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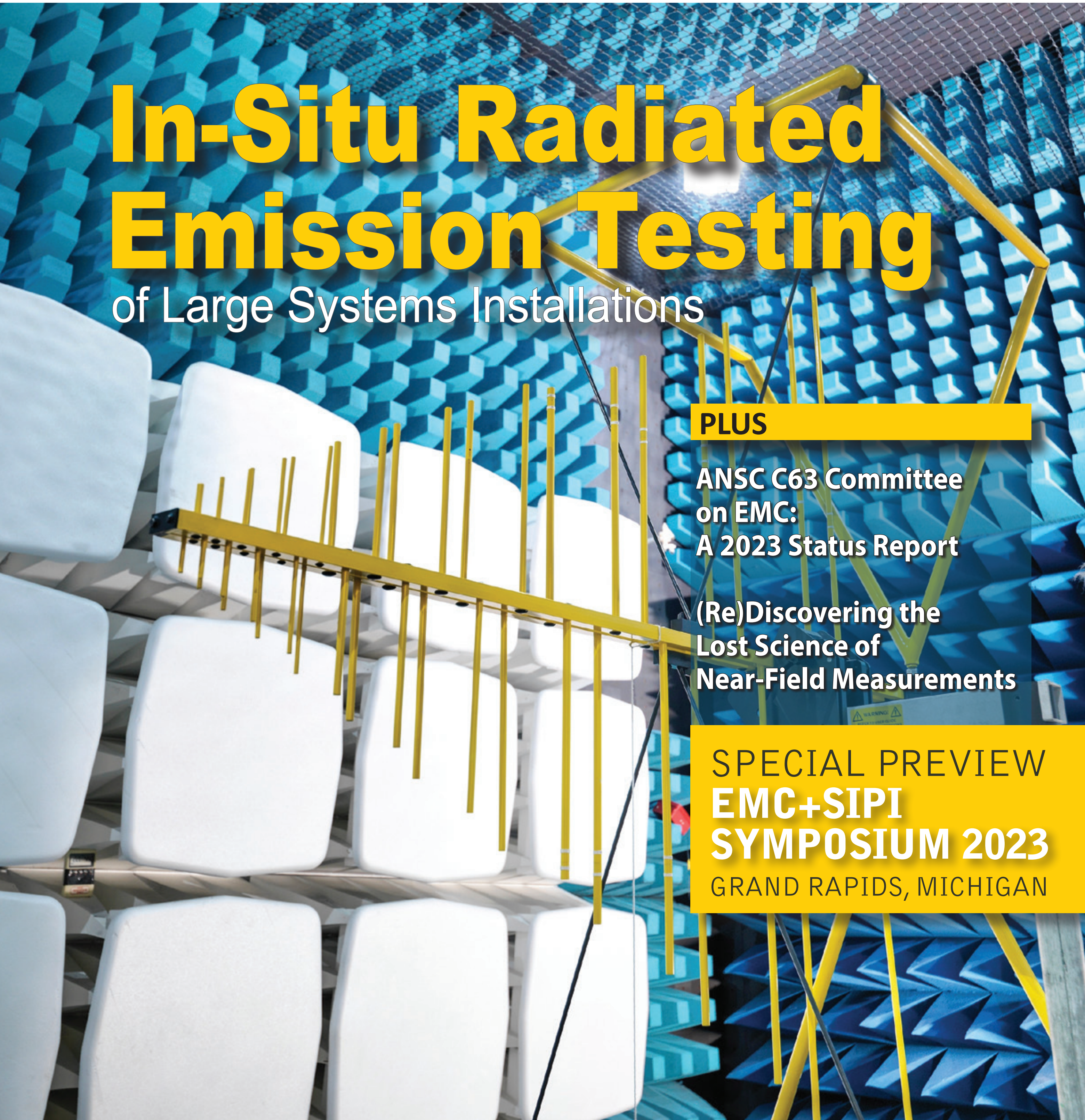

In-Situ Radiated Emission Testing

of Large Systems Installations

PLUS

ANSC C63 Committee on EMC: A 2023 Status Report

(Re)Discovering the Lost Science of Near-Field Measurements

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By Dr. Min Zhang

When it comes to in-situ radiated emission measurements, the combination of near- and far-field measurements is often the best approach. Near-field measurements can help identify the sources of emissions, including individual modules or components and their frequency and amplitude characteristics. This information can then be used for far-field measurements. Far-field measurements involve using antennas to measure the radiated noise, with full-size antennas recommended for measurements between 30 and 200 MHz.

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This article is intended to cover recent operations of the ANSC C63 Committee, including an announcement of a Chairmanship change and detailed descriptions of the most recently released C63 Standards.

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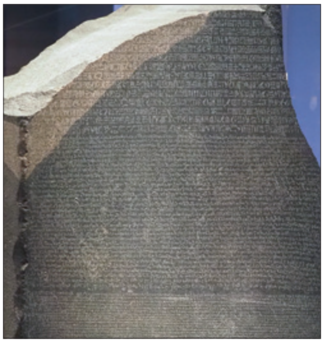
By Ken Javor

This article is the third in a series commemorating 70 years since the advent of modern EMI testing. But this last article is itself divided into multiple parts, due to the topic's complexity. Unlike the previous two articles, which mainly tracked evolution and explained issues, these next installments argue that we started off correctly seventy years ago, but then took the wrong fork in the road in 1967.



46 2023 IEEE International Symposium on Electromagnetic Compatibility, Signal and Power Integrity

July 31 - August 4, 2023

A Preview of the Symposium taking place in Grand Rapids, Michigan

FCC Proposes Expansion of Short-Range Radar Operation

The new rules will allow the deployment of unlicensed field disturbance sensors

In an effort to support the growth of short-range, state-of-the-art radar technologies, the U.S. Federal Communications Commission (FCC) has adopted new rules that expand the legal operating band.

According to a Report and Order, the new rules will allow the deployment of unlicensed field disturbance sensors (a kind of radar device) to operate in the 60 GHz band. Field disturbance sensors are increasingly being used in a variety of important applications, including sensors that alert users to children that have been left in dangerously hot motor vehicles, and mobility and health devices that can detect hand gestures and respiratory functions.

The 60 GHz band has traditionally been available for unlicensed operation of indoor/outdoor communication devices based on the WiGig standard, as well as wireless local area networking devices. Prior to the issuance of its Report and Order, the FCC has issued waivers of its rules in selected cases. Allowing the use of the expanded band range is expected to foster the deployment of additional devices that leverage the benefits of field disturbance sensors and speed the introduction of new and advanced radar-based devices to market.

EU Commission Updates Recognized Standards List for PPE Regulation

The Commission of the European Union (EU) has released an updated list of standards that can be used to demonstrate conformity with the essential requirements of its Regulation (EU) 2016/425 concerning personal protective equipment (or PPE).

The PPE Regulation, which took effect in April 2018, replaced the EU's original PPE Directive (89/686/EEC). The Regulation is aligned with the EU's new Legislative Framework policy and includes slight modifications to the scope and risk categorization of products.

Under the Regulation, personal protective equipment is defined as "equipment designed and manufactured to be worn or held by a person for protection against one or more risks to that person's health and safety hazards." Specifically excluded from the scope of the Regulation is equipment designed specifically for use by armed forces or law enforcement personnel, equipment to be used for self-defense (except for that intended for sporting activities), and equipment intended for the protection or rescue of individuals on vessels or aircraft.

The extensive list of CEN and Cenelec standards was published in the Official Journal of the European Union and replaces all previously published standards lists for the Regulation.

FCC Threatens Fines for Illegal Use of Mobile Frequencies

A Pennsylvania man has been ordered to cease operating surveillance cameras that are interfering with cellular service in his area.

According to a Citation and Order issued by the U.S. Federal Communications Commission (FCC), officers of the FCC's Enforcement Bureau launched an investigation in June 2022 into claims by T-Mobile that harmful interference to its cellular services in the York, PA area was emanating from surveillance security cameras installed at a single-family home in York, PA occupied by Luis Martinez.

The Bureau's investigation confirmed T-Mobile's findings, and Enforcement Bureau officers instructed Martinez to either remove the cameras or readjust the camera's settings so that the device operated within the 2.4 GHz band. Although Martinez reportedly disconnected the cameras, he eventually switched them back, reinitiating the interference.

FDA Updates Consumer Information on OTC Hearing Aids

The U.S. Food and Drug Administration (FDA) has updated its information webpage for consumers on over-the-counter (OTC) hearing aids.

Authorized by the FDA for sale in October 2022, OTC hearing aids are expected to help address a condition experienced by nearly 30 million adults in the U.S. who live with a mild to moderate degree of hearing loss. OTC hearing aids can be purchased in stores and online and no longer require a prescription or a visit to a licensed healthcare professional, provided that the purchaser is 18 years of age or older.

The FDA's updated information page on OTC hearing aids provides detailed information on labeling requirements for hearing aid packaging, as well as detailed guidance on the factors that consumers should consider when purchasing them. It also provides a list of additional resources about OTC hearing aids available elsewhere on the FDA's website.

FDA Releases New Video on Cybersecurity in Healthcare Facilities

As part of its effort to protect healthcare workers and patients from equipment malfunction attributable to cybersecurity breaches, the U.S. Food and Drug Administration (FDA) has released a new video to help facilities prepare for a potential cybersecurity event.

Posted to the FDA's website, the brief video, titled "Tips for Heath Care Facilities: Cybersecurity Incident Preparedness and Response," provides an overview of how facilities can create an emergency preparedness plan for cybersecurity incidents. The video also provides suggestions for helping to ensure patient safety during a prolonged cybersecurity event.

The new video is one of a series of three released to date on the issue of cybersecurity risks impacting medical devices. The previously released videos include "Cybersecurity Awareness for Connected Medical Devices" and "Tips for Clinicians: Keeping Your Patients' Connected Medical Devices Safe."

IN-SITU RADIATED EMISSION TESTING OF LARGE SYSTEMS INSTALLATIONS

Combination of Near- and Far-Field Measurements for Radiated Emissions

Dr. Min Zhang is the founder and principal EMC consultant of Mach One Design Ltd, a UK-based engineering firm that specializes in EMC consulting, troubleshooting, and training. His in-depth knowledge of power electronics, digital electronics, electric machines, and product design has benefitted companies worldwide. Zhang can be reached at info@mach1design.co.uk.

By Dr. Min Zhang

As an EMC consultant, assessing the EMC performance of large systems and machines is a common task. Over the years, I have encountered a wide range of equipment, including high-power variable-speed drives (VSDs) in factories, specialized equipment installed on ships, food processing equipment, and many others. With technological advancements, there are now even more large systems that require in-situ EMC assessment, such as quantum computers, additive manufacturing machines, waste recycling equipment, renewable energy power generators, high-power electric vehicle chargers, and more.

While testing equipment in an accredited EMC chamber is ideal, it may not be a realistic option for large machines for several reasons. First, a large chamber is required to accommodate these machines. Second, while the chamber is being charged for use, it can take days or even weeks to install the machine in a chamber and then disassemble it after the testing is complete. Finally, logistics and lead time for using the chamber can also add to the overall cost and time required for EMC testing of large machines.

Fortunately, the Technical Construction File (TCF) route to EMC compliance is available for everyone except those who manufacture radiocommunication transmitting products. Engineering companies, rather than those manufacturing mass-produced electronic products, may find the TCF route more cost-effective than the self-certification to standards route. For very large products or those that only come together on the customer's premises, it may be impossible to test to harmonized standards anyway. In such cases, the TCF route may be the only feasible option for EMC compliance. [1]

Among the various in-situ EMC tests that manufacturers can perform, the radiated emission test is one of the most important as it demonstrates that the unit does not interfere with other equipment nearby through electromagnetic radiation. However, the radiated emissions of a large unit can be challenging to assess in situ due to two main factors.

The first factor is ambient noise, which consists of nearby radio and TV broadcast transmitters, handheld devices like walkie-talkies, equipment and machinery used during the assessment, and ESD events.

The second factor is reflections caused by metal structures, including racks, cabinets, junction boxes, conduits, and pipes. If in-situ testing is not designed and performed correctly, there can be a significant difference between chamber testing and in-situ testing, sometimes up to a 20 dB difference. Therefore, it is essential to carefully consider and address these challenges during in-situ testing to ensure an accurate assessment of a unit's radiated emissions.

THE "THREE-STEP" APPROACH

In reference [2], Wyatt introduced a practical three-step approach for in-situ radiated emission assessment. The approach can be summarized as follows:

- *Step 1:* Conduct a near-field assessment to identify the sources of emissions, such as individual modules/components, and to determine their frequency and amplitude characteristics. This assessment often consists of two parts, one is a paper exercise, and the other is based on measurement results using near-field measurement tools;
- *Step 2:* Perform a cable structure radiation assessment to evaluate the emissions from cables and identify potential coupling paths; and
- *Step 3:* Conduct far-field measurements to assess the radiated emissions from the system as a whole.

This approach is theoretically sound and can be performed at a relatively low cost. Figure 1 lists some of the equipment that is often involved in performing both near- and far-field measurements. This article provides a detailed explanation of each step in the approach to facilitate a thorough understanding and effective implementation of the method for in-situ radiated emission assessment.

STEP 1 – NEAR-FIELD ASSESSMENT

In a large unit, there can be many subsystems/modules, each with its own EMC characteristics. Some of the components are developed in-house. Therefore, engineers/system integrators will know the subsystem's electrical and electronics architecture (EEA). From the EMC perspective, we need to know:

1. The switched mode power supplies/motor drives in the subsystem, their switching frequency, and, if possible, their switching speed;
2. The ICs used in the subsystem, the clock frequency, the oscillator frequency, etc.;
3. Communication lines between the subsystems, whether the communication line is based on SPI, I2C, Ethernet, CAN, LIN, etc.; and
4. Wireless devices, such as WiFi and BLE modules, etc.

In a large unit, it is likely that many of the modules are commercial-off-the-shelf (COTS) parts, which means that the system integrators may not have the requisite knowledge of the internal design of these devices. COTS parts may or may not come with relevant regulatory certification (e.g., CE, FCC, etc.), and it is rare for them to be accompanied by EMC test results.

It is important to note that the idea of "CE+CE=CE" is a misconception [3]. When subsystems are integrated into a single system, the EMC performance is unknown, and it cannot be assumed that the final product will automatically meet the necessary EMC requirements.

Therefore, a near-field measurement of the subsystems is essential to ensure that all clock frequencies and their harmonics are recorded, as these spectrums may appear in the far-field measurement. In cases where the subsystem/module can fit in a TEM cell, I prefer to test and record the module using the TEM cell quickly. Most of the time, the modules in a large unit may not fit in a TEM cell; therefore, we use near-field probes (both magnetic and electric field loops) to "sniff" the subsystem and record spurious levels that could potentially radiate in the far field.

It should be noted that the purpose of these measurements is not to correlate the results in the far field. Instead, the information obtained from the near-field measurements is used to determine the frequencies of critical spurious emissions in the far-field results.

Harmonics of Clock Frequencies

When documenting clock frequencies, it is important to consider their harmonics (up to the 9th harmonic).

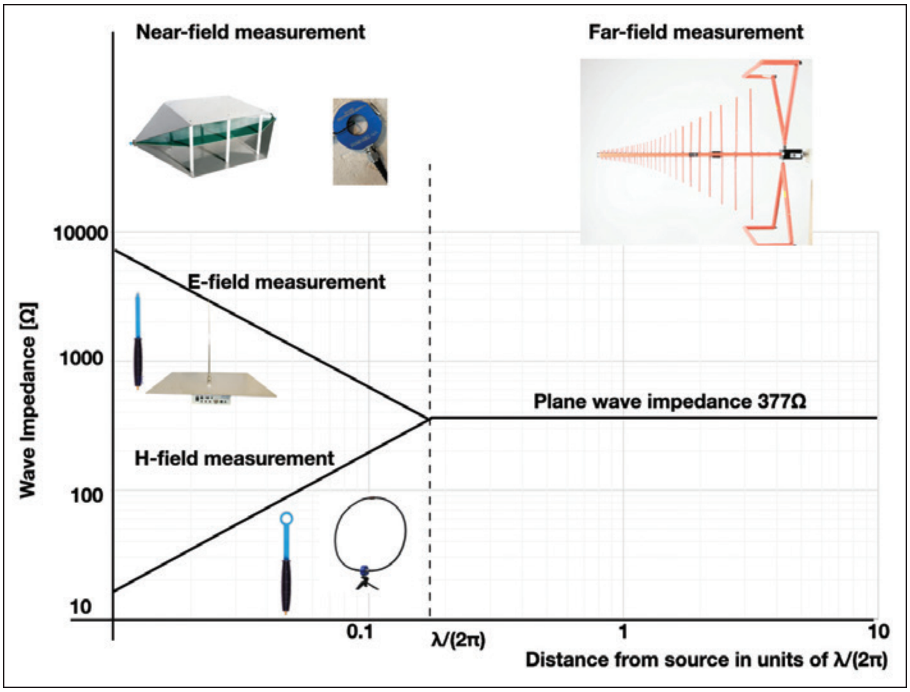
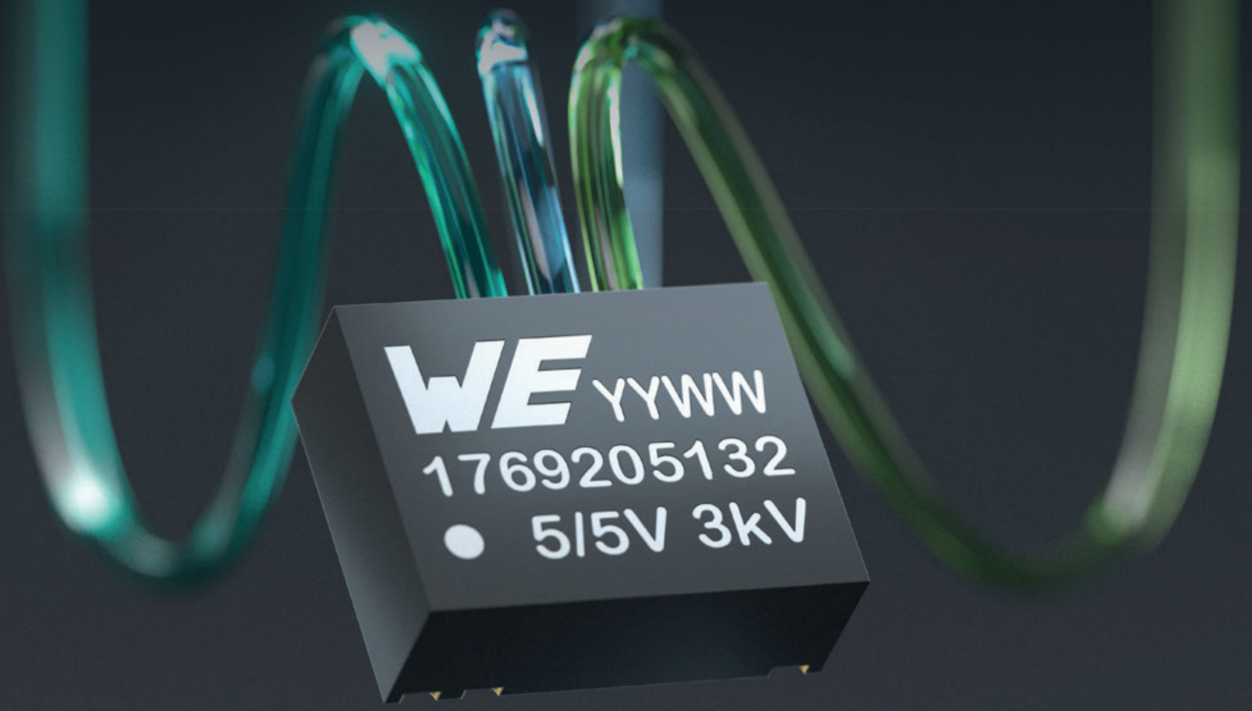


Figure 1: Near and far field measurement tools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Certain harmonics can radiate more strongly than others depending on the physical structure, so it is important to take this into account during EMC testing.

A case study highlights this issue. In this example, a WiFi module from a trusted, well-established supplier was implemented in a large unit. The WiFi module passed all EMC and radio performance tests. However, the stacked board design of the unit (where the WiFi module is mounted) resulted in a structural resonance between 100 and 200 MHz. The communication between the WiFi module and the signal processing board was through the motherboard, and the clock frequency was initially set at 48MHz.

During far-field measurement, a 144MHz noise (the 3rd harmonic) was detected, exceeding the limit line. It was observed that odd harmonics of the clock frequency were radiating because of the 50% duty ratio of the clock signal. However, the data line had a broadband noise profile. When the clock frequency was reduced to 24 MHz, the 5th (120MHz) and 7th (168MHz) harmonics became high, indicating a structural resonance in the design.

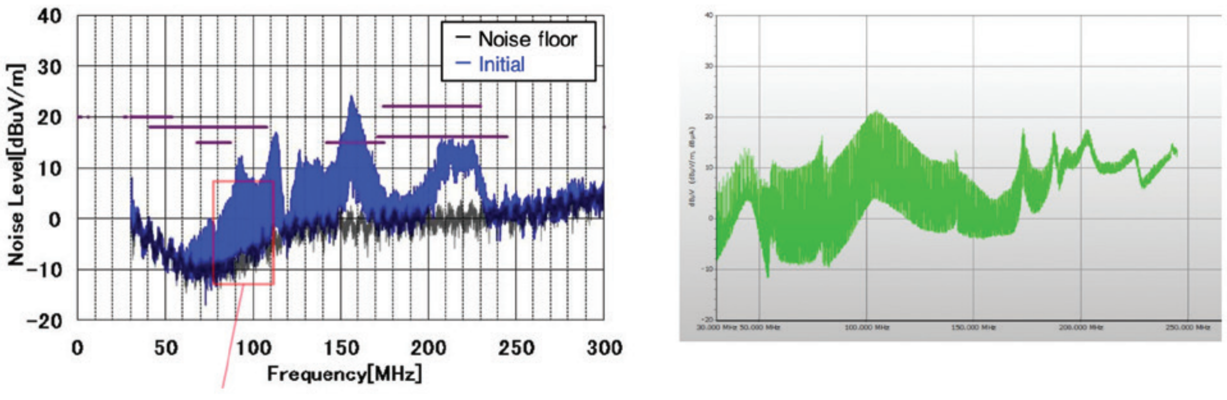
This case study highlights the importance of considering the harmonics of each clock frequency during EMC testing. A noise source requires an antenna-like structure to radiate efficiently in the far field, so paying attention not only to the fundamental frequency but also its harmonics is crucial to identify potential sources of EMI and to develop appropriate mitigation strategies.

Correlation Between the Near- and Far-Field Radiation

It is not recommended to use near-field measurement results to directly predict far-field emissions. This is because near-field readings are highly dependent on the geometry of the source and its properties, making it difficult to provide correlations between measurements performed in the near field and those done in the far field. While it is generally true that the stronger the field near the source, the stronger it will register in the far field, this correlation is not precise enough to provide reliable predictions [4].

IEC 61000-4-20 describes several methods for predicting radiated emissions using a transverse electromagnetic (TEM) cell, which differ in how many orientations of the device under test (DUT) are measured in the TEM cell to calculate the vector sum of emissions. The main simplifying assumption in this algorithm is that the radiating structures of the DUT have no greater gain than a dipole and a dipole radiating pattern [5]. The output of the algorithm measurements is then converted into an equivalent far-field value.

However, the effectiveness of this algorithm is limited, and a simple correlation between near-field and far-field measurements is not achievable based on tests we performed in the field. This is especially true if the module has cable connections to other modules in the system. Figure 2 demonstrates the difference between a far-field antenna measurement result and the TEM cell-predicted result.



(a) Far-field measurement using a biconical antenna

(b) TEM Cell far-field prediction

Figure 2: Difference between a far-field antenna measurement result and the TEM cell-predicted result

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AMP2070A	1.0-6.0GHz	150	100	52
AMPP2070D-LC	1.0-6.0GHz	200	150	53
AMP2030-LC	1.0-6.0GHz	300	200	55
AMP2030B-LC	1.0-6.0GHz	400	250	56
AMP2030D-LC	1.0-6.0GHz	750	400	59
AMP2030-LC-1KW	1.0-6.0GHz	1000	600	60
AMP2030-LC-3KW	1.0-6.0GHz	3000	2500	65

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STEP 2 – MEASURING RF CURRENT ON CABLES

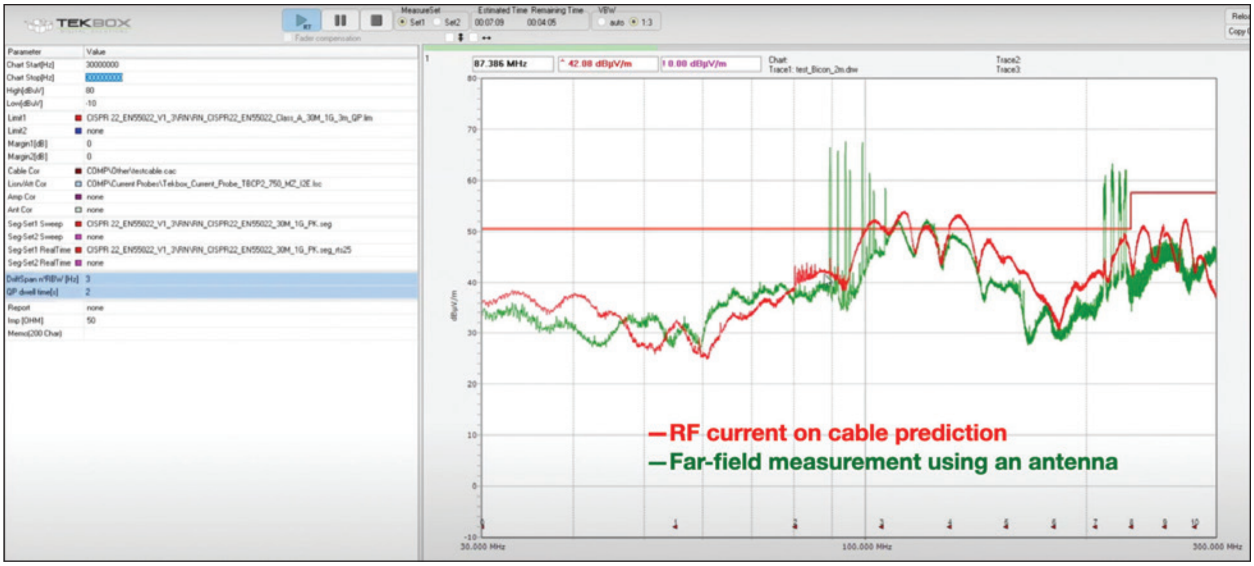
After conducting a near-field assessment, the next step is to use an RF current probe to measure a sampling of cables [2]. Inside the metal chassis (this often is the cabinet that hosts the overall system), there can be hundreds of wire connections. Monitoring each individual wire or cable bundle inside the metal chassis may not be practical, so attention should be paid to cables outside the metal chassis, such as power and signal leads. A metal cabinet often serves as a Faraday cage and attenuates the field generated inside the cabinet. It is also worth "sniffing" the seam or opening of the cabinet to check for any leakage fields that could potentially radiate.

When using an RF current probe to measure cables, it is recommended to make several measurements along the cable, as standing waves on the cable can cause readings to differ between different parts of the cable. Harmonics between 30 and 500 MHz should be noted down.

While there have been discussions on predicting far-field results using current probe readings, it is often found that the cable radiation prediction method works well up to a few hundred MHz. Above 300 MHz, cables start to attenuate RF current, which may cause the prediction method to over-predict the far-field results. Readers who want to explore this topic may find References [6] and [7] useful (in which the detailed calculation method is presented), and there are software tools available that can automate the whole process and present the results once the measurement is made, as demonstrated in reference [8]. Figure 3 shows the results of the RF current prediction method against antenna measurement. Notice that the antenna measurement inevitably picks up the radio transmitter signals (in this case, both FM and DAB), while the cable prediction method does not show these ambient spectrums.

STEP 3 – FAR-FIELD MEASUREMENTS

In the final step of the radiated emission assessment, the radiated emissions from the DUT are measured using antennas. Both full-size and reduced-size antennas are available in the market for this purpose. While reduced-size antennas can be advantageous for far-field measurements above 200 MHz, as they can be moved around easily and placed in locations where a full-size antenna may not fit, they may not be suitable for measuring radiation fields between 30 MHz and 200 MHz. This is because reduced-size antennas often have lower sensitivity and a higher antenna factor (AF) compared to full-size antennas, resulting in higher system noise floors that can exceed the test limits being used for comparison. Therefore, it is always recommended to use a full-size antenna for measuring radiated emissions between 30 and 200 MHz.



Parameter	Value
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Chart Stop[Hz]	[illegible]
High[dBuV]	80
Low[dBuV]	-10
Limit1	CISPR 22_EN55022_V1_3\RN\RN_CISPR22_EN55022_Class_A_30M_1G_3m_QP.lim
Limit2	none
Margin1[dB]	0
Margin2[dB]	0
Cable Cor	COMP\Other\testcable.cac
Lisn/Att Cor	COMP\Current Probes\Tekbox_Current_Probe_TBCP2_750_MZ_I2E.lsc
Amp Cor	none
Ant Cor	none
Seg-Set1 Sweep	CISPR 22_EN55022_V1_3\RN\RN_CISPR22_EN55022_30M_1G_PK.seg
Seg-Set2 Sweep	none
Seg-Set1 RealTime	CISPR 22_EN55022_V1_3\RN\RN_CISPR22_EN55022_30M_1G_PK.seg_rts25
Seg-Set2 RealTime	none
DwltSpan n*RBW [Hz]	3
QP dwell time[s]	2
Report	none
Imp [OHM]	50
Memo(200 Char)	

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Chart:
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Trace2:
Trace3:

Figure 3: The RF current prediction method compared with an antenna measurement

Reference [2] proposes a circle 3 m from the faces of the system under test, and every 30 degrees should be measured. In some cases, due to the limited space where the large unit is located, moving the antenna closer to the DUT is an option. Reducing the measurement distance from 3 m to 1 m equals approximately 10 dB less free space loss or lifting the limits 10 dB higher. However, one should consider that the antenna may move into the near-field zone at lower frequencies.

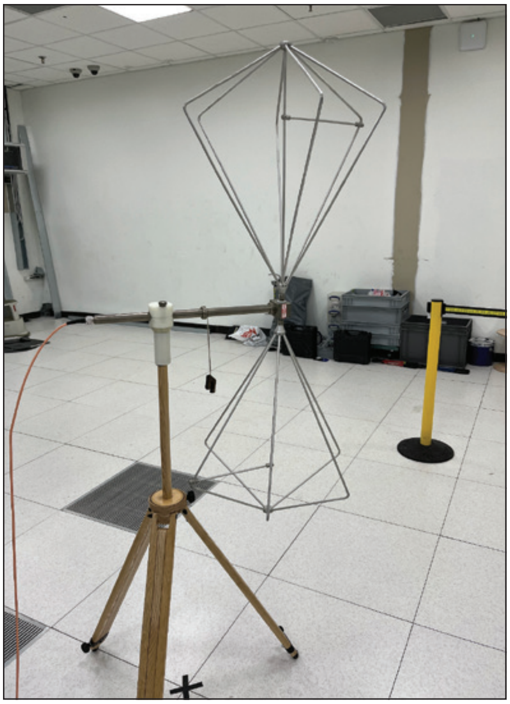

Figure 4: Ambient measurement before the DUT was installed

One misconception is that using an active reduced-size antenna or connecting a low noise amplifier to a passive reduced-size antenna will lower the noise floor and increase sensitivity. However, this is only true in a chamber environment where the noise floor is generally low. In a non-chamber environment, the low noise amplifier amplifies both ambient noise and the signal being measured. As a result, the spectrum analyzer will beep constantly due to RF input overloading. Therefore, reduced-size antennas are always inferior to full-size antennas in terms of performance in the lower frequency range.

When performing the far-field measurement, it is always recommended to measure the ambient noise first (i.e., while the DUT is in its off-state). For systems that cannot be easily shut down, such as quantum computers or additive manufacturing equipment, an EM survey before the system is installed is necessary, which requires early planning. Figure 4 shows an EM survey performed in a data center before the DUT was installed. One can spot the fire detection device on the wall, which radiates some narrow band spectrums. This information should be recorded in the ambient sweep.

When conducting a pre-sweep of ambient noise, it is important to keep in mind that not all noise sources

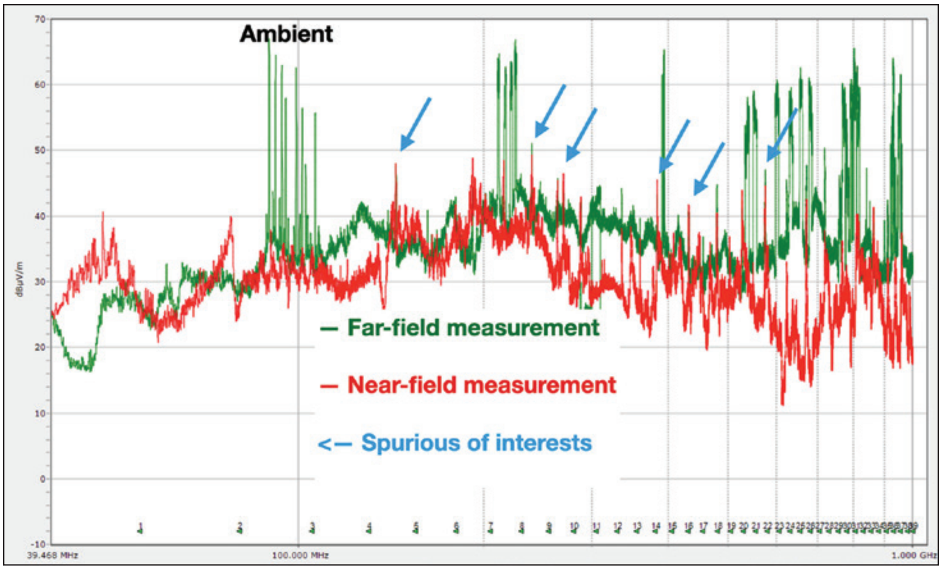

Figure 5: Using near-field measurement to help determine far-field emissions

may be captured. Some sources may be intermittent or may only be present when other equipment nearby is turned on. Additionally, ESD events can also contribute to far-field radiation and may be picked up by the measurement antenna. In these cases, previously recorded near-field measurement results can be useful in determining whether the far-field radiation is coming from the DUT or ambient noise. Software that can load multiple results can be helpful in comparing and analyzing both the near- and far-field measurements.

An example of this is shown in Figure 5. In this case, the red trace shows the near-field measurement results while the green trace shows the far-field measurement. As it can be seen, the ambient noise can be distinguished so that we can focus on the noise generated by the DUT (the blue pointers shown in Figure 5). Quasi-peak scans can then be performed on selected points to determine whether the noise exceeds the limit line.

SUMMARY

This article presents a step-by-step approach to in-situ radiated emission tests. A combined near-field current probe, and far-field measurement are essential to get the true characteristics of the EMC performance of a large unit. Correlation methods between the near- and far-fields are discussed, and their accuracy is presented. Readers should now have a good idea of how to perform in-situ radiated emission tests.

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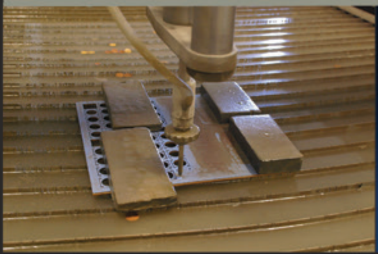

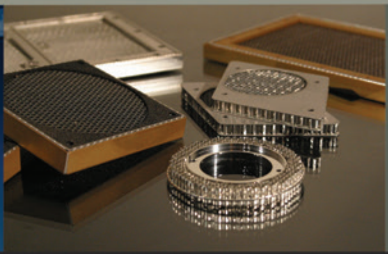

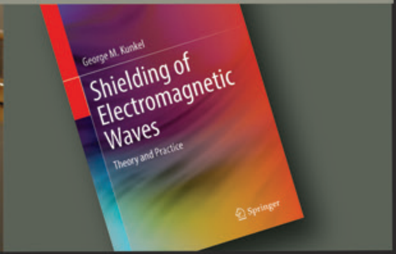
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ANSC C63 COMMITTEE ON EMC: A 2023 STATUS REPORT

Highlights of the C63 Committee and its Key EMC Standards

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By Daniel D. Hoolihan

INTRODUCTION

Periodically we attempt to bring EMC technical personnel up to date with the activities of the ANSC C63 on EMC. This article covers the last five years of Committee activity in electromagnetic compatibility standards for North American markets (U.S. and Canada).

Despite the COVID-19 pandemic, progress continued in developing and refining C63 Standards. Subcommittees of the Main Committee (all eight of them) were encouraged to meet on a quarterly basis using teleconferencing techniques for most of 2020, 2021, and 2022. Working groups were encouraged to meet as often as necessary to expedite the development of their respective standards (each C63 standard under development or refinement has a Working Group assigned to do the work under the surveillance of the appropriate Subcommittee).

The end result was that ten C63 Standards were developed, revised, or reaffirmed during the last five years!

BRIEF HISTORY

As some readers will remember, the ANSC C63 on EMC (the C63 Committee) started in 1935 with an announcement in the "Industrial Standardization and Commercial Standards Monthly – Volume 6 – November – 1935." This monthly document was published by the American Standards Association (ASA) with the cooperation of a U.S. government body, the National Bureau of Standards (NBS).

The article was titled "All Interested Groups Will Work On Radio-Electrical Coordination." It went on to say, in part:

> *In line, with the procedure of the American Standards Association, every group having an interest in a given project is invited to name representatives to serve on the committee which develops standards. At a meeting called by the sponsor, the Radio Manufacturers Association (RMA), the following men were elected officers: W. R. G. Baker – Chair, L. C. F. Horle – Vice-Chair, and Virgil M. Graham – Secretary.*

After its start as an ASA sectional committee on Radio-Electrical Coordination and after having several other variations of names over the years, most recently as the ANSI-Accredited Standards Committee C63 on EMC, 2023 marks the Committee's 88th year of operation, and the launch of its latest name, the American National Standards Committee (ANSC) C63 on EMC.

The Committee's standards continue to be approved by the American National Standards Institute (ANSI) and edited and published by the Institute of Electrical and Electronics Engineers (IEEE).

WHAT IS AN AMERICAN NATIONAL STANDARD?

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether they have approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard.

American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

(Please note that American National Standards may be revised or withdrawn at any time. ANSI procedures require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication.)

Purchasers of American National Standards may receive current information on all standards by calling or writing ANSI.

CHANGE IN C63 COMMITTEE LEADERSHIP

Effective as of January 1, 2023, the Committee has a new Chair, Bob DeLisi, from UL Solutions in Melville, New York. The previous Chair, Daniel Hoolihan, served for 11 years (2012-2022), several years longer than the normal 6-year commitment primarily due to COVID-19 complications. The two previous Chairs before Hoolihan were Donald Heirman (2006 -2011) and Dr. Ralph Showers (1965 – 2005).

RECENT STANDARDS

The C63 Committee has approximately twenty active standards which are: 1) currently up to date; 2) being reaffirmed; 3) being revised; or 4) being developed for the first time.

STANDARDS INCORPORATED BY REFERENCE INTO THE FCC RULES

Recently (February 2023), the U.S. Federal Communications Commission (FCC) released a Report and Order incorporating by reference into the FCC Rules the following C63 Standards:

(Note: Incorporation by Reference (IBR) is the process that federal agencies use when referring to materials published elsewhere to give those materials the same force and effect of law in the Code of Federal Regulations (CFR) as if the materials had actually been published in the *Federal Register.)*

***American National Standards Institute (ANSI) C63.25.1:2018** – American National Standard Validation Methods for Radiated Emission Test Sites; 1 GHz to 18 GHz:* The incorporation of this standard consolidates guidance from existing standards to clearly apply through higher frequency bands. This new standard covers 1 to 18 GHz.

***ANSI C63.10:2020** – American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices:* The update of this standard addresses changes in technology since 2013.

***ANSI C63.4a-2017** – Addendum to the American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz, Amendment 1: Test Site Validation:* The incorporation of this standard provides two options for an electromagnetic compatibility (EMC) measurement standard for unintentional radiators to accommodate testing of larger devices and retain the status quo for testing that would not benefit from the updates.

DETAILED DISCUSSION

C63.25.1:2018

The C63 Committee has decided to develop three new site validation standards for qualifying sites for their suitability to testing to national and international standards. The first of these to be released and approved by ANSI is C63.25.1:2018 which covers the frequency range of 1 GHz to 18 GHz.

C63.25.1:2018 introduces a new test method called the time domain site validation (TDSV) method which has some advantages over the existing site voltage standing wave ratio (SVSWR) method presently specified in CISPR 16-1-4, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Antennas and test sites for radiated disturbance measurements.* However, it also continues to allow the internationally accepted SVSWR method.

The Commission is incorporating C63.25.1:2018 as an option to an already existing requirement so there is no need for a transition period for the standard.

C63.10:2020

This standard was approved by ANSI on September 10, 2020, and updates the measurement procedures set forth in ANSI C63.10:2013, which is currently referenced in sections 2.910, 2.950, 15.31, and 15.38 of the FCC's rules. The revised standard addresses many procedures for testing the compliance of a wide variety of unlicensed wireless transmitters.

The C63.10:2020 standard was developed with a balloting group including Canadian entities. Thus, it is a North American Standard rather than a U.S. Standard and it accommodates both U.S. and Canadian regulations. To provide a smooth transition to this revised standard, the FCC will permit the use of either ANSI C63.10:2013 or ANSI C63.10:2020 for a period of two years from April 2023.

C63.4a:2017

This amendment introduced modifications to the normalized site attenuation procedures for validating radiated test sites for use in the 30 MHz to 1 GHz frequency range. Some of these modifications involve a new acceptable test distance (five meters) and an expanded test volume to accommodate devices with heights that exceed two meters. The FCC adopted this amendment in order to accommodate the testing of larger devices (greater than two meters in height) and to allow for harmonization with Canada (the Innovation, Science and Economic Development (ISED) department). Thus, by retaining the existing standards and also adopting the amended standard, two options are provided for an EMC measurement standard for unintentional radiators to accommodate the improvements where they are needed and retain the status quo for testing that would not benefit from the updates.

OTHER C63 STANDARDS

Besides the previously-mentioned standards, a number of other standards have been developed over the past few years for use by North American organizations, including industry bodies and government agencies.

C63.29:2022 *– American National Standard for Methods of Measurement of Radio-Frequency Emissions from Lighting Devices:* This new standard specifies procedures for verifying the electromagnetic compatibility (EMC) compliance of lighting equipment of various categories, including but not limited to self-ballasted lamps, luminaires (light fixtures), dimmers, etc., and of various technologies, such as fluorescent, gas-discharge, and light emitting diodes (LED). Test procedures for radiated field strength and conducted disturbance measurements are included, with reference to established standards, where applicable. This C63 standard EMC covers measurement methodologies but is not intended to describe regulatory limits.

C63.27:2021 *– American National Standard for Evaluation of Wireless Coexistence:* Wireless coexistence testing focuses on devices and systems that intentionally use wireless and it extends beyond traditional EMC to examine the device's performance in frequency bands where it uses wireless communication. This standard provides methods for evaluating the ability of a device to

coexist in its intended radio frequency (RF) wireless communications environment. The test process and methods may be used to evaluate any set of technologies or protocols.

This document has been revised to clarify the procedures set forth in the 2017 version. In particular, the testing requirements for each tier of testing have been streamlined, enabling more concise testing.

Additional guidance was added to Annex A to address the testing of unlicensed LTE and IEEE 802.11 devices. The guidance surrounding the Likelihood of Coexistence calculation was expanded and is now featured in its own Annex.

On December 19th, 2022, the U.S. Food and Drug Administration (FDA) added C63.27:2021 to its list of Recognized Consensus Standards.

C63.30:2021 *– American National Standard for Methods of Measurements of Radio-Frequency Emissions from Wireless Power Transfer Equipment:* This new standard specifies procedures for verifying the electromagnetic compliance of wireless power transfer (WPT) devices of various technologies, including but not limited to small charging mat-type wireless power chargers (e.g., for cell phone or laptop), medium-size wireless charging devices (e.g., for home appliances), as well as large wireless power charging systems (e.g., for automobile or industrial machinery).

This first edition includes measurement procedures applicable to wireless power transfer devices that are or are soon to be introduced on the market at the time of publication of this standard (2021). As new WPT technologies mature, they will be addressed in future revisions of this standard.

The C63 Committee has petitioned the FCC to Incorporate by Reference this new standard and make it part of the FCC Regulations.

C63.24:2021 *– American National Standard—Recommended Practice for In Situ RF Immunity Evaluation of Electronic Devices and Systems:* The use of electronic products and systems requires a sufficient level of radio-frequency (RF) immunity to help ensure that they operate at acceptable quality levels in their intended use environments. While fluorescent lights, microwave ovens, portable wireless devices, commercial radio and TV stations, and other RF sources have been part of the electromagnetic (EM) environment for a number of years, interference problems with many types of equipment have been exacerbated by the recent dramatic growth in personal RF devices such as cellular telephones, wireless network connections, cordless telephones, and security/fire protection portable transceivers.

It is common today to have multiple wireless devices transmitting in close proximity to one another. Type testing, in which a representative sample of a product or system is tested in a lab, is a common method of evaluating the RF immunity of the design. However, type testing has its limitations.

Type testing cannot ensure that all manufactured samples of a product will have the required RF immunity. In general, there is some manufacturing variance, and at times design changes can negatively impact RF immunity. A second issue, particularly with large distributed systems, is that it is difficult and sometimes impossible to replicate in a laboratory the actual configuration to be used and the complex electromagnetic environment in which the product is to be installed. Nonetheless, testing for immunity where both the electronic device and system are installed and where interference has been found is most representative of the immunity an end user will experience.

This recommended practice addresses the need to evaluate the actual RF immunity of devices and systems as they are installed and used. This is particularly true for large, complex systems that are too large to be set up in a laboratory in the same way they would be set up and installed at the user's location. Often such systems are custom installed to meet the unique needs of each customer, which further changes it from the laboratory sample that was type-tested.

Another contribution of this recommended practice is that it more closely replicates the actual RF threats to which the equipment will be exposed, as it is focused on only performing immunity tests where actual interference has been experienced. For example, radiated immunity tests are performed with a spacing between the equipment under test (EUT) and the portable RF source where the EUT performance was degraded. In general, there is nothing to control how close or far a cell phone or other transmitting device will be from other equipment in actual use. Using the actual cause of interference is the most representative of what is actually happening when interference occurs.

Thus, this recommended practice was developed in response to the recognized need to supplement type-testing with in-situ evaluation when there is a strong need to ensure adequate RF immunity in the actual installed equipment. It provides methods that can be used after electronic equipment or systems are delivered and installed.

C63.17:2013 (Reaffirmed 2020) *– American National Standard Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices:* In November 1993, the U.S. FCC invited ANSI C63 “to consider development of standard measurement procedures to support” proposed new provisions to Part 15 of Volume 47 of the Code of Federal Regulations (47CFR15) for unlicensed personal communications services (UPCS) devices.

At its December 1993 meeting, ANSI C63 established a subcommittee (SC 7) to attempt to develop such standards in cooperation with representatives of the Wireless Information Networks Forum (WINForum) and other interested parties.

The standard ANSI C63.17-1998 was the result of the efforts of C63/SC 7.

In the Fall of 2004, the FCC revised provisions of 47CFR15 governing the 1920 MHz to 1930 MHz UPCS band. A working group was formed under the aegis of SC 7 to rewrite ANSI C63.17-1998 to reflect

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the changes in 47CFR15. The revised standard, ANSI C63.17-2006, was, again, the result of the efforts of SC 7.

In July 2012, the FCC released revised provisions of 47CFR15 governing the 1920 MHz to 1930 MHz UPCS band. These revisions facilitate the implementation of improved services utilizing this band. A working group was again formed under the aegis of SC 7 to revise ANSI C63.17-2006 to reflect the changes in 47CFR15. The revised standard, C63.17-2013, was the result of the efforts of SC 7.

The 2013 version of the standard was reaffirmed by the C63 Committee in 2020.

This standard sets forth uniform methods of measurement of the electromagnetic and operational compatibility of unlicensed personal communications services (UPCS) devices. The recommended methods are applicable to the radio transmitter and monitoring devices contained in the UPCS device. These methods apply to the measurement of individual UPCS devices. Additional methods may be added to this standard to fulfill future requirements.

This standard does not cover licensed personal communications services (PCS) devices.

C63.23:2012 (reaffirmed in 2020) *– American National Standard Guide for Electromagnetic Compatibility—Computations and Treatment of Measurement Uncertainty:* ANSI C63.23 is intended to provide measurement laboratories with guidelines and generally-accepted laboratory practices in the determination of EMI measurement uncertainties. The primary application of ANSI C63.23 is for use with ANSI C63.4. This guide may apply to other C63 standards as appropriate.

This document concentrates on the measurement instrumentation uncertainty, which is a subpart of the total uncertainty of the measurement, and it includes only the effects of those contributors that are related to the measurement instrumentation.

The guide provides methods for determining the uncertainty of measurement for electromagnetic interference (EMI) measurement results. It provides information on the application of Type A statistical evaluations. For Type B evaluations, this guide also provides information on where to obtain specified published information that can lead to an evaluation of uncertainty.

The current document provides information on the range 150 kHz to 30 MHz for conducted emissions on main lines and 30 MHz to 18 GHz for radiated emission measurements.

C63.19:2019 *– American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids:* This standard has a history starting in the 1995-1996 period initiated by a Steering Committee organized by the U.S. FCC. As a result of that meeting and subsequent work by Subcommittee 8 of the C63 Committee, ANSI C63.19-2001 was approved by ANSI and published by the IEEE. That original version was followed by two revisions; ANSI C63.19-2006 and ANSI C63.19-2007. Several modifications were made to the 2007 version which resulted in ANSI C63.19-2011.

In 2015, a project was authorized to prepare a new version of ANSI C63.19 to address the following issues: 1) the growing importance of VoIP and VoLTE for telephony services; 2) hearing aid user satisfaction with HAC; 3) adequacy of volume control; 4) adequacy of T-coil reception; 5) harmonization with IEC 60118-13; 6) cover new technologies, particularly with television white space (TVWS) devices and other cellular devices at 600 MHz, 3.5 GHz, and 5.0 GHz, which may include extending the lower boundary of the frequency range covered; 7) use of software-defined radio (SDR) and other new instrumentation in HAC measurements; and 8) simultaneous transmissions, particularly in smartphones.

The 2019 version of the C63.19 standard addressed all eight of the above issues.

C63.18:2014 (Reaffirmed in 2019) *– American National Standard Recommended Practice for an On-Site, Ad Hoc Test Method for Estimating Electromagnetic Immunity of Medical Devices to Radiated Radio-Frequency (RF) Emissions from RF Transmitters:* This Recommended Practice is a guide to evaluating the electromagnetic immunity of medical devices from radiated radio-frequency (RF) emissions from common RF transmitters such as two-way radios; walkie-talkies; mobile phones; wireless-enabled tablets, e-readers, laptop computers, and similar devices; RFID readers; networked MP3 players; two-way pagers; and wireless personal digital assistants [PDAs].

A comprehensive test or a guarantee is not provided by this protocol, but instead, a basic evaluation is given that can help identify medical devices that might be particularly vulnerable to interference from common RF transmitters. Existing or newly purchased medical devices can be evaluated by this ad hoc test protocol or the protocol can be implemented for pre-purchase evaluation.

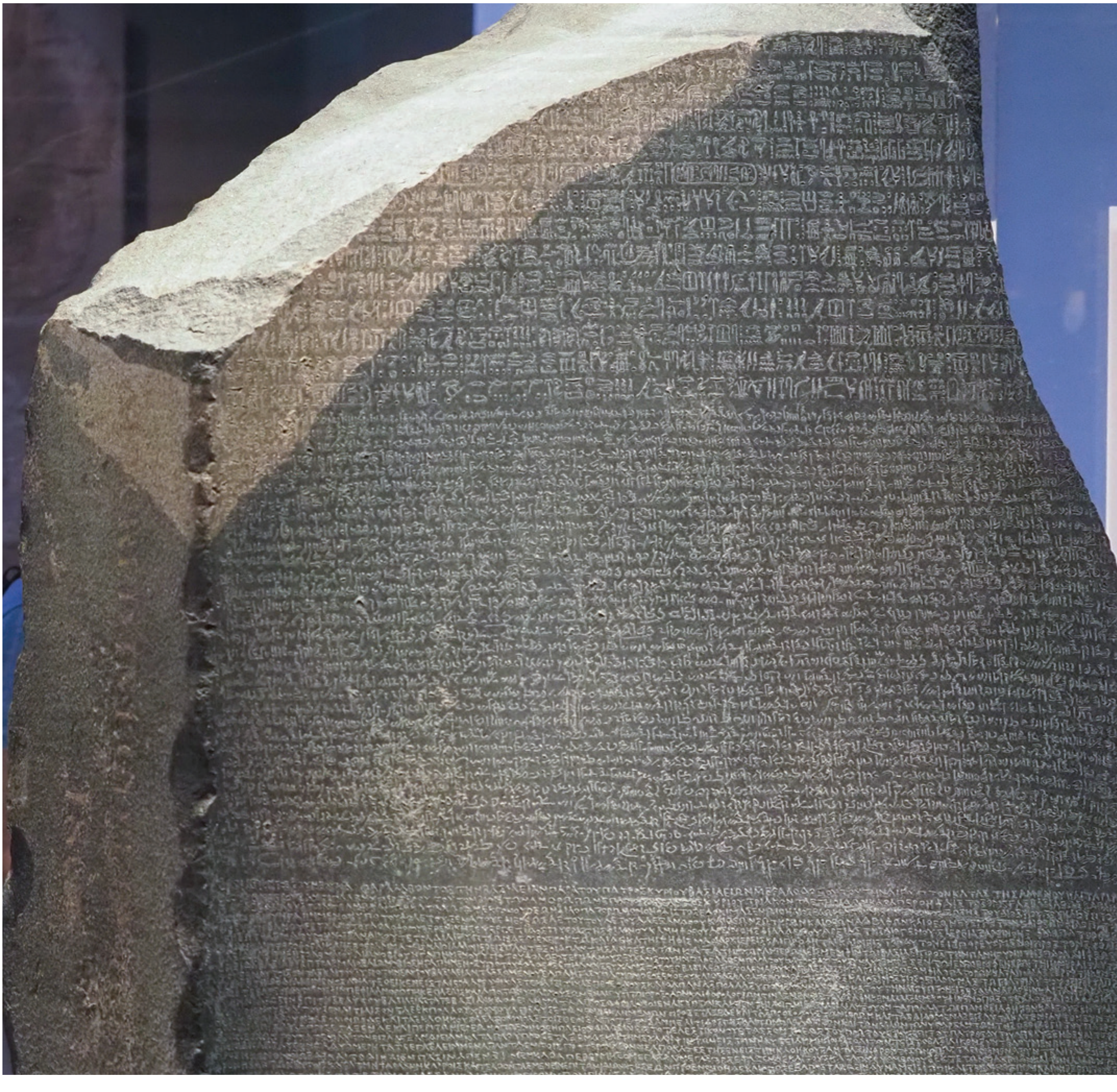
This recommended practice applies to medical devices used in healthcare facilities but can also be adapted to medical devices in home healthcare settings and/or mobile healthcare settings. It does not apply to implantable medical devices (e.g., pacemakers and defibrillators), transport environments such as ambulances and helicopters, or RF transmitters rated at more than 8 W of output power.

Testing with transmitters greater than 8 W in healthcare facilities is not recommended because of possible adverse effects on critical care medical devices that are in use in nearby areas of the facility.

Also, in-band RF interference where the fundamental frequency of an RF transmitter overlaps with frequencies used by a hospital wireless network or wireless monitoring, or other medical device wireless links is not addressed by this recommended practice.

(RE)DISCOVERING THE LOST SCIENCE OF NEAR-FIELD MEASUREMENTS, PART 1

Understanding Radiated Emissions Measurements Made at One-Meter Separation: It's Not What You've Been Led to Believe



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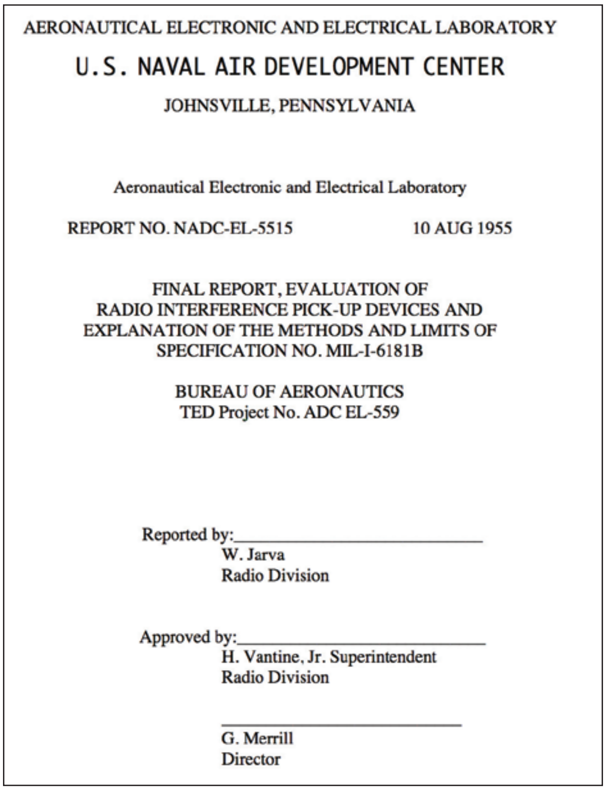
By Ken Javor

BACKGROUND[1]

The first article in this series (see *In Compliance Magazine*, May 2023) described in detail the use of radios that used unshielded connections (termed antenna lead-ins) between the radio and the external antenna.[2] The antenna lead-in was a single wire above ground, using aircraft structure for a return path, that was connected to high impedances at both ends. That is, the radio input was the grid of a vacuum tube, so basically a small capacitance, and the external antenna was an electrically short wire over most of the 0.15 – 20 MHz (200 –15 meters) frequency (wavelength) range of the radio.



AERONAUTICAL ELECTRONIC AND ELECTRICAL LABORATORY

U.S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, PENNSYLVANIA

Aeronautical Electronic and Electrical Laboratory

REPORT NO. NADC-EL-5515 10 AUG 1955

FINAL REPORT, EVALUATION OF
RADIO INTERFERENCE PICK-UP DEVICES AND
EXPLANATION OF THE METHODS AND LIMITS OF
SPECIFICATION NO. MIL-I-6181B

BUREAU OF AERONAUTICS
TED Project No. ADC EL-559

Reported by:______________________
W. Jarva
Radio Division

Approved by:______________________
H. Vantine, Jr. Superintendent
Radio Division

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G. Merrill
Director

NADC-EL-5515 is the Rosetta Stone of the EMC discipline

Figure 1 shows a WWII-era handbook drawing of such an installation.[3] Handbooks of the time went to great lengths showing photographs of poor and good radio antenna lead-in installations.[4] Controlling the loop area of the lead-in over ground relative to that of adjacent culprit noise emitters (crosstalk) was emphasized.

The specification that introduced EMI requirements based on controlling interference to/from these unshielded transmission lines was MIL-I-6181B, released in May 1953.[5] As described in Reference 2, a report is available describing the selection of test antennas and set-ups for measuring to limits controlling radiated coupling to the unshielded antenna lead-in.[6] NADC-EL-5515, released in 1955, is the rationale behind the radiated emission measurement limits and test methods of MIL-I-6181B.

NADC-EL-5515 should be required reading for every vehicle EMC engineer. If the physics described in NADC-EL-5515 were universally understood by

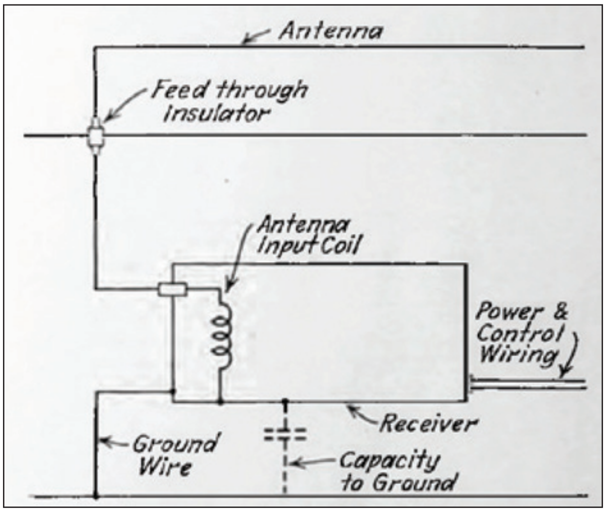


Figure 1: Typical installation of radio, antenna, and ground connections for a WWII-era 0.15 – 20 MHz radio installation.

EMC engineers, there would be no need for the near field physics discussion in this article. Unfortunately, this knowledge is truly lost, and it is apparent from the state of aerospace (RTCA/DO-160 section 21) and automotive vehicle radiated emission EMI specifications (CISPR 25), and standards that support them (SAE ARP-958), that such understanding is sadly lacking.[7,8,9]

PURPOSE

Hence, the true purpose of this article, which is only peripherally historical. The reader is requested to be patient, as much of what is presented will appear at first rather obvious. The more obvious, the better, because the conclusion is antithetical to most people's thinking, and a surprising conclusion is much more convincing if the trail there is familiar and well-worn. The conclusion is this simple: only a far-field measurement results in a true field intensity measurement. That is, the signal level measured at the EMI receiver, adjusted for any losses/gains in the transmission line path, is only relatable to a specific field intensity when the antenna's physical aperture is immersed in a field of constant amplitude across it.

Under any other conditions (the near field) that relationship cannot be made, and any artificial attempts (one-meter field intensity limits supported by a one-meter antenna factor) are not only doomed to failure but also wrongheaded. This means that there is no valid use for such artificial constructs, and they lead to bad engineering decisions. This is not to say that near-field measurements are useless – far from it. A near-field measurement is absolutely necessary when the actual culprit - victim interaction is near field. But the point is, far- vs. near-field measurements are not simply quantitatively, but also qualitatively different.

We will start by defining and differentiating the concepts of far and near fields, all from an EMI test point of view. Far field is easiest, so we begin there.

FAR FIELD

The far field as an abstraction is a simple concept to visualize and understand intuitively. The near field is more complex, but as a starting point, we are in the near field when we are not in the far field. In terms of radiated emission measurements, the concept of far field is mostly associated with standards such as CISPR 22 and the newer 32.[10,11] These standards provide for test sample/antenna separations of 3 to 30 meters at and above 30 MHz. The far field assumption means limits scale directly with separation distance. It also means that – and this is key – these standards do not specify antenna types, only that they be calibrated in the far field. As we shall see, limit scaling with distance and the assumption that the same result may be obtained with any suitably calibrated antenna are hallmarks of a far-field measurement. Neither of these is true in the near field. And this is what MIL-I-6181B and NADC-EL-5515 first presented to the EMC world, and which remains true to the present day, albeit too few practicing EMC engineers appreciate it.

All of the following criteria need to be met in order to be in the far field of a transmitting source:

1. The far field is traveling electromagnetic energy. That means the far field propagates independently of the existence of the transmitting antenna once it is launched. The electric and magnetic field components of a traveling wave (Poynting's theorem) are in contrast to the quasi-static and induction field components close to the antenna, which begin and end on antenna elements, and vanish when the antenna excitation is removed. An example of the independence of the traveling wave from its source is the light from a distant star reaching Earth. The star may in fact no longer exist, but the light it radiated away is still traveling through space. Closer to home, one necessary (but insufficient in and of itself) requirement for achieving the far field is being at or beyond the distance at which the amplitude of the traveling wave exceeds that of the quasi-static and induction components. Heinrich Hertz derived this criterion for an electrically short dipole.
2. A far-field traveling electromagnetic wave emanates from a point source. This means that the wave front has spherical curvature. This doesn't mean that the radiating source is literally a point, which would yield not only spherical curvature but also spherical symmetry. It means the transmitting source is so far away from the observation point that it appears as a point; the distance from the observation point to any point on the transmit antenna is equal. This assumption is inherent in the derivation of the Hertzian short dipole field components.
3. The wave front is not only spherical but also plane. Meaning that the sphere's radius of curvature is large enough that over the physical aperture of our receive antenna there is no variation in field intensity or power density. The spherical wave front approximating a plane wave is the source of expressions for the far field such as $2D^2/\lambda$.

Now for the distance from an observation point to *any* point along an extended structure to be equal, the observation point must be infinitely far away. Similarly, a plane surface may be described as the surface of a sphere of infinite radius. But none of that is very practical for daily use. Instead, we decide on how closely our spherical surface needs to approximate a plane surface, typically by positing a maximum phase difference between any two lines from the observation point to different portions of the transmitting source. Figure 2 shows this process specifying the allowable variation from a plane wave as a fraction of a wavelength.

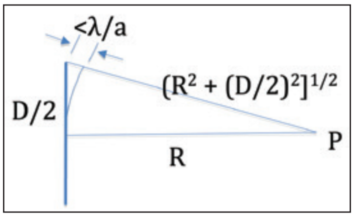


Figure 2: Geometry for determination of far-field distance based on how close a spherical wave front approximates a plane surface

In Figure 2, the circular arc struck between the radius labeled R and the radius that is its hypotenuse marks off the length of the hypotenuse that is greater than R and denotes it as a fraction of a wavelength. The value we assign to "a" depends on the application of interest.

Setting

$$R + \lambda/a = \sqrt{(R^2 + (D/2)^2)}$$

and solving for R, we get

$$R = (a/2\lambda)\ (D/2)^2 - \lambda/2a \quad \text{or}$$
$$R = aD^2/8\lambda - \lambda/2a$$

When we pick a maximum phase front variation of a sixteenth wavelength (a = 16), we get

$$R = 2D^2/\lambda - \lambda/32$$

In order for this to approximate the familiar $2D^2/\lambda$, the first term must greatly exceed the second term.

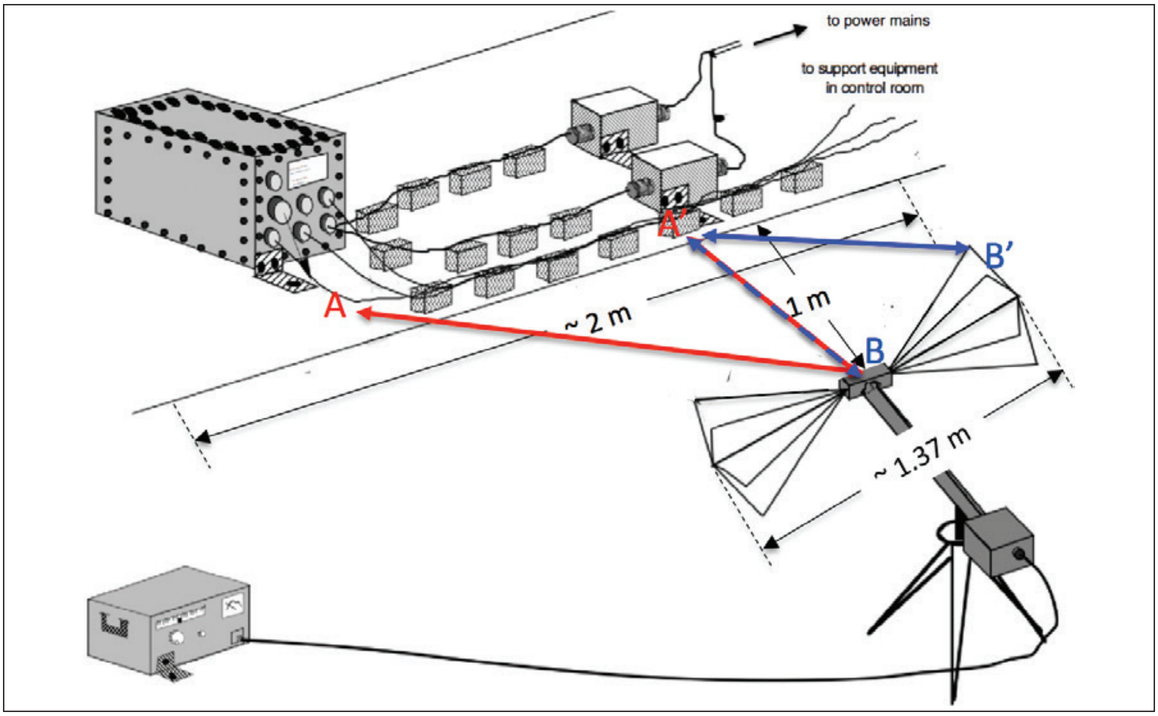


Figure 3a: One-meter separation radiated measurements are near-field measurements. The test set-up boundary is longer than the distance to the measurement antenna. The antenna physical aperture (length in the case of the biconical) is of the same order of magnitude as the separation from the test sample. For the test set-up to be in the far field of the antenna, line segments AB and A'B would need to be approximately equal in length. Likewise, for the antenna to be in the far field of the test set-up, line segments A'B and A'B' would need to be nearly equal in length. In a one-meter separation measurement, neither condition is obtained.

This is certainly the case when the transmit antenna is at least a half-wavelength long.

From this analysis, in addition to learning/reviewing the derivation for $2D^2/\lambda$, we understand that it is based on a traveling electromagnetic wave far from the point source. We can also see that if the antenna is electrically short, the derivation doesn't work at all. The phase difference between the two radial distances in Figure 2 will always be smaller than the phase difference associated with distance d/2. If the antenna dimensions are an insignificant fraction of a wavelength this problem formulation says the far field is at any distance from the antenna, including zero. That is, if the phase difference from the center of the antenna to its end is the same or smaller than the phase difference we posit as acceptable for the far field criterion, then even a point on the antenna centerline is in the far field in terms of the above analysis. This merely emphasizes that the analysis assumes an electrically long antenna and a traveling electromagnetic wave.

NEAR FIELD

Now let's look at the opposite situation: the one-meter radiated emission measurements that are very similar between MIL-STD-461, and RTCA/DO-160 section 21 and CISPR 25.[12] In these standards, minimum lengths

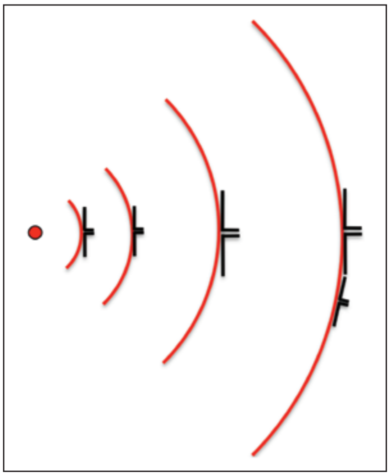


Figure 3b: The spherical wave front of a point source radiator. As the distance from the source increases, the spherical wave front appears increasingly planar. But planar is a relative quantity. The dimensions of the receive antenna also determine the far field distance. When the wave front is plane enough, measurements using different antennas will correlate.

of cables vary from 1.5 m (CISPR 25) to 3.3 meters (RTCA/DO-160). This means that the antenna separation from the radiating structure is much less than the length of the radiating structure.

Figure 3a demonstrates that the radiating structure is not a point source. Further, the dimensions of the antennas used below 1 GHz are on the order of the separation distance, so that the test antenna is not measuring a single, constant amplitude of field intensity over its physical aperture, but instead is integrating a complex variation of field intensity over its physical length. Figure 3b shows the radiation situation most people visualize when making antenna measurements. Figure 3c is similar to Figure 3a and in direct contrast to Figure 3b, showing the extreme near field. Figure 3c is an end view of the isometric view shown in Figure 3a, showing the electric field due to a wire over a ground plane.

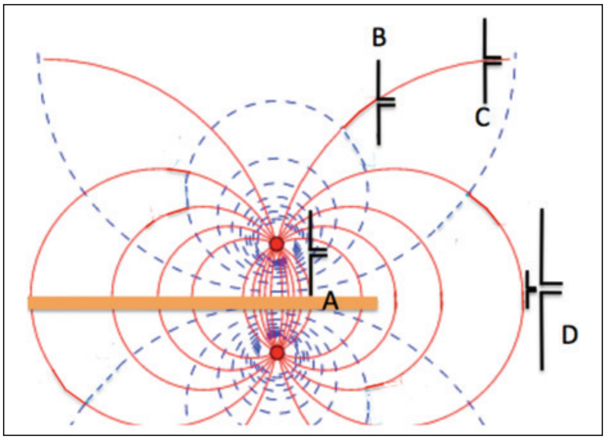


Figure 3c: The electric field (red) of a wire suspended over a ground plane (orange). Field lines below the ground plane are images. Field lines to the right of the ground plane's end point are not accurately rendered. They would curve around and connect at right angles to the ground plane. Wave front or field curvature is far from the plane, and correlation to another measurement at another distance using a different or even similar antenna is impossible.

Figure 3c emphasizes that antenna placement is critical. Placement of identical antenna types at various positions from A to C reveals that the received signal will be dependent on the orientation of field lines, which is strongly a function of the position close to the test sample. Inspection of two of the same type antennas with different lengths at position D emphasizes that the longer antenna is not measuring constant field intensity over its physical aperture, but instead is integrating a variation of field intensity over its physical length. We cannot predict from the position D measurement with the smaller antenna what the larger antenna would measure because while the smaller antenna is illuminated by a near-constant amplitude electric field, the larger antenna is not. And we cannot extrapolate from the measurement with the larger antenna to using the same antenna or another antenna at another position, for the same reason.

In Figure 3b, the voltage measured at the antenna port where the phase front is constant over the antenna physical length is directly proportional to the field intensity impinging upon it. In contrast, in Figure 3c the single value of "field strength" derived from the voltage at the antenna is only representative of what is measured at this particular position relative to the test sample, and using a particular antenna, at a particular orientation. The measured value is not a scalable far field "field intensity" in the sense that one can use it to predict the field intensity at some other distance or measured with a different antenna.

A real-world example of these limitations is FCC rules for EMI testing on an open area test site (OATS) back in the 1980s. The original test method used half-wave dipoles at a three-meter separation from the test sample. At 30 MHz, this placed a 5-meter-long antenna at 3 meters distance. The antenna was longer than the separation: near field. When biconicals started to become popular as tunable dipole replacements, the FCC ruled that while biconicals were acceptable, if there were any question about whether the test sample met the limit, a dipole measurement would be made, and that result would be used. The ~140 cm biconical was actually a better far-field measurement due to its much shorter length, but the point was that a standard had to be maintained, and they knew that biconical and 30 MHz half-wave dipole measurements would not agree.

A final note about Figures 3a, 3b, and 3c: The issues illustrated are frequency independent. Regardless of frequency – dc to light – if the above conditions apply, the measurement is near field.

In the words of NADC-EL-5515, referring to antenna types used for EMI testing in the 1950s:

> *"For instance, a resonant dipole antenna has good sensitivity to low-impedance (magnetic) fields near its center and high-impedance (electric) fields near its ends. Other antennas, such as the discone, have a completely different distribution of impedance, polarization, physical size, and contour. Obviously, a comparison of the effect of a given interference field upon the dipole and the same field on a discone can only be made in a very general manner. For this reason, (MIL-I-6181B) radio interference limits are derived expressly for each particular antenna that is to be used, and an exact correlation between different types of antennas is not expected."*[13]

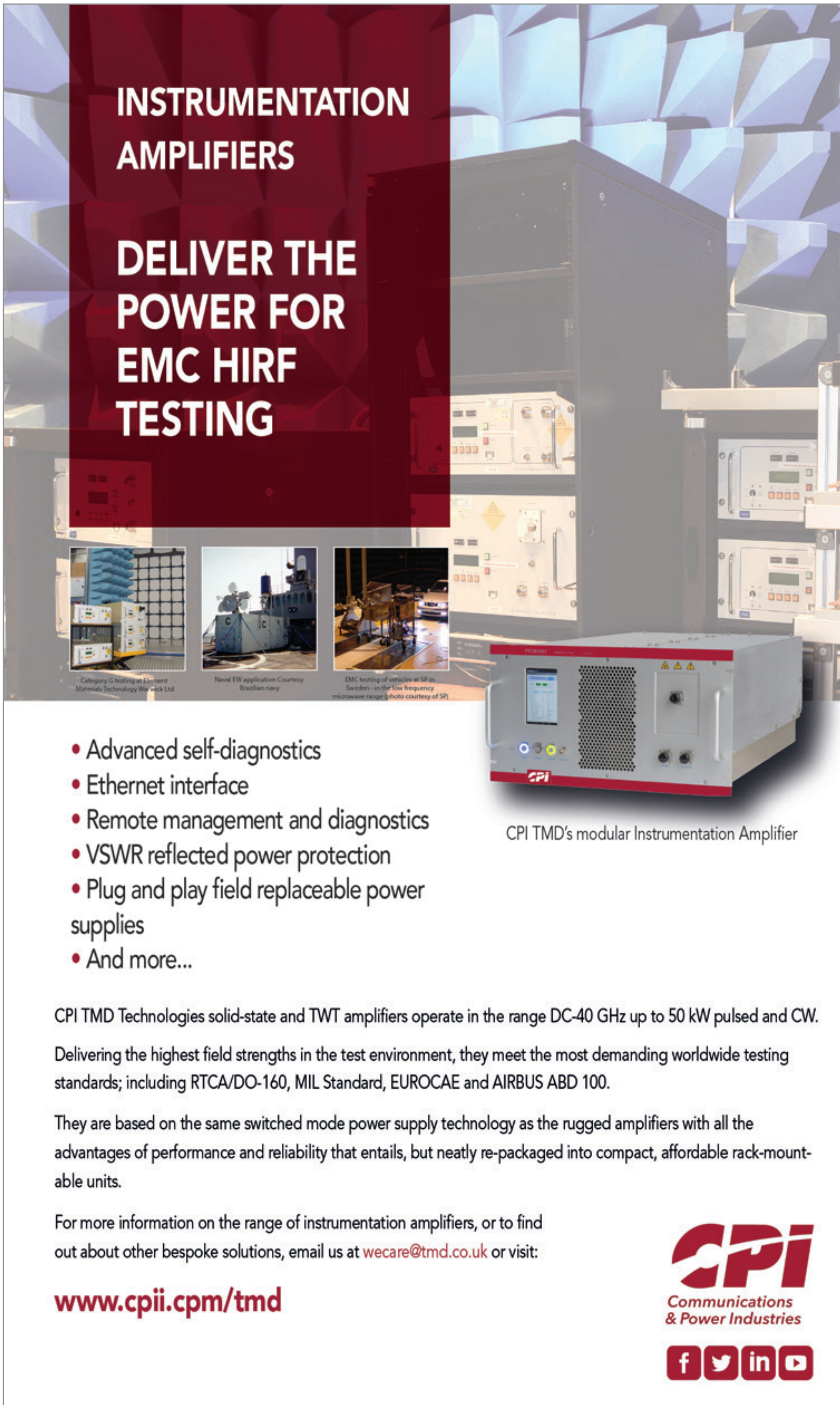
This is the end of the first installment of "(Re)Discovering the Lost Science of Near Field Measurements." Future installments will include sections on:

- Describe, compare, and contrast near field antenna-induced vs. field intensity limits
- Introduction and detailed description of the meaning of antenna-induced signals
- Rationale behind the switch from antenna-induced to field intensity EMI limits
- Technical problems incurred using field intensity limits in the extreme near field
- Practical problems resulting from using field intensity limits where antenna-induced is more appropriate

ENDNOTES

1. All standards and specifications referenced herein which are not copyrighted are available from http://www.emccompliance.com.
2. Javor, Ken, "Seventy Years of Electromagnetic Interference Control in Planes, Trains and Automobiles," *In Compliance Magazine*, May 2023.
3. Also see Figures 2 and 3 of Reference 2.

4. NAVAER 16-5Q-517, Elimination of Radio Interference Problems in Aircraft, circa 1946-47.
5. MIL-I-6181B, Interference Limits, Tests and Design Requirements, Aircraft Electrical and Electronic Equipment, 29 May 1953.
6. NADC-EL-5515, Final Report, Evaluation of Radio Interference Pick-Up Devices and Explanation of the Methods and Limits of Specification No. MIL-I-6181B, 10 August 1955.
7. RTCA/DO-160, original through C revision, Environmental Conditions and Test Procedures for Airborne Equipment.
8. CISPR 25, all editions, various titles. “Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles” is the 1995 title.
9. SAE ARP-958, all revisions, Broadband Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods, 01 March 1968.
10. CISPR 22 - Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement (withdrawn).
11. CISPR 32 - Electromagnetic Compatibility of multimedia equipment – Emission requirements.
12. MIL-STD-461E, and newer, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 1999-present.
13. A discone antenna is half of a biconical, mounted vertically above or below a ground plane that provides the missing biconical element as an image in the ground plane.



FAR-FIELD CRITERION FOR WIRE-TYPE ANTENNAS

By Bogdan Adamczyk

This article presents the derivation of the far-field criterion for two fundamental wire-type antennas: electric (or Hertzian) dipole and magnetic dipole.

Dr. Bogdan Adamczyk is professor and director of the EMC Center at Grand Valley State University (http://www.gvsu.edu/emccenter) where he regularly teaches EMC certificate courses for industry. He is an iNARTE certified EMC Master Design Engineer. Prof. Adamczyk is the author of the textbook "Foundations of Electromagnetic Compatibility with Practical Applications" (Wiley, 2017) and the upcoming textbook "Principles of Electromagnetic Compatibility with Laboratory Exercises" (Wiley). He can be reached at adamczyb@gvsu.edu.

1. ELECTRIC (HERTZIAN) DIPOLE

Hertzian dipole, shown in Figure 1, consists of a short thin wire of length *l*, carrying a phasor current $\hat{I}_0 = I_0$, positioned symmetrically at the origin of the coordinate system and oriented along the *z*-axis.

The complete fields of the Hertzian dipole, at a distance *r* from the origin, can be obtained from the vector magnetic potential $\boldsymbol{A}$ shown in Figure 1, (see [1] for the derivations), and can be expressed as, [2],

$$\hat{E}_r = 2\frac{I_0 l}{4\pi}\eta_0\beta_0^2 \cos\theta\left[\frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right]e^{-j\beta_0 r} \tag{1.1}$$

$$\hat{E}_\theta = \frac{I_0 l}{4\pi}\eta_0\beta_0^2 \sin\theta\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)e^{-j\beta_0 r} \tag{1.2}$$

$$\hat{H}_\phi = \frac{I_0 l}{4\pi}\beta_0^2 \sin\theta\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right)e^{-j\beta_0 r} \tag{1.3}$$

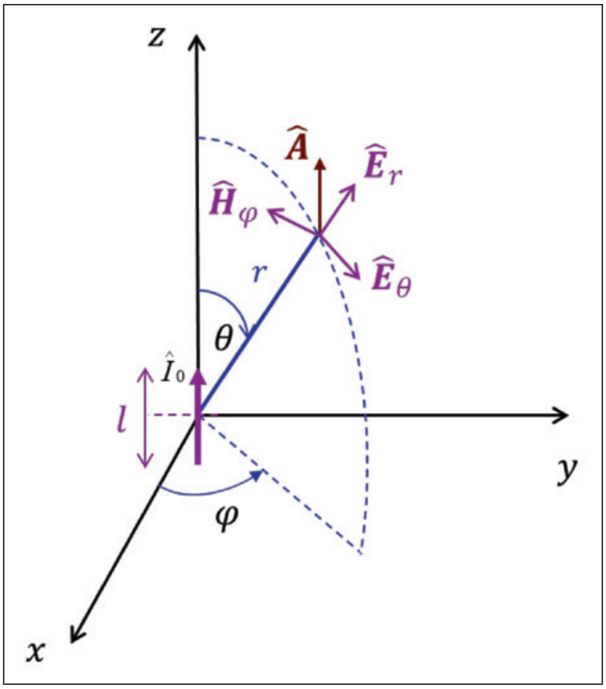


Figure 1: Hertzian dipole

where η_0 is the intrinsic impedance of free space, and β_0 is the phase constant.

With this electromagnetic wave, we associate *wave impedance*, defined as

$$\hat{Z}_{w,e} = \frac{\hat{E}_\theta}{\hat{H}_\phi} \tag{1.4}$$

A far-field criterion (distance *r* from the antenna) for Hertzian dipole (and other wire-type antennas) is derived from the requirement that the magnitude of the wave impedance in far field is equal to the intrinsic impedance of free space.

$$\left|\hat{Z}_{w,e}\right| = \frac{\left|\hat{E}_\theta\right|}{\left|\hat{H}_\phi\right|} \cong \eta_0 = 120\,\pi \cong 377\Omega \tag{1.5}$$

A far-field criterion (distance r from the antenna) for Hertzian dipole (and other wire-type antennas) is derived from the requirement that the magnitude of the wave impedance in far field is equal to the intrinsic impedance of free space.

Using Eqns. (1.2) and (1.3) in Eq. (1.4) we get

$$\hat{Z}_{w,e} = \frac{\frac{I_0 l}{4\pi}\eta_0 \beta_0^2 \sin\theta\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}-j\frac{1}{\beta_0^3 r^3}\right)e^{-j\beta_0 r}}{\frac{I_0 l}{4\pi}\beta_0^2 \sin\theta\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}\right)e^{-j\beta_0 r}} \tag{1.6}$$

or

$$\hat{Z}_{w,e} = \frac{\eta_0\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}-j\frac{1}{\beta_0^3 r^3}\right)}{\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}\right)} \tag{1.7}$$

Multiplying the numerator and denominator by $j(\beta_0 r)^3$ we obtain

$$\hat{Z}_{w,e} = \frac{\eta_0\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}-j\frac{1}{\beta_0^3 r^3}\right)}{\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}\right)}\frac{j(\beta_0 r)^3}{j(\beta_0 r)^3} \tag{1.8}$$

or

$$\hat{Z}_{w,e} = \eta_0 \frac{-(\beta_0 r)^2+j(\beta_0 r)+1}{-(\beta_0 r)^2+j(\beta_0 r)} \tag{1.9}$$

Letting,

$$\beta_0 = \frac{2\pi}{\lambda_0} \tag{1.10}$$

we obtain

$$Z_{w,e} = \frac{\hat{E}_\theta}{\hat{H}_\phi} = \eta_0 \frac{1-\left(\frac{2\pi r}{\lambda_0}\right)^2 + j\left(\frac{2\pi r}{\lambda_0}\right)}{-\left(\frac{2\pi r}{\lambda_0}\right)^2 + j\left(\frac{2\pi r}{\lambda_0}\right)} \tag{1.11}$$

We can evaluate this expression at different distances (in terms of the wavelength) from the antenna, for instance, ($r = \lambda_0/2\pi$, $r = \lambda_0$, $r = 3\lambda_0$). When evaluated at $r = 3\lambda_0$, the wave impedance becomes

$$\hat{Z}_{w,e} = 375.93\angle - 0.01° \cong \eta_0,\ r = 3\lambda_0 \tag{1.12}$$

The result in Eq. (12) leads to the *far-field criterion* for the Hertzian dipole (and other wire-type antennas):

$$r_{far\ field} = 3\lambda_0 \tag{1.13}$$

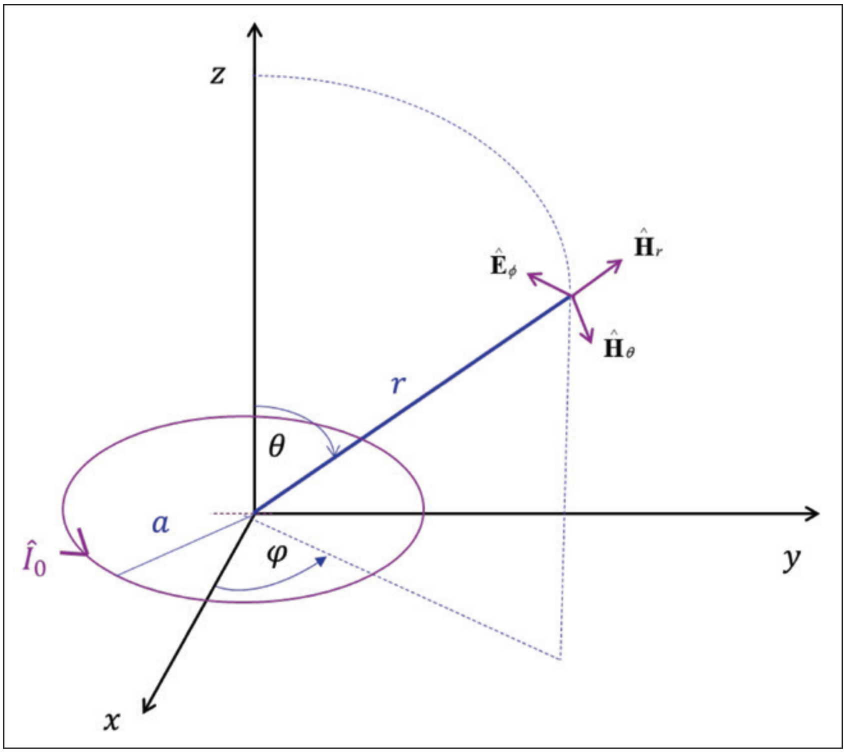


Figure 2: Magnetic Dipole

2. MAGNETIC DIPOLE

Magnetic dipole, shown in Figure 2, consists of a small thin circular wire loop of radius a, carrying a current $\hat{I}_0 = I_0$, positioned in the xy plane, with the center of the loop at $z = 0$.

The complete fields of the magnetic dipole, at a distance r can be expressed [2],

$$\hat{E}_\phi = -j\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4} sin\,\theta \left[j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right] e^{-j\beta_0 r} \tag{2.1}$$

$$\hat{H}_r = j2\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4\eta_0} cos\,\theta \left[\frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right] e^{-j\beta_0 r} \tag{2.2}$$

$$\hat{H}_\theta = j\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4\eta_0} sin\,\theta \left[j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right] e^{-j\beta_0 r} \tag{2.3}$$

The wave impedance for magnetic dipole is defined as

$$\hat{Z}_{w,m} = \frac{\hat{E}_\phi}{\hat{H}_\theta} \tag{2.4}$$

Using Eqns. (2.1) and (2.3) in Eq. (2.4) we get

$$\hat{Z}_{w,m} = \frac{-j\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4} sin\,\theta \left[j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right] e^{-j\beta_0 r}}{j\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4\eta_0} sin\,\theta \left[j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right] e^{-j\beta_0 r}} \tag{2.5}$$

or

$$\hat{Z}_{w,m} = -\eta_0 \frac{\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right)}{\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)} \tag{2.6}$$

Multiplying the numerator and denominator by $j(\beta_0 r)^3$ we obtain

$$\hat{Z}_{w,m} = -\eta_0 \frac{\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}\right)}{\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}-j\frac{1}{\beta_0^3 r^3}\right)} \frac{(\beta_0^3 r^3)}{(\beta_0^3 r^3)} \tag{2.7}$$

or

$$Z_{w,m} = -\eta_0 \frac{(j\beta_0^2 r^2+\beta_0 r)}{(j\beta_0^2 r^2+\beta_0 r-j)} = -\eta_0 \frac{\beta_0 r+j\beta_0^2 r^2}{\beta_0 r+j(\beta_0^2 r^2-1)} \tag{2.8}$$

Letting,

$$\beta_0 = \frac{2\pi}{\lambda_0} \tag{2.9}$$

we obtain

$$\hat{Z}_{w,m} = \frac{\hat{E}_\phi}{\hat{H}_\theta} = -\eta_0 \frac{\left(\frac{2\pi r}{\lambda_0}\right)+j\left(\frac{2\pi r}{\lambda_0}\right)^2}{\left(\frac{2\pi r}{\lambda_0}\right)+j\left[\left(\frac{2\pi r}{\lambda_0}\right)^2-1\right]} \tag{2.10}$$

Evaluating Eq. (2.10) at $r = 3\lambda_0$ we get

$$\hat{Z}_{w,m} = -\eta_0 \frac{6\pi+j(6\pi)^2}{6\pi+j[(6\pi)^2-1]} = -\eta_0 \frac{6\pi+j36\pi^2}{6\pi+j[36\pi^2-1]} \cong -\eta_0 \tag{2.11}$$

Thus, the magnitude of the wave impedance

$$\left|\hat{Z}_{w,m}\right| \cong \eta_0 \tag{2.12}$$

We have arrived again at the *far-field criterion* as

$$r_{far\ field} = 3\lambda_0 \tag{2.13}$$

REFERENCES

1. Bogdan Adamczyk, *Foundations of Electromagnetic Compatibility with Practical Applications*, Wiley, 2017.
2. Clayton R. Paul, *Introduction to Electromagnetic Compatibility*, Wiley, 2006.

THE DILEMMA BETWEEN CUSTOMERS AND SUPPLIERS ON EOS FAILURES

Bridging the Gap using tAMR

By Ashok Alagappan for EOS/ESD Association, Inc.

NEVER-ENDING EOS CUSTOMER RETURNS

During the last four decades, damage to devices from electrical overstress (EOS) has confounded both IC suppliers and customers. The Industry Council on ESD Target Levels investigated numerous EOS root causes and established a white paper on the subject, JEP174 [1]. The original motivation came after observing that the most common and top Pareto item as indicated in the failure Pareto analysis in Figure 1 for semiconductor component field returns is Electrical Over Stress (EOS) failures. More often, NTF, or no trouble found, has been attributed to EOS failures as well. One of the major reliability challenges is a failure that appears to be electrically induced physical damage (now commonly known as EIPD) as shown in optical, X-ray, and decapsulated images in Figures 2a, 2b, and 2c. The failures were produced with no prior indications, leaving customers wondering what might have caused it, when it might have occurred, and how it might have happened. A thorough analysis including but not limited to curve tracing, electrical characterization, optical and x-ray microscopy, and decapsulation is often required to prove that failures are in fact caused by electrical overstress. Failure analysis reports from the industry indicate failures can range from damage to the package to fused and melted wire bond to melting or burning of the stacked material that is hidden in the semiconductor die.

Ashok Alagappan has over 15 years of experience in the Semiconductor industry, specializing in design and manufacturing of semiconductor products. At Ansys, he is working with customers across the spectrum, from aerospace to automotive to commercial, providing expert analysis and solutions for defining and improving reliability of electronic products and Integrated Circuit (IC) components.

Founded in 1982, EOS/ESD Association, Inc. is a not for profit, professional organization, dedicated to education and furthering the technology Electrostatic Discharge (ESD) control and prevention. EOS/ESD Association, Inc. sponsors educational programs, develops ESD control and measurement standards, holds international technical symposiums, workshops, tutorials, and foster the exchange of technical information among its members and others.

If this is any indication of the problem that several end customers face on a day-to-day basis, it is evident that EOS failures are a clear and present danger to semiconductor component reliability. However, it

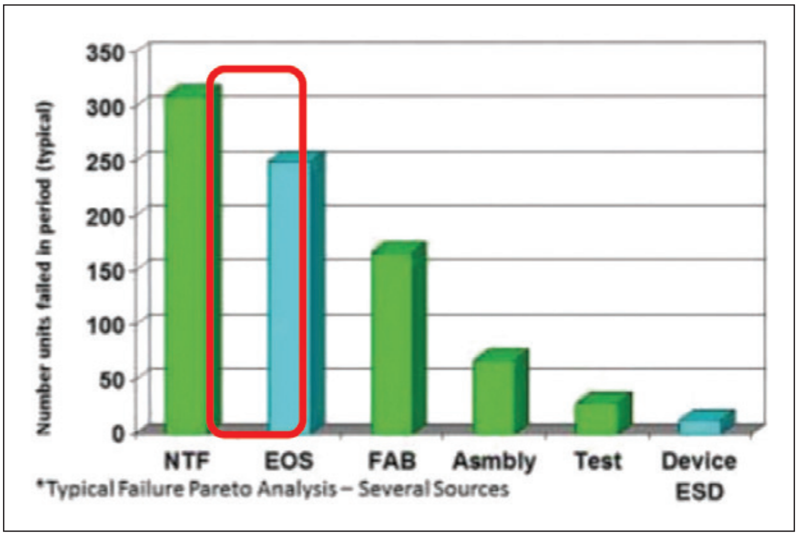
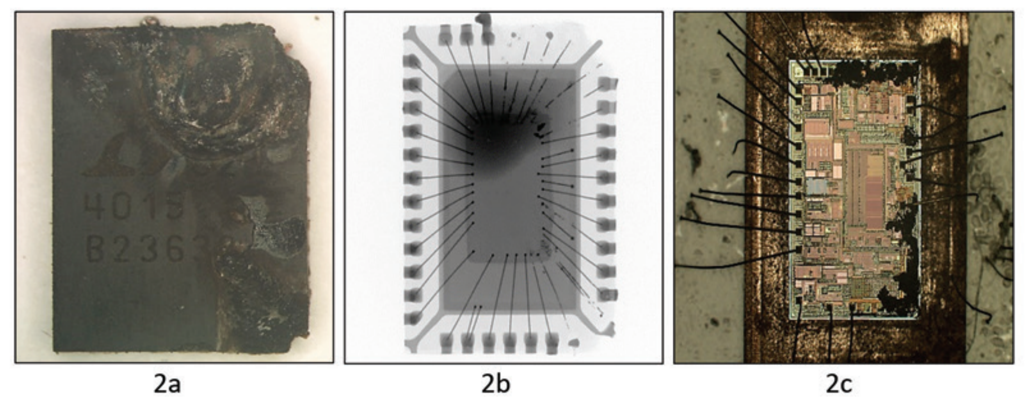


Figure 1: Failure Pareto showing EOS as the top item (Danglemayer Assoc & Semitracks Inc)

has been elusive when it comes to the identification of a root cause and solution. The most important question that needs to be answered is what causes semiconductor components to fail due to electrical overstress when there are protective strategies in place within the component, as well as external to it? In addition, the component datasheets have absolute maximum ratings (AMR) published that serve as a warning for system designers to pay attention to maintain the reliability of the component. However, in the white paper on EOS, it was noted that AMR does not provide the full picture.



2a 2b 2c

Figure 2: a) Crater on top of the package due to EOS, b) X-ray image showing melted bond wire, c) decapsulated image of the die showing damage on die

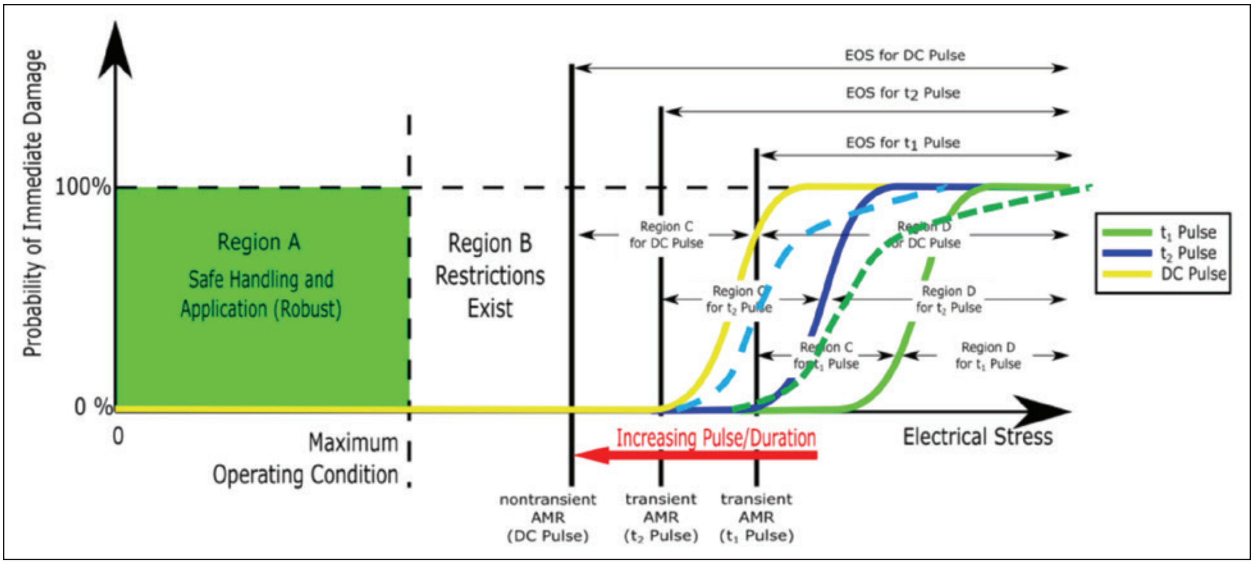


Figure 3: Effect of pulse duration on the probability of damage

To answer the question of what causes EOS failures, a holistic approach needs to be taken. While absolute maximum ratings (AMR) are published in product datasheets, they don't address the limitations due to the inherent transients that the components experience due to several reasons such as inductive coupling, EMI/EMC, etc. that are typically application specific. The presence of these transients which range from Direct Current (DC) to nanosecond (ns) and their impact on component reliability are often not considered mainly because of the lack of understanding of their effects.

EFFECTS OF TRANSIENT AMR

It is more important to understand the types of signals that manifest on the pins of the integrated circuit components and the boundary conditions in the form of ratings and specifications that are in place to have a minimal impact. The absolute maximum ratings (AMR) have often been associated with DC stress limits that should not be violated to maintain product reliability. However, under certain conditions, this AMR may need to be exceeded to meet some specific applications where transients are involved. But these transients are not all the same as they will vary in duration and magnitude. For example, if the AMR was specified as 3 V, during certain field events the product or system might see up to 7 V for a few microseconds or a few milliseconds. There is a misunderstanding that the shorter the transient, the less power is delivered and hence the lower the likelihood of EOS damage. However, to understand the transient nature of AMR for all product and system applications, we must define the transient nature of AMR or what is referred to as tAMR. This can provide comprehensive insight into signal integrity aspects of a component in relation to the overall system design.

Figure 3 illustrates the effect of pulse duration and the impact of immediate damage. The regions below the Maximum Operating Condition depicted as A and B are safe for all handling and applications, with region B being where the effects are understood when violated. Exceeding the absolute maximum rating or AMR is the most critical condition where the damage probability begins. The yellow curve in Figure 3 below represents this behavior and it predicts that as the stress is increased beyond this limit the probability of immediate damage goes up and eventually reaches 100%. But if there is a condition where the pulse duration is shorter in time it should take a higher level of stress to reach the same probability of immediate damage at any given stress point. As an illustration, this is shown by the blue solid curve in Figure 3; an even shorter pulse time is shown by the green solid curve. This might sound reasonable theoretically, but is this approach realistic or accurate?

The curves with less transient times do not necessarily shift in a parallel fashion as shown by the blue and green solid curves. One can envision that since the power to failure from the well-known Wunsch-Bell relation is a function of time to failure, the true shifts in these probability curves might involve a stochastic process. We can perhaps try to represent them with the dashed blue and green curves to convey that at lower stress levels the shift for transient pulses would be less compared to the shift at higher stress levels. These cannot be confirmed without detailed studies that include field relevant studies and gathering data that relate to various transient conditions and their impact on robust system designs. There are complex parameters involved such as minimum stress to create thermal damage, power to failure versus pulse widths for specific example case studies, and an understanding of statistical reliability models and the limits and regions of their applications, etc.

There have been several case studies from different applications published in Industry Council WP4 [1]. The common thread among the cases appears to be a lack of clarity on the specifications for absolute maximum rating for transient signals. It becomes even more important in high-reliability applications such as automotive, medical, and aerospace.

TRANSIENT STRESS AND RELIABILITY PREDICTION USING SIMULATION

As illustrated in Figure 3, the impact of a transient pulse can be immediate or progressive degradation. EOS pulse could potentially degrade the reliability affecting the maximum stress level for a given lifetime. A maximum acceptable level of stress for critical electrical parameters like current, voltage, or power needs to be established from a Wunch-Bell relationship for short-stress conditions and a reliability model will determine the maximum stress level for longer-stress conditions. Simulation methodologies can provide valuable assistance in analyzing and understanding the transient stresses and failure mechanisms. Also, simulation can help narrow down the focus area by identifying the regions of interest on the chip/system and transient waveforms of interest. These insights can be of great help in designing more robust devices, circuits, and systems. Simulation tools and workflows provided by Ansys can be of valuable assistance in the analysis of tAMR by providing both qualitative and quantitative results.

CONCLUSIONS

In summary, a characterization method for representing transient AMRs like the one proposed in the Industry Council White Paper on tAMR needs to be considered and evaluated. The proposed method defines a safe operating area (SOA) within the derated limits of the failure threshold due to degradation mechanisms including thermal degradation. If the customer is knowledgeable and aware of the methodologies and is willing to work with the supplier in ensuring that reliability is predicted and designed into the system, it will potentially prevent field failures of semiconductor components due to electrical overstress.

As a final note, there is much to be investigated on this complicated subject of tAMR. The Industry Council on ESD Target Levels plans to publish a new extension of White Paper 4 on the subject soon.

REFERENCE

1. Industry Council White Paper 4, JEP174. https://www.jedec.org/document_search?search_api_views_fulltext=jep174

ANSI Z535.1 – SAFETY COLORS IN FOCUS

By Erin Earley

In our "On Your Mark" columns, we often discuss the importance of American National Standards Institute (ANSI) Z535. This family of standards is critical for manufacturers and workplaces across the U.S. in their focus on accident prevention and risk reduction. That's because they form a guide for the design, application, and use of signs, colors, and symbols intended to identify and warn against hazards and for other accident prevention purposes. This month's column explores one of these standards in depth: ANSI Z535.1 – Safety Colors.

Erin Earley, head of communications at Clarion Safety Systems, shares her company's passion for safer products and workplaces. She's written extensively about best practices for product safety labels and facility safety signs. Clarion is a member of the ANSI Z535 Committee for Safety Signs and Colors, the U.S. ANSI TAG to ISO/TC 145, and the U.S. ANSI TAG to ISO 45001. Erin can be reached at eearley@clarionsafety.com.

WHY COLORS USED IN SAFETY SYMBOLS AND LABELS MATTER

Color is often used in warnings and instructions to supplement a word message or safety symbol. The idea is that the use of these so-called "safety colors" can help to increase a worker's recognition of the hazard and increase the necessary reaction time to hazardous situations or emergencies. When color is used in a standardized way, or in a color-coding system, it can help to create a unified look for safety symbols or labels used to warn about hazards on equipment or in a workplace.

"Effectively communicating hazards is vital for safety. The use of color can help with comprehension and understanding of safety messages, but it has to be very specifically defined," says Angela Lambert, head of standards compliance at Clarion Safety Systems, with a focus on ANSI and ISO, and the chair of the ANSI Z535.1 subcommittee that works to keep the standard up to date. "The orange used in a warning label's signal word panel has to look like orange. It can't look like 'yellowish orange' or 'reddish orange'. It's important to avoid, at a glance, having that color be confused with yellow (which is used in signal word panels for caution situations) or red (which is used in a signal word panel for danger situations)."

WHAT IS ANSI Z535.1?

ANSI Z535.1 – Safety Colors establishes safety color codes intended to alert and inform people to take precautionary actions in the presence of hazards.

At left, signal word panels and their color-coding, per ANSI Z535.4. At right, examples of color-coding for the three types of symbols used in product safety labels.

This color coding is used across safety labels, signs, and tags and for the identification and location of fire equipment, first aid equipment, obstacles, and other hazards.

Using ANSI Z535.1 color codes helps to create a unified look for hazards in workplaces and on equipment, which can help increase a worker's recognition and increase the reaction time in an urgent situation. The standard defines, in scientific terms using charts and diagrams, the technical definitions, color standards, and color tolerances for these colors: safety red, safety orange, safety yellow, safety green, safety blue, safety purple, safety black, and safety white.

Per the standard, its intention is to provide, "a system for specifying safety colors, in terms of Munsell notations, CIE colorimetric data, defined chromaticity regions, and color formulas for each ANSI and ISO safety color used on safety signs, labels, and tags."

As outlined in the standard itself, its purpose is to:

- Implement a uniform system for specifying safety colors
- Include safety color formulas for a variety of applications and media for specifying ANSI and ISO Safety Colors (in Annex C)
- Harmonize with safety colors specified in the Code of Federal Regulations
- Harmonize with ISO 3864-4, Graphical symbols—Safety colours and safety signs

THE STANDARDS ORIGIN – AND LATEST UPDATES

ANSI Z535.1 is the oldest of the family of ANSI Z535 standards. It originated as the American War Standard in 1945, which contained a "Safety Color Code." It was developed at the request of the War Department and approved by the American Standards Association (ANSI's original name) – and has evolved since then.

ANSI Z535 is reviewed and updated on a periodic basis, and 2022 and 2023 are revision cycle years. In its most recent update, ANSI Z535.1 was republished in 2022, revising the previous version which was published in 2017. The 2022 edition – the tenth revision of the standard since its origin – incorporated minor updates to how it relates to and can be combined with other applicable standards and regulations.

USING COLOR STANDARDS AND BEST PRACTICES IN YOUR SYMBOLS, LABELS, AND SIGNS

When it comes to using standardized and best practice colors in your safety symbols, labels, or signs, it is key to understand and use the specifications outlined in ANSI Z535.1. "ANSI Z535.1 safety colors are tightly defined and should be adhered to for proper color discrimination or color coding," Lambert says.

For how to use or apply color, ANSI Z535.1 only defines the colors themselves, not their uses. One of the major revisions of the ANSI Z535.1 Safety Color Code in 2002 was to delete information concerning the application of the safety colors. Per the standard, "*The intention of making this change was to maintain Z535.1 as the standard that defines the safety colors in terms of their color tolerances. The application of the colors (i.e., how they are to be used) properly belongs to the other standards in the ANSI Z535 series as well as to other standards that include uses for safety colors.*"

As an example, for information on how to apply color to your labels and signs, you can turn to ANSI Z535.4's section 7 on safety signs and label colors. It states:

7.1 Standard colors: Safety colors shall conform to ANSI Z535.1.

7.2 Signal word panels

> *7.2.1 DANGER: The word DANGER shall be in safety white letters on a safety red background.*
>
> *7.2.2 WARNING: The word WARNING shall be in safety black letters on a safety orange background.*
>
> *7.2.3 CAUTION: The word CAUTION shall be in safety black letters on a safety yellow background.*
>
> *7.2.4 NOTICE: The word NOTICE shall be in italicized safety white letters on a safety blue background.*
>
> *7.2.5 SAFETY INSTRUCTIONS or similar words: The signal words used for a SAFETY INSTRUCTIONS sign or panel shall be in safety white letters on a safety green background.*

As another example, for information on how to apply color to the symbols used in safety labels, you can turn to ISO 3864-2 as well as ISO 3864-1. In its section 4.3 on "Use of Colour," ISO 3864-2 states:

"When a geometric shape is used around a graphical symbol, the shape's corresponding safety colour shall identify the type of safety information to be conveyed by the graphical symbol (e.g. warning, prohibition or mandatory action, see ISO 3864-1)."

Banana Skins

429 Interference with critical auto systems

One car manufacturer found that the craze for CB radio caused more than a jamming of the airwaves. They found that if a CB was operated in close proximity to their car, the central locking engaged, locking the passengers within the vehicle! On a slightly more serious note, another prestige car manufacturer found that whenever the vehicle passed by an operating ambulance or fire station, the air bags activated.

(Extract from "Critical Nature of EMC," Schaffner, Components in Electronics, *May 2000, page 22.)*

430 Mobile threat to drivers

Mobile phone makers and car manufacturers are investigating claims that handsets can cause car safety airbags to inflate and interfere with automatic braking systems. Tests carried out by Volvo in Sweden found that phones operating independently of car electrics can trigger airbags and interfere momentarily with control systems.

(Extracts from: "Mobile Threat to Drivers," Computer Weekly, *August 12, 1993, page 1.)*

431 Interference examples from 1996

- A semi-submersible oil exploration platform moving off-station when its global positioning by satellite system was disrupted by the signal from a portable radio. This was due to poor shielding on an interconnection cable.
- Police cars' central locking systems operating during use of their mobile radios.
- Vehicle anti-lock braking devices operating when a radio transmitter beaming across a highway five miles away, was used.
- A fatality when electromagnetic interference (EMI) caused a computer-controlled crane to drop its load.
- Two fatalities when robots went out of control in a factory.
- Failure of a portable gas detector, monitoring toxic gases while personnel repaired a sewer, when a hand-portable radio was used near it.

- Proximity devices operating due to EMI.
- A train operated abnormally when its rear locomotive developed a computer fault which caused it to be affected by radio emissions as it passed an airport (18th September 1995, 06:45, Birmingham New Street to London Euston).
- A ladle making an incorrect stroke and burning a die-casting machine operator, possibly caused by EMI.
- A radio controlled crane going out of control, possibly due to EMI.
- An electron beam welding machine interfering with radio transmissions.
- A computer-aided drawing system malfunctioning because of electric trains three miles away.
- A hydraulic pump in a nearby building causing errors in a tensile testing machine.
- An expensive process shutting down due to the use of an X-ray techniques in a nearby building site to monitor the quality of welded pipes.
- Nearby fluorescent luminaires affecting the operation of radio receiving equipment.
- A PC network regularly ‘crashed’ at dusk, found to be due to the switching on of nearby fluorescent street lighting.
- ‘And then there was the North Sea oil platform whose IT systems crashed on random occasions throughout the day for no apparent reason. The problem there was identified as visiting helicopters, the rotor blades of which were acting as giant Van Der Graff generators, accumulating enormous static charges that were discharged on landing.’[11]

(Extracts from “Coping with the EMC Regulations,” P. Ridley, IEEE Engineering Management Journal, *April 1996, page 101. Some of these incidents have also been reported by others in other Banana Skins.)*

432

Pacemakers unaffected by stun guns

According to a study carried out by the Cleveland Clinic and published in Eurospace by the European Society of Cardiology®, a standard electrical discharge from a TASER® X26 electronic control device or stun gun, does not affect the integrity of implantable pacemakers and defibrillators and did not trigger an implanted cardioverter defibrillator (ICD) shock in devices programmed to the standard non-committed shock delivery mode.

The impact of electromagnetic interference on cardiac devices has been a long-standing concern and, in some instances, has been known to cause damage to internal circuitry, over-sensing, under-sensing, failure to pace, failure to capture, triggering of elective placement indicators, and inappropriate defibrillation shocks.

(*Extracts from: “Study:* Pacemakers Unaffected by Energy from Stun Guns,” *EMC News, Interference Technology, May 2007.)*

The regular “Banana Skins” column was published in the EMC Journal, starting in January 1998. Alan E. Hutley, a prominent member of the electronics community, distinguished publisher of the EMC Journal, founder of the EMCIA EMC Industry Association and the EMCUK Exhibition & Conference, has graciously given his permission for In Compliance to republish this reader-favorite column. The Banana Skin columns were compiled by Keith Armstrong, of Cherry Clough Consultants Ltd, from items he found in various publications, and anecdotes and links sent in by the many fans of the column. All of the EMC Journal columns are available at: https://www.emcstandards.co.uk/emi-stories, indexed both by application and type of EM disturbance, and new ones have recently begun being added. Keith has also given his permission for these stories to be shared through In Compliance as a service to the worldwide EMC community. We are proud to carry on the tradition of sharing Banana Skins for the purpose of promoting education for EMI/EMC engineers.

2023 IEEE International Symposium on Electromagnetic Compatibility, Signal Integrity and Power Integrity

Hosted by the IEEE Electromagnetic Compatibility Society, the world's largest organization dedicated to the development and distribution of information, tools and techniques for reducing electromagnetic interference

The IEEE EMC Society will host five full days of EMC and Signal and Power Integrity education and networking opportunities for engineers of all levels and specialties. This year join colleagues and industry experts in Grand Rapids, Michigan.

EMC+SIPI Symposium offers a comprehensive selection of electromagnetic compatibility, signal and power integrity, standards testing and compliance, and education programs – from engineering to consultative business management and everything in between. Engineers will learn to increase efficiencies and productivity, enhance performance, and gain insight needed to solve daily and future strategic challenges.

In addition to the robust technical program, there are a variety of networking events to choose from as well as a quality exhibit hall featuring industry providers showcasing current and innovative products and services.

Monday, July 31

TIME	SESSION NAME	FORMAT
8:00 am - 12:30 pm	Introduction to EMI Modeling Techniques	Tutorial
8:00 am - 12:30 pm	Machine Learning and AI for EMC and SIPI	Workshop
8:00 am - 12:30 pm	Automotive EMC Standards Update	Tutorial
8:00 am - 12:30 pm	American National Standards Committee (ANSC) C63 - EMC	Tutorial
8:00 am - 12:30 pm	Basic EMC Measurements	Tutorial
8:00 am - 6:00 pm	Fundamentals of EMC	Tutorial
1:30 pm - 6:00 pm	EMC Testing Basics	Tutorial
1:30 pm - 6:00 pm	Half-bridge MOSFET Switching and Its Impact on EMC	Tutorial
1:30 pm - 6:00 pm	Automotive EMC, ESD, and SI Design Considerations and Test Methodologies	Tutorial
1:30 pm - 6:00 pm	Smart Grid and EMC Issues	Tutorial
1:30 pm - 6:00 pm	Shielding: Emerging Challenges and Standards	Tutorial

Tuesday, August 1

TIME	SESSION NAME	FORMAT
8:00 am - 5:30 pm	Global University	
10:30 am - 12:00 pm	EMC Assessment and EMI Modelling for Electrical and Electronic Devices in the Low-Frequency Range	Special Session
10:30 am - 12:00 pm	EMI Issues and Solutions of Modern Power Electronics Systems with Wide Bandgap Semiconductor Devices	Ask the Experts
10:30 am - 6:00 pm	Technical Papers	
1:30 pm - 3:00 pm	EMC Challenges of Automotive Electrification	Ask the Experts
1:30 pm - 4:30 pm	Stochastic Simulation for EMC and Signal Integrity	Special Session
1:30 pm - 6:00 pm	Engineer Soft Skills	Tutorial
1:30 pm - 6:00 pm	Special Short Cource with John Golding	SIPI Short Course

Wednesday, August 2

TIME	SESSION NAME	FORMAT
8:00 am - 5:30 pm	Global University	
8:00 am - 6:00 pm	Technical Papers	
8:00 am - 12:30 pm	Lessons Learned from NASA EMC: Looking Back and Forward	Tutorial
8:00 am - 12:30 pm	Cutting Through the Copper Tape: Getting to Root Cause When Troubleshooting	Tutorial
10:00 am - 11:30 am	Signal Integrity Challenges of SerDes Interfaces	Ask the Experts
1:30 pm - 6:00 pm	Recent Advancements in HPEM, HEMP, and IEMI Protection	Tutorial
2:00 pm - 3:30 pm	Challeges in Medical EMC	Ask the Experts

Thursday, August 3

TIME	SESSION NAME	FORMAT
8:00 am - 12:30 pm	Global University	
8:00 am - 6:00 pm	Technical Papers	
8:00 am - 12:30 pm	Getting to the Root of it: Tools and Techniques to Enhance Root Cause Analysis	Tutorial
1:30 pm - 6:00 pm	Lessons Learned Creating Reliable Computational Models for SI. PI, and EMC Applications	Tutorial
2:00 pm - 5:00 pm	Advanced EMC Design Bases on Near-Field Modeling and Metasurface	Special Session

Friday, August 4		
TIME	**SESSION NAME**	**FORMAT**
8:00 am - 12:30 pm	SI and PI Simulation and Measurement Challenges for Electrical Packages	Workshop
8:00 am - 12:30 pm	Military EMC	Tutorial
8:00 am - 12:30 pm	Reverberation Chambers: RC You There!	Workshop
8:00 am - 12:30 pm	Cable/Connector Assembly Shielding Effectiveness Characterization from DC to 40GHz: The New Standard P2855	Workshop
8:00 am - 6:00 pm	EMI Can Cause Functional Safety (and Other) Risks that Can't be Covered by EMC Testing Alone	Workshop
1:30 pm - 6:00 pm	Signal Integrity and ESD - Simulations for ESD Design	Tutorial
1:30 pm - 6:00 pm	International Standards and Regulations	Workshop
1:30 pm - 6:00 pm	Product Safety Compliance and Global Market Access	Tutorial
1:30 pm - 6:00 pm	Recent Advancements in Measurement Uncertainty	Workshop

WORKSHOP JULY 28-29, 2023

Emission Meaurements of ANSI C63.4 and Time Domain Applications (ANSI C63.25 Series)

Location: Grand Valley State University/E3 Compliance in Grand Rapids, MI

This workshop will share the activity currently underway in the ANSC C63® committee for C63.4 and C63.25 series. Among the many updates, EMC Site Validation requirements are migrating from C63.4 to the C63.25 standards series: ANSC C63 - C63.25.1, C63.25.2, and C63.25.3. This workshop is designed to increase your understanding of the C63.4 standard and the expected changes in the next revision, and what to anticipate in the new C63.25 series on EMC site validation methods.

In the C63.4 workshop, you will learn:

- RF emission measurement procedures
- National and international regulatory implications
- Test facility and instrumentation requirements
- Equipment test arrangements and configurations

In the Time Domain (C63.25) workshop, you will learn:

- Application for site validation
- Application for antenna calibration

Support material provided

- A complete lecture flash drive
- FCC handouts and references

Expert Instructors

The workshop features industry experts and active technical contributors to ANSC C63, including Andy Griffin (Cisco), C63.4 Working Group Chair, and Zhong Chen (ETS-Lindgren), Chair of Subcommittee 1 (SC1), Techniques and Development. Standards C63.4 and C63.25 are developed and maintained by SC1.

Friday, July 28

8:30 am
Registration and Continental Breakfast

9:00 am to 5:00 pm
Workshop Lectures

Saturday, July 29

8:30 am
Continental Breakfast

9:00 am to 12:00 pm
Workshop Lectures and Live Demonstrations

Visit https://www.c63.org for more information.

Exhibitors

https://emc2023.org

***In Compliance Magazine* thanks our advertisers for their support of our publication. Please visit their booths while at the show.**

Exhibit Hall Hours

Tuesday, August 1

Grand Opening
9:20 am

Exhibit Hall Open
9:30 am – 4:00 pm

Welcom Reception
6:00 pm – 8:00

Wednesday, August 2

Exhibit Hall Open
10:00 am – 5:00 pm

Thursday, August 3

Exhibit Hall Open
10:00 am – 1:00 pm

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Booth 500

AR

See AR at the IEEE EMC 2023 Symposium, Booth #500 in Grand Rapids, MI

Visit our booth and see our new 250S6G18, a fully solid state, air-cooled, RF Power Amplifier delivering 250 Watts from 6 to 18 GHz. This is your TWT replacement for testing from 6 to 18 GHz for field levels of 200 V/m and higher.

While you're in the booth, ask to see demonstrations of our newest release of emcware, 7. Fully included in the purchased product, emcware 7 gives you the capability to perform NSA and sVSWR testing on your OATS or semi-anechoic chamber for site validation for radiated emissions testing.

We will be showcasing our wide selection of RF power amplifiers, Conducted Immunity Systems, emcware, field probes, and accessories from 10 kHz to over 40 GHz.

SunAR RF Motion will also highlight products such as their EMI test antennas and antenna positioning equipment.

Our capabilities in the RF Power space have been well known for over 50 years, and we aren't stopping or resting, as we continue to push past the boundaries of power limits and frequency limits.

Also, don't forget to stop by the booth and enter to win our yearly prize giveaway!

Booth 301

ETS-Lindgren

ETS-Lindgren designs, manufactures, installs, and services EMC/EMI, RF/Microwave, MIMO/OTA, and Acoustic test and measurement systems and components. Our patented technology has resulted in many milestones: the world's first CTIA Authorized Test Lab and the first oversize RF shielded sliding door for full vehicle test chambers. Our comprehensive EMP/IEMI solutions is the first full line of products to be independently tested and certified. Our services include field services, calibration and repair, engineering and consulting, product testing, and our ETS-U Education service. ETS-Lindgren is committed to the management of test and measurement systems through every phase of the lifecycles to ensure customers realize the maximum benefits.

Stop by IEEE EMC+SIPI Booth #301 to speak with one of our test and measurement experts, see our variety of product solutions, or experience on of our in-person demos. With decades of experience in compliance testing and measurement, ETS-Lindgren is Committed to a Smarter, More Connected Future.

Not attending the show? Contact your local ETS-Lindgren representative or visit https://www.ets-lindgren.com.

ETS·LINDGREN®
An ESCO Technologies Company

Booth 408

HV TECHNOLOGIES, Inc.

HV TECHNOLOGIES, Inc. provides EMC test solutions by world renowned, independent manufacturers focused solely on producing the highest quality EMC test instruments. Come visit the HVT booth to check out the newest products we have to offer and discuss your test requirements with our staff. We will be displaying the following test instruments:

- **IMU3000** – Multi-function generator for Surge, EFT, Power Fail, Ringwave and more.
- **MIL3000** – Flexible solution for MIL-STD-461 CS06, CS106, CS115 & CS116 transients. The most advanced military conducted susceptibility test generator available.
- **ESD3000** – Handheld, AA rechargeable battery operated Electrostatic Discharge simulator. Precise, reliable waveforms.
- **Pulse Measurement** – Free space D-dot electric field measurement chain.
- **EMC Positioners** – Ultra accurate and reliable boresight antenna mast, field probe positioner and compact turntable.
- **MT400** – 400W Class A solid state power amplifier.
- **EMI Hardened Camera** – Full HD, 1080p EMI hardened camera system with ultra-low emissions.
- **Fiber Optic Converters** – EMI hardened fiber optic data converters for CAN, USB, Automotive Ethernet and others.

HVT – Since 1998, the intelligent provider of top quality, high performance EMC test solutions.

HV TECHNOLOGIES, Inc.
HVT
25 Years Strong
1998-2023

Booth 208

KITAGAWA INDUSTRIES (KGS)

In 1955, KITAGAWA INDUSTRIES (KGS) opened their doors selling injection molded plastics (such as spacers, cable ties, and clamps) and rubber products. In the 1980's, KGS expanded their line to include EMC mitigation products, utilizing their expertise in injection molding for clamp-type ferrite cores.

KGS continued their global reach to further expand into thermal interface materials and vibration damping gels and shock absorbing rubber sheets.

KGS persists to evolve and develop new products to meet strict requirements of the automotive industry, especially those for the EV market.

KGS product line include solutions for mechanical, electrical (EMC), electro-mechanical purposes including (but not limited to) EMI absorbers, massive assortments of ferrite cores, cable shields, conductive foam, shielding tapes, EMC grounding straps, SMT grounding components, a wide variety of thermal interface materials, vibration dampers, and plastic straps/clamps/spacers.

In 2020, the US-based operations celebrated its 30th year of successful business in Silicon Valley.

KGS
KITAGAWA INDUSTRIES America, Inc.

Booth 513

MVG
Microwave Vision Group

The Microwave Vision Group (MVG) has been meeting the technical demands of the EMC, AMS, and RF communities for over 30 years. MVG will be exhibiting its unique solutions for EMC testing.

Our EMC team will answer you're your questions about the facilities MVG designs, manufactures and delivers:

- EMC Test Chambers
- Shielded Doors
- RF Shielded Rooms
- EMC Antennas
- EMC Absorbers

MVG offers a full array of high-performance anechoic chambers and other products specially designed to meet the increased performance demands of today's EMC testing requirements.

This event will create great networking opportunities, you can find us Booth 513.
Paul Duxbury, Director of Business Development for EMC, will be happy to discuss with you during the event!

MVG
Microwave Vision Group

Booth 509

Ophir RF

Need POWER? With over 25 years of experience, Ophir RF has you covered!

With the most comprehensive arrays of "State of the Art" High-Power RF Systems and Modules, Ophir RF provides the power you need for EMC, Laboratory Test and Measurement, Electronic Warfare, Radar, Communications and Medical applications.

Our core products include RF Amplifiers covering the frequency range 10 kHz to 40 GHz, and 1 watt to 24 kilowatts of power. We are well known in the industry for successfully adapting amplifiers or custom designing solutions to suit each unique project.

Drop by our booth #509 to discuss how we can assist you in your power and testing requirements.

OPHIR RF
THE ART OF WIRELESS

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Booth 700

Raymond EMC

Come see us at Booth 700!

Raymond EMC may be the fastest growing EMC chamber company in North America! Our superior commitment to client care and customer service is setting us apart from the rest. Raymond EMC is changing the concept of what you deserve when you procure a chamber. We strive to facilitate a smooth and easy process while working diligently at exceeding expectations.

Stop by to meet members of our dedicated team to find out more about our efficient and cost-effective approach to chamber projects. Ask us about our many products, services and turn-key solutions, including our service and maintenance programs and have a look at some of the innovative initiatives we are taking.

Raymond EMC is proud of the product customization we can offer. Speak to our team about how we can tailor solutions to meet your exact requirements. Nothing is too small for our attention!

Make sure you stop by our booth for a fun game of Cornhole and the chance to win some prizes! Also don’t forget to check out the demonstration “Multiplying Competency: Remote & Autonomous Chamber Validation” by Raymond’s R&D Lead Nika Amralah and RATLR’s Phill Miller on August 1st 1:00-4:00 pm!

We can’t wait to see you!

RAYMONDEMC

Booth 615

Spira Manufacturing Corporation

Celebrating 45 Years of Inspiration in EMI Shielding!

Find out why top manufacturers choose Spira when they need the best, most reliable EMI/RFI Shielding Gaskets and Honeycomb Filters – exceptional products, on-time delivery, superior customer service, and expert technical support.

Spira’s unique spiral design offers extremely low compression set, long life and high shielding. Gaskets are available both groove or surface mounted, EMI/environmental protection, and meet requirements including ITAR, DFAR and RoHS.

Featuring:

- Spira-Shield. All Spira gaskets utilize this patented spiral design which yields EMI shielding quality up to 165 dB, offering exceptionally long life. Lower cost commercial versions also available.
- EMI & Environmental Connector-Seal Gaskets. Pass your shielding tests the first time. Superior EMI and environmental protection for flange-mounted connectors in front or back mount configurations.
- Shielded Honeycomb Air-Vent and Fan Filters. High and reliable shielding at competitive prices.
- Groundbreaking book on EMI Shielding Theory. Visit our booth & enter to win a free copy!

Join us for our 45th Anniversary celebration!

Visit Spira’s booth to see the latest in EMI shielding inspiration and get expert application support. Spira products are manufactured in the USA, ISO-9001/AS9100 certified.

SPIRA

Booth 325

Würth Elektronik

Würth Elektronik offers sophisticated electronic components for a multitude of applications in all industrial sectors. For us, it’s not the individual component that’s most important – it’s finding the solutions to problems. We’re the reliable partner for our customers. With Würth Elektronik, customers realize electronic visions – we’re on board from start to finish.

The passive division include inductors, ferrites, chokes, LEDs, capacitors, crystals, resistors, sensors, transformers and wireless charging coils. Board-to-Board, Wire-to-Board, Terminal Blocks, and Input/Output connectors are included in the electromechanical division. Online tools have been developed for use by engineering customers to design in magnetics for switchmode power supplies: REDEXPERT, for non-isolated, and isolated, flyback designs.

Visit booth 325 to talk with our technical experts and for immediate assistance, our LIVE chat team is available at https://www.we-online.com 24/7. Discover seamless support and solutions tailored to your needs.

WE

WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

Monday, July 31 6:00 pm - 10:00 pm

Young Professionals Speed Networking
@ Founders Brewing Company

Tuesday, August 1 6:00 pm - 8:00 pm

Welcome Reception @ Exhbit Hall

Sunday, July 30

MEETING NAME	TIME
EMC Society Board of Directors Meeting	9:00 am – 5:00 pm

Monday, July 31

MEETING NAME	TIME
Speaker Breakfast	7:00 am – 9:00 am
Technical Advisory Committee (TAC) Meeting #1	7:00 am – 9:00 am
Standards Advisory & Coordination Committee (SACCom)	8:00 am – 9:45 am
Standards Development and Education Committee (SDECom)	10:30 am – 12:00 pm
Strategic Standards for Education Round Table	1:30 pm – 3:00 pm
SC-1 Smart Grid and EMC Issues Committee Meeting	5:30 pm – 6:30 pm
Young Professionals Speed Networking with EMC	6:00 pm – 10:00 pm

Tuesday,August 1

MEETING NAME	TIME
TC-2 EMC Measurements Committee Meeting	7:00 am – 8:30 am
IEEE EMC Society Education Committee	7:00 am – 9:00 am
Speaker Breakfast	7:00 am – 9:00 am
T-EMC Associate Editor Meeting	8:00 am – 10:00 am
Machinery Sector Version of IEEE 1848 on EM Resilience - Working Group	8:00 am – 9:00 am
IEEE 473 Recommended Practice for Site Surveys	12:00 pm – 1:00 pm
TC-8 Aeronautics and Space EMC Meeting	12:00 pm – 1:00 pm
TC-9 Computational Electromagnetics Committee Meeting	12:00 pm – 1:00 pm
SC-5 Power Electronics EMI/EMC Special Commitee Meeting	12:10 pm – 1:00 pm
Update on P2710 “Recommended Practice for Techniques to Evaluate the Performance of Enclosures and Other Methods for Electromagnetically Shielding Portable Electronic Devices”	2:00 pm – 4:00 pm
Welcome Reception	6:00 pm – 8:00 pm
Young Professionals - After the Welcome Reception Social	8:00 pm – 11:00 pm

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Wednesday, August 2 7:00 pm - 10:00 pm

Evening Gala @ Steelcase Ballroom

Thursday, August 3
12:30 pm - 2:00 pm

Awards Luncheon
@ Steelcase Ballroom

Wednesday, August 2

MEETING NAME	TIME
Speaker Breakfast	7:00 am – 9:00 am
TC-1 EMC Management Committee Meeting	7:30 am – 9:00 am
L-EMCPA	8:00 am – 9:00 am
Shielding Standards Continuity Working Group	8:00 am – 9:00 am
TC-11 Nanotechnology and Advanced Materials Committee Meeting	8:00 am – 9:00 am
TC-12 EMC for Emerging Wireless Technologies Committee Meeting	8:00 am – 9:00 am
IEEE 299 and 299.1 Working Group Meeting	9:00 am – 10:00 am
Managing Functional Safety Risks Caused by EMI - IEEE 1848-2020 Continuity Working Group	9:00 am – 11:00 am
TC-10 Signal and Power Integrity Meeting	12:00 pm – 1:00 pm
Past Presidents Luncheon	12:00 pm – 1:30 pm
TC 5 High Power Electromagnetics (HPEM)	12:00 pm – 1:30 pm
TC-7 Low Frequency EMC Committee Meeting	12:00 pm – 1:30 pm
IEEE Standard Project P2855 Working Group Meeting	12:00 pm – 2:00 pm
TC-4 Electromagnetic Interference Control Committee Meeting	12:00 pm – 2:00 pm
Youth Technical Program	1:00 pm – 3:30 pm
CEM and Validation	2:00 pm – 4:00 pm
Evening Gala	7:00 pm – 10:00 pm

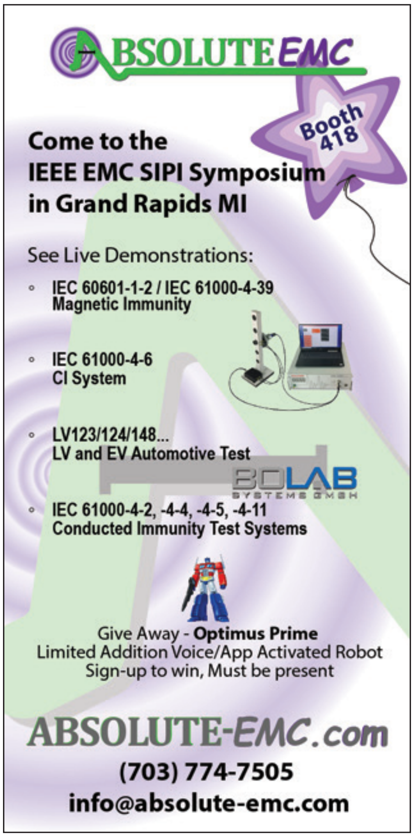
Thursday, August 3

MEETING NAME	TIME
Team EMC Bike Ride	6:50 am start
Speaker Breakfast	7:00 am – 9:00 am
TC-6 Spectrum Engineering Technical Committee Meeting	7:00 am – 8:30 am
P2838 WG Lightning Qualification Standard	7:00 am– 10:00 am
IEEE 1848 MSSV (Machinery) Study Group	8:30 am – 12:00 pm
TC-3 Electromagnetic Environment Committee Meeting	9:00 am – 10:00 am
Awards Luncheon	12:30 pm – 2:00 pm
EMC-S PerCom Meeting	2:00 pm – 3:00 pm
Discussion: Is There a Role for Open Software in EMC + SIPI	2:00 pm – 4:00 pm
Standards Development & Education Committee (SDECom) Meeting	2:00 pm – 4:00 pm
SC-3 Machine Learning and AI in EMC and SIPI	2:00 pm – 4:00 pm
EMC Board of Directors Meeting	6:00 pm – 8:00 pm

Friday, August 4

MEETING NAME	TIME
Speaker Breakfast	7:00 am – 9:00 am
Technical Advisory Committee (TAC) Meeting #2	7:00 am – 9:00 am
IBIS Summit	8:00 am – 12:00 pm

PRODUCT Showcase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Advertiser Index

Upcoming Events

Always check the event website for current information.

July 10-13

Military Standard 810
(MIL-STD-810) Test Training

July 23-28

IEEE International Symposium on Antennas and Propogation and USNC-URSI Radio Science Meeting

July 31-August 4

2023 IEEE International Symposium on Electromagnetic Compatibility, Signal & Power Integrity (EMC+SIPI)

September 4-8

EMC Europe

September 12-14

The Battery Show

September 17-22

European Microwave Week

September 21

2023 Minnesota EMC Event

October 1-6

45th EOS/ESD Symposium and Exhibits

October 4-6

The Battery Show India

October 8-13

45th Annual Meeting and Symposium of the Antenna Measurement Techniques Association (AMTA)

November 7-9

Fundamentals of Random Vibration and Shock Testing Training

December 4-7

Military Standards 810
(MIL-STD-810) Test Training

45th EOS/ESD SYMPOSIUM AND EXHIBITS

October 1-6, 2023
Riverside Convention Center
Riverside, CA

Program and registration details updating at:
https://esda.events/

Our program is packed! While we prepare for the full program, check out the incredible tutorials available this year and the deep discounts for registering early for the symposium!

Tutorials offered:

FC340: ESD Program Development and Assessment – ANSI/ESD S20.20 Seminar - Two days ($1,710)

FC100: ESD Basics for the Program Manager ($950)

FC101: How To's of In-Plant ESD Auditing and Evaluation Measurements ($950)

DD/FC240: System Level ESD/EMI (Principles, Design Troubleshooting, & Demonstrations) - ($585)

DD134: Fundamentals of ESD System Level ($585)

Symposium pricing:

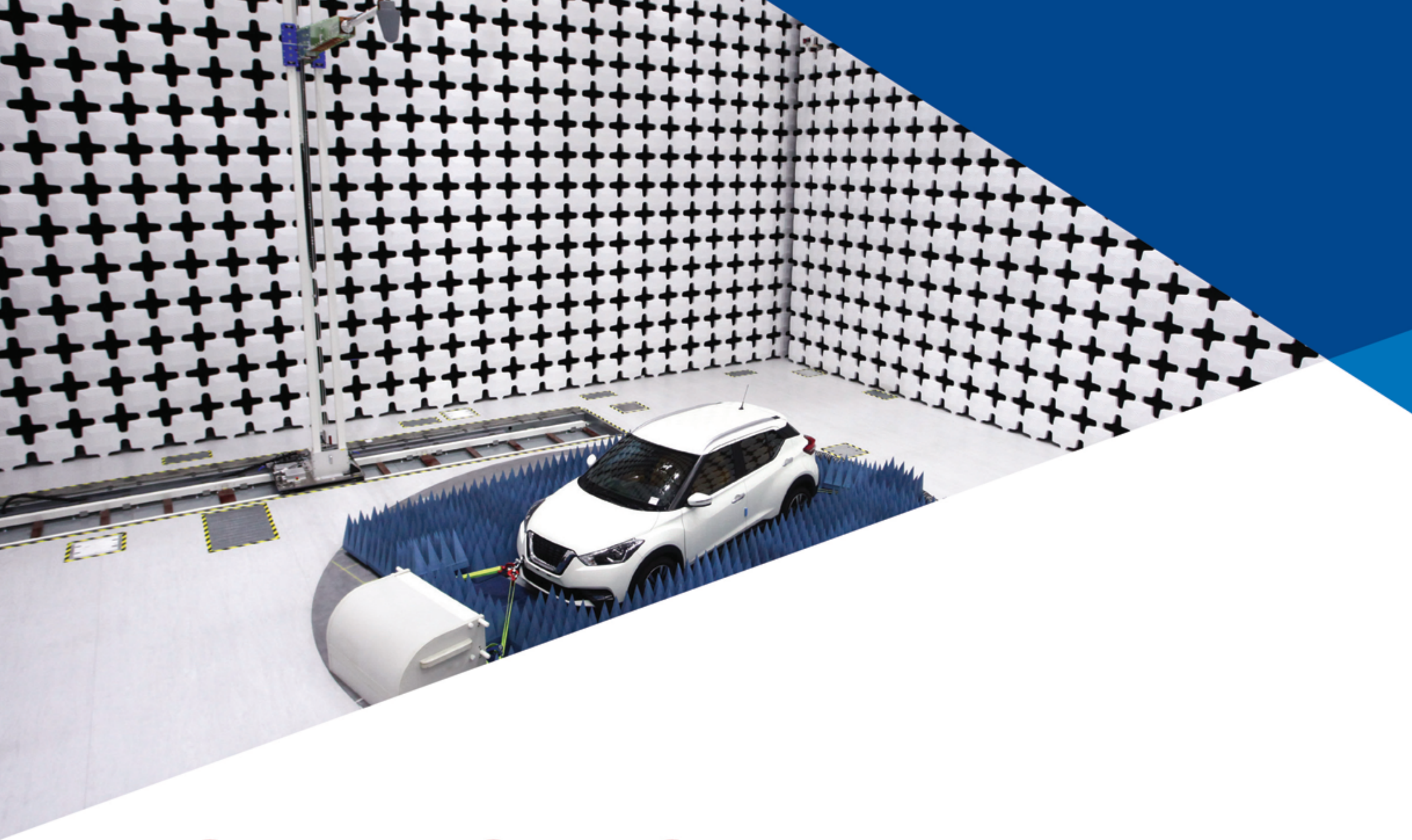
ESDA Member: $600
Changes to $800.00 after Monday, July 24, 2023

ESDA Life Member Fee $525.00
Changes to $725.00 after Monday, July 24, 2023

Non-ESDA Member Fees $700.00
Changes to $800.00 after Monday, July 24, 2023

Membership discounts apply to current members as of May 31, 2023. Memberships processed after this date will not apply.

Register at:
https://cvent.me/G57zBw



FAST TRACK TO THE FUTURE OF EMC COMPLIANCE

The future is here! With the increasingly sophisticated technology in our homes and industry, as evident in modern personal electronics, mobile devices, medical equipment, and automobiles, the potential for electromagnetic interference is significant. In the case of automotive technology, where cars are now essentially computers on wheels with varying degrees of automated control and “infotainment” capabilities, testing of these emerging technologies to ensure safety and reliability has never been more important – or challenging. With decades of experience in compliance testing and measurement, *ETS-Lindgren is Committed to a Smarter, More Connected Future*.

As an international manufacturer of market-leading components and turnkey solutions that measure, shield, and control electromagnetic and acoustic energy, ETS-Lindgren empowers some of the biggest industry names, and latest technological advances, to anticipate and meet global compliance standards. From chambers to test cells, absorbers, positioners, antennas, and software, ETS-Lindgren’s EMC solutions are designed for repeatability, diversity, scale, and precision. More importantly, through our ability to provide turnkey systems, create real-world test scenarios, troubleshoot potential failures, and maximize the chance of passing standards within the allotted time and budget, we help our customers bring life-changing products to market – faster.

Stop by IEEE EMC+SIPI Booth #301 to see one of our demonstrations or speak with one of our test and measurement experts. Not attending the show? Contact your local ETS-Lindgren representative or visit our website at ets-lindgren.com.

Connect with us at:

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