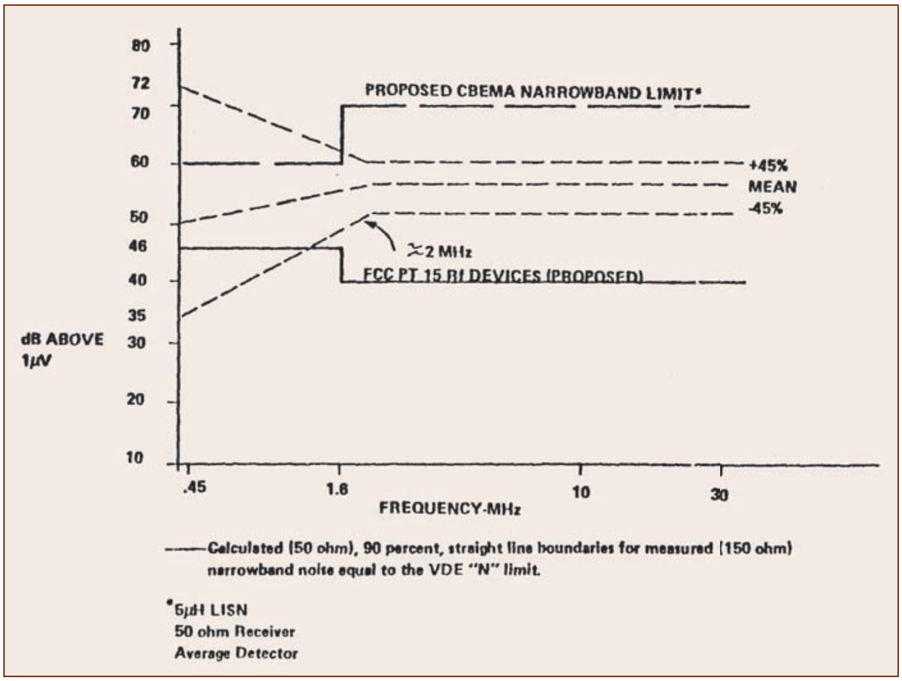


Figure 6: Comparison of conducted emanation narrowband limits

This is illustrated in Figure 7 (Figure 9-7 in Report).

A similar graph was generated with similar results for narrowband conducted emissions with a 50-ohm LISN.

SECTION 10 – EMANATION MEASUREMENT

This section of the report recommends a standard way of measuring emissions with standardized test equipment. The recommendations included the following:

1. tuned RF voltmeters with a CISPR quasipeak detector and/or a peak and average detector
2. 50-ohm Line Impedance Stabilization Network (LISN)
3. free-field radiated emission measurement or equivalent with allowance for practical site characteristics
4. permissible measurement at antenna distances other than the control distance of 30 meters and down to 3 meters
5. measurement of products with only normal operational ground configuration; i.e., grounded or ungrounded
6. measurement of either units or systems at the manufacturer's option

The study endorsed the CISPR bandwidth specifications in the 30-1000 MHz range (120 kHz bandwidth) but thought that the 9 kHz bandwidth of the CISPR receiver for the 150 kHz to 30 MHz range was being too stringent by about 20 dB. Fifty-ohm measuring receivers are preferred by the study, but other input impedances are acceptable provided the impedance of the 50-ohm LISN was maintained.

For radiated EDP/OE emanations, the NB limit is equal to the QP broadband limit, so a single QP measurement can be made to evaluate a source of emission that will produce both NB and BB responses. For conducted EDP/OE emissions, the BB QP limit is 21 dB greater than the NB limit so the single limit approach is not recommended for conducted emissions. However, the study pointed out that an EDP/OE product satisfying the NB limit with a QP measurement also satisfies the broadband limit.

The study recommended that a unit under test should be configured and operated in a manner which tended to maximize its emanation characteristics in a typical application. Power and signal distribution should simulate typical application and usage and at least one module of each type should be operational.

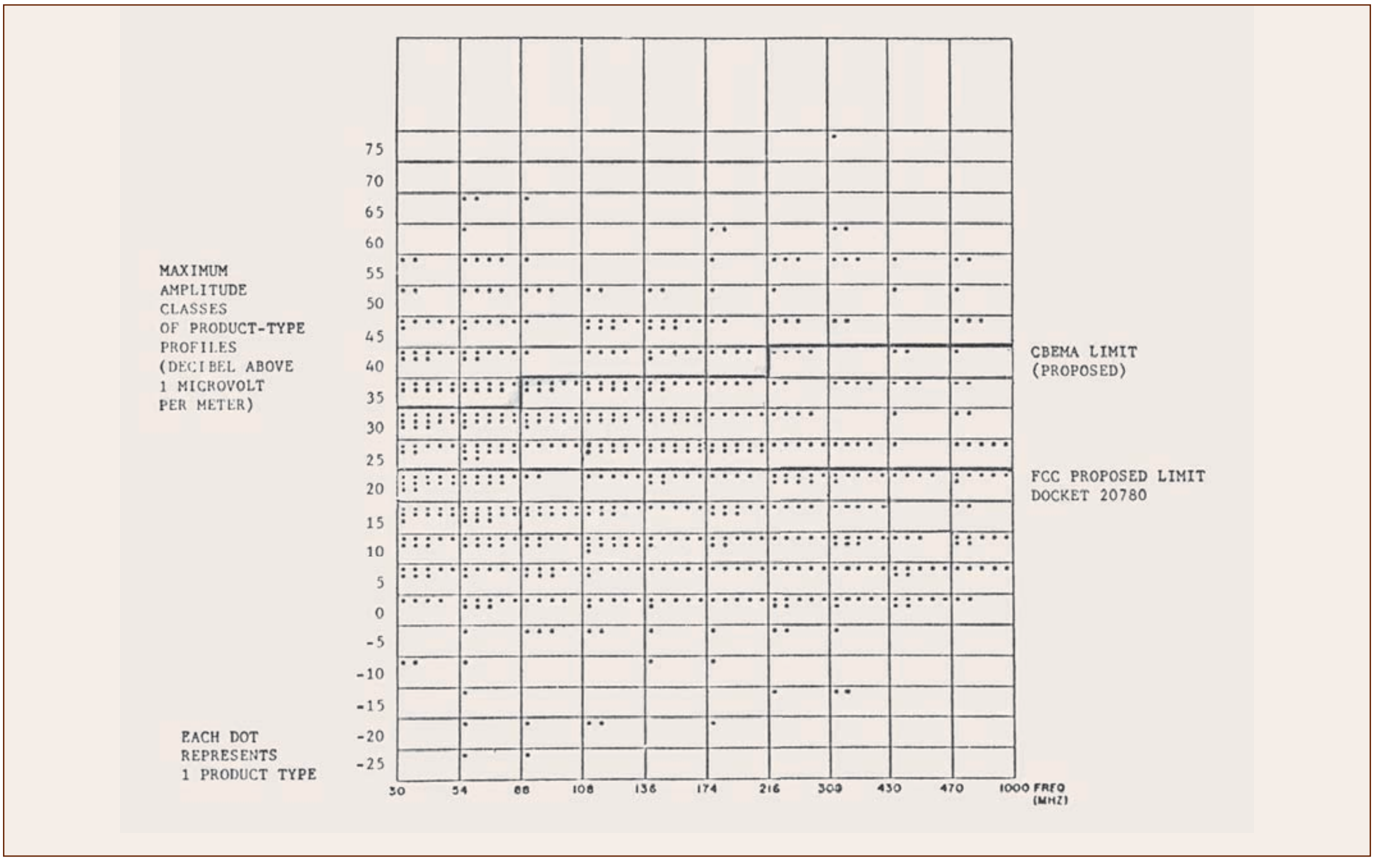


Figure 7: Narrowband radiated emanations at 30 meters

The study also concluded that measured system profiles do not increase over the system profiles synthesized from individual product profiles in a typical system configuration. Therefore, the study concluded that "the worst-case individual product emanation levels of the level of a typical test system can be used to determine the maximum system amplitude level for many possible combinations of products."

The study also stated that "In the case of test units which functionally interact with other units, either the actual interfacing units or simulators may be used to provide representative operating conditions provided the effects of the simulator can be isolated or identified."

Also, the study recommended that the measurement site for radiated emissions be a "special environment" to allow valid and repeatable measurements to be made. So the study recommended using a "free-field, non-reflecting electromagnetic environment as closely as possible." Furthermore, the site should be flat, free of overhead wires, free of nearby reflecting structures, large enough for a thirty-meter measurement and satisfy a space-attenuation of radiated fields. Also, site ambient levels were recommended to be at least 6 dB below the regulatory limit.

The study permitted a "practical site" allowing measurements at a minimum test distance of 3 meters. *However, the study found that "results of measurements in such practical sites at varying distances between the equipment being tested and the measurement antenna, have been found to be within +/- 6 dB of those predicted using a 20 dB/decade fall-off relationship between the equipment and the antenna."* The study also said that "Other test sites such as RF semi-anechoic chambers that are properly evaluated to show equivalence to a free-field site may be valid."

Recommendations for "antenna requirements" included (1) a calibrated dipole (tuned or broadband) for 30 - 1000 MHz and (2) a horn antenna used in the range of 890-1000 MHz. The 50-ohm, 50-uH Line Impedance Stabilization Network described in CISPR Publication 11 is recommended by the CBEMA paper.

SECTION 11 – CONCLUSION

The conclusion of the CBEMA report is duplicated in its entirety below.

"This report represents the culmination of many years of effort devoted to an assessment of the potential of EDP/OE products for EMI with authorized communication services. This assessment has shown that the incidence of interference to communications services from EDP/OE has been small and can be kept small in the future by emanation limits specifically developed for EDP/OE products. It is technically and economically important that limits specifically based on the relationships between EDP/OE products and principal receivers be applied. This is necessary because existing and proposed limits not so based, have been found in some cases to either, under-protect communication services, or require unnecessary product emanation suppression, as well as to complicate the interference control process.

Specific environmental as well as emanation source characteristics distinguish commercial EDP/OE from other electrical/electronic equipment. An interference model and emanation limits have been developed specifically for commercial EDP/OE and U.S. communication services; however, the methodology and perhaps the specific limits proposed in this document can be more broadly applied to other types of equipments, and communication services in other countries.

Theoretical analysis supported by empirical data shows that the two types of interference analyzers customarily used in Europe and the USA can both be used to obtain an equivalent degree of interference control. Practical measurement considerations lead CBEMA to recommend the use of interference analyzers complying with the requirements of CISPR 1, 2, and 4; however, other measurement techniques can produce equivalent results.

CBEMA believes that these limits provide more than adequate protection for principal communication services. Both limits and measurement methods have been corroborated by favorable experience, empirical evaluation, and statistical estimates, and are strongly recommended for commercial EDP/OE environments where interference controls are deemed necessary."

SUMMARY

In 1979, two years after the release of the CBEMA paper, the FCC announced its *FCC Rules on Computer Emissions*. The rules had two dates for implementing the Rules; the first date was October of 1981 when all NEW Electronic Data Processing and Office Equipment had to meet the FCC Rules on Emissions, and the second date was October of 1983 when *ALL EDP/OE equipment manufactured after that date* had to meet the FCC Rules.

In general, the 1979 FCC Rules imposed on the EDP/OE manufacturers were very close to the recommended CBEMA limits for commercial equipment.

(the author)

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is the Founder and Principal of Hoolihan EMC Consulting. He is a Past-President of the EMC Society of the IEEE and is presently serving on the Board of Directors. He is presently an assessor for the NIST NVLAP EMC and Telecom Lab Accreditation program. As of the first of this year, he is the Chair of the ANSI ASC-C63R committee on EMC.

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The Magic of Impedance Paper

BY MARK NAVE

EMC engineers are constantly using passive components. Calculating a RC corner frequency, L-C resonant frequency or characteristic impedance, though typical first-year student tasks, are nonetheless a necessary part of the EMC engineer's responsibilities. Very quickly, the tedium becomes mind numbing to the point of irritation!

Alas, there is a quick and easy solution, impedance paper. The exact origin of impedance paper is long lost to history, but sometime in the past an inventive soul endeavored to plot on log paper impedance, capacitive reactance, and inductive reactance. A section of the result is shown in

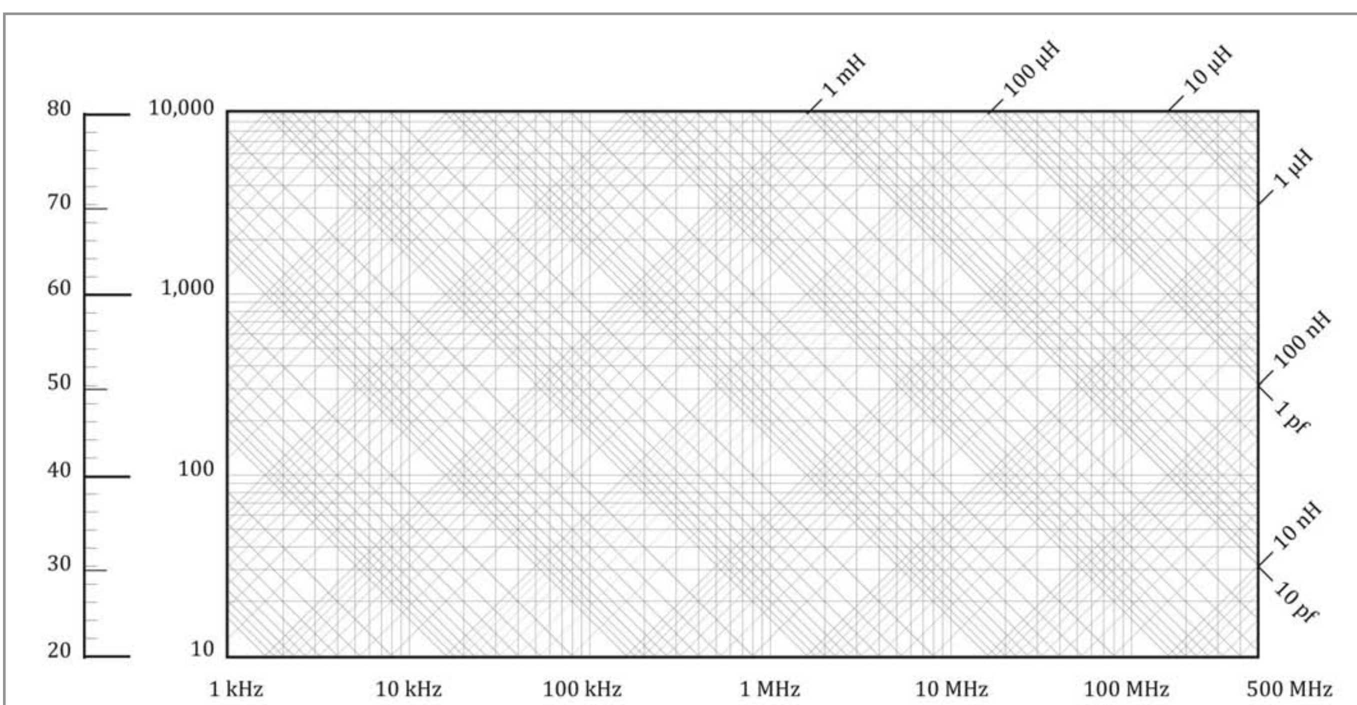

Figure 1

Subsequent articles will address using impedance paper for capacitive and inductive filter attenuation calculations. Graphical calculations are faster and easier, often generating the intuitive insights needed to develop a trial solution for subsequent computer analysis.

Figure 1. A modern rendering of the same approach is freely available at http://www.incompliancemag.com/impedance_paper as a PDF file. The convenience of reading values from a graph is truly a liberation from tedium; the resonant frequency of an arbitrary inductance and capacitance is found from the graph at the intersection of their curves.

For example, 10µH and 10pF resonates at about 14 MHz, with a characteristic impedance of 1,000 Ω. Need a lower resonant frequency? Slide down to the 100 pF curve and find the resonance of 5 MHz, with a characteristic impedance of about 300 Ohm (shown in Figure 2).

Even greater insight is given into the synthesis problem. Need a filter with a 100 Ω characteristic impedance and 100 kHz resonance? The closest L and C values are easily read by inspection. Even better, combinations of values closest to standard values can be evaluated for the closest solution. This can save the effort of *many* calculations.

Subsequent articles will address using impedance paper for capacitive and inductive filter attenuation calculations. Graphical calculations are faster and easier, often generating the intuitive insights needed to develop a trial solution for subsequent computer analysis.

1. *Powerline Filter Design for Switched Mode Power Supplies, 2nd Ed*. 2010. Mark Nave Consultants.

(the author)

MARK NAVE

Mark Nave entered EMC at Don White Consultants. Since then, he was worked at Raytheon, E-Systems, Network Appliance, Cisco, and was the principal at EMC Services, Inc., a training and consulting company focusing on SMPS EMC. He is currently performing contract work, and can be reached at (352) 562-5000.

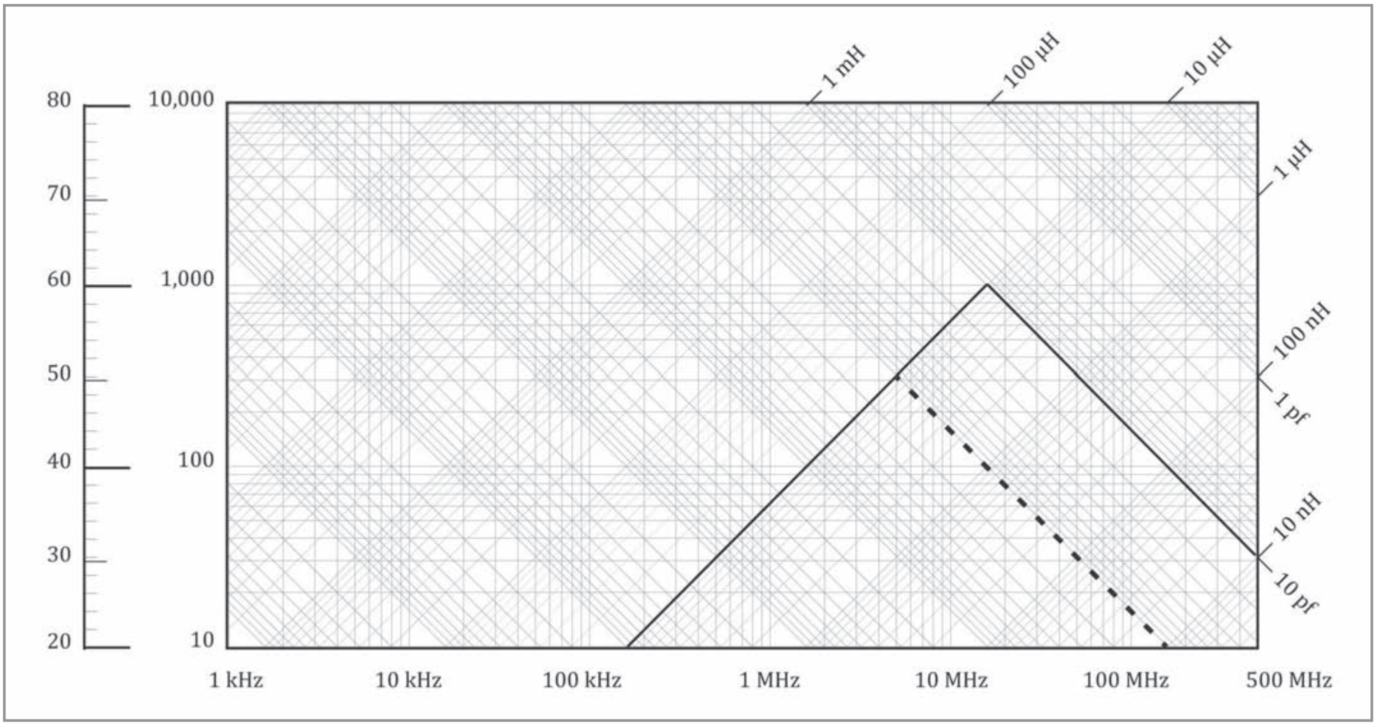

Figure 2

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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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The CBA series provides a complete range of solid-state class-A power amplifiers designed with frequency and power ratings for EMC immunity test applications. These robust and dependable power amplifiers ensure complete reliability at low costs. Furthermore, Teseq stays tuned for the next challenge, continuously expanding its selection of power amplifiers with more power and frequency ranges to meet ever-changing demands.

CBA Series at a glance:

- **Solid-state class-A operation**
- **Frequency range 10 kHz to 6 GHz**
- **Reliable - designed and tested for EMC applications**
- **Safe operation during open-circuit and short-circuit**
- **Outputs suitable for all EMC loads, any VSWR**

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