NOVEMBER 2025

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FEATURE ARTICLES

COLUMNS

DEPARTMENTS

FCC Imposes Nearly $1 Million Fine Against Pirate Radio Operator

The U.S. Federal Communications Commission (FCC) has issued a nearly $1 million fine against a New Jersey-based party for unlicensed radio operations.

According to a Forfeiture Order issued by the Commission in mid-September, Masner Beauplan has been ordered to pay a financial penalty of $920,000 for operating an unauthorized radio station in Irvington, NJ, known as "Radio Leve Kanpe." Under the Order, Beauplan is required to pay the penalty within 30 days or face further action by the U.S. Department of Justice.

This case dates back to late 2023, during which time Beauplan engaged in the pirate radio broadcasting activities referenced in the Order for a period of 46 days. The Commission subsequently issued a Notice of Apparent Liability for Forfeiture (NAL) against Beauplan in September 2024. However, Beauplan has failed to file any response to the Commission in connection with the NAL.

FDA Rescinds Rule that Applied Med Device Rules to Lab-Developed Tests

The U.S. Food and Drug Administration (FDA) has now rescinded 2024 rules that required laboratory-developed tests (LTDs) to comply with the agency's pre-marketing authorization requirements applicable to medical devices.

Under the scope of the 2024 rules, the FDA revised its existing pre-market authorization requirements to include LTDs.

The revised rules required that hospitals and healthcare systems that develop their own LDTs for use in-house seek FDA authorization prior to their use.

However, LTDs are generally not commercially distributed and are used exclusively in healthcare settings to provide accurate, high-quality results that give physicians timely and critical information to diagnose and treat patients.

From the outset, the 2024 rule changes faced pushback from many healthcare organizations, including the U.S. American Hospital Association (AHA), that claimed the FDA's action represented an overreach of its authority. That view was ultimately validated in a federal court decision earlier this year that vacated the FDA's 2024 rule revisions.

FCC Launches "Operation Clean Carts" Initiative

The U.S. Federal Communications Commission (FCC) is touting its early success in removing from the market certain equipment deemed to be a "significant national security threat to communications networks."

According to an article posted on Wolters Kluwer's "Vital Law" website, FCC Chair Brendan Carr communicated in a post on X, the social media platform, that a combined effort by the agency and e-commerce sites resulted in the removal of "several million listings for covered equipment."

Further, Carr notes that e-commerce sites have also made "new commitments…to both adopt additional best practices and coordinate with the FCC to monitor and prevent the unlawful online sale of Covered List equipment."

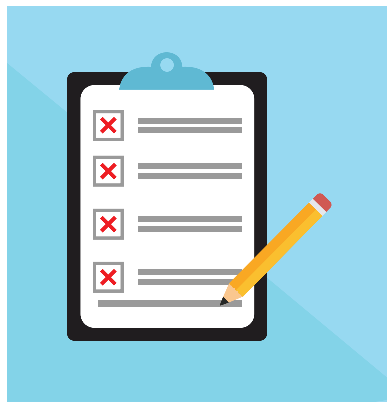
The initiative, named "Operation Clean Carts," comes in the wake of the FCC's efforts to remove recognition of equipment approvals issued by foreign-controlled testing laboratories, including those operating under the supervision of China's State-owned Assets Supervision and Administration Commission (SASAC).

FCC Begins Process to Withdraw Recognition from Test Laboratories

The U.S. Federal Communications Commission (FCC) has initiated proceedings to withdraw recognition from multiple test laboratories.

In seven separate Notices of Intent issued in early September, the FCC notified test laboratories of its intent to withdraw their recognitions as FCC-accredited facilities. The laboratories affected include CVC Testing, CVC Testing Shanghai, Chongqing Academy of Information and Communications, CQC Internet of Vehicles Technical Service Co. Ltd., TTL CAICT, TUV Rheinland-CCIC Ningbo Co. Ltd., and UL-CCIC.

According to the FCC, the basis for its action is that these companies are “owned by, controlled by, or subject to the direction of” entities identified by the U.S. government as untrustworthy under rules adopted in May 2025.



Additionally, four other laboratories—CESI (Guangzhou) Standards, China Academy of Information and Communications Technology (CAICT), Shanghai Institute of Measurement and Testing Technology (SIMT), and CCIC Southern Testing Co., Ltd.—have had their recognitions expire or renewal requests denied since the new rules were adopted.

The FCC’s rules, which took effect in September, prohibit the recognition of test labs and Telecommunications Certification Bodies that are owned by or subject to the control and direction of foreign adversary governments.

FCC Looks to Accelerate Wireless Infrastructure Buildout

The U.S. Federal Communications Commission (FCC) is actively exploring ways to expand the wireless infrastructure in the U.S.

According to a Notice of Proposed Rulemaking (NPRM), the Commission will begin a formal investigation into how to accelerate the buildout of cell phone and other wireless infrastructure components, as well as overcoming state and local restrictions that have limited or blocked the deployment of 5G and 6G technologies in certain areas.

The FCC says that mobile data traffic is expected to grow at a compound annual growth rate (CAGR) of 12% between now and 2030. Also, the use of artificial intelligence (AI) and AI-based technologies is likely to grow dramatically, further increasing the demand for mobile network capacity.

FCC, T-Mobile Reach Settlement on Device Compliance

The Enforcement Bureau of the U.S. Federal Communications Commission (FCC) has reached an agreement with T-Mobile US to resolve claims regarding the company's reported violation of the Commission's Equipment Marketing Rules.

According to a Consent Decree issued by the Commission in mid-September, T-Mobile marketed for sale in 2024 the REVVL 7 PRO 5G smartphone prior to the device receiving the required FCC equipment authorization. In a response to a Letter of Inquiry sent from the Enforcement Bureau in October 2024 regarding the pre-authorization marketing of the device, T-Mobile claimed that compliance with FCC rules was part of its agreement with Wingtech, the manufacturer of the device.

However, the Commission disagreed that the terms of T-Mobile's agreement with Wingtech satisfied the documentation requirements to support its compliance claims.

Under the Consent Decree, T-Mobile has agreed to the facts in the case as presented by the Commission. Further, the company has committed to implementing a comprehensive compliance plan to ensure that devices marketed by T-Mobile in the future are compliant with the FCC's Equipment Marketing Rules and to file annual compliance reports with the FCC for a period of three years.

Finally, T-Mobile has agreed to make a "voluntary contribution" of $7000 to the U.S. Treasury.

Study Shows Extended FDA Clearance Time for Medical Devices

The duration of the regulatory review and clearance process for medical devices in the U.S. remains at stubbornly high levels, according to a recent assessment.

According to an article posted to the website of MD+DI, FDA 510(k) review times average between 140-175 days for the year to date, a timeframe the article says "remain(s) elevated compared to historical baselines." Further, between 70-80% of 510(k) submissions exceed the 90-day target review timeframe previously established by the agency.

The extended review times for medical devices have been significantly impacted by staffing cuts implemented by the FDA earlier this year under the federal government's efficiency initiatives. The article notes that the agency eliminated more than 220 positions in February and made additional staff reductions in April. Staff reductions, as well as other changes at the FDA, have imposed "significant risk to review timelines."

The article notes that one way to potentially shorten review times would be for medical device manufacturers to take greater advantage of third-party review programs. Currently, only 14% of eligible 510(k) submissions utilize the third-party pathway. Choosing this option would help to shift the review burden, especially for those 510(k) applications that lead to additional information requests during a substantive review.

TDK's MU6 Power Supply Simplifies Compliance for Medical and Industrial Equipment

TDK Corporation has expanded its MU series with the MU6 modular power supplies, featuring extremely low acoustic noise (36 dBA) and delivering up to 1500W with 13 fully isolated outputs in a compact 1U (41mm) profile. The BF-ready medical isolation and seven-year warranty target applications in medical, dental, broadcast, audio, and industrial equipment.

Rohde & Schwarz Expands MXO Family with Compact, High-Performance MXO 3 Oscilloscope

Rohde & Schwarz completes its MXO family with the compact MXO 3 Series oscilloscope, offering industry-leading performance with 4.5 million waveforms/second, 12-bit ADC resolution, and up to 1 GHz bandwidth in 4-channel (MXO 34) or 8-channel (MXO 38) configurations. The space-saving design features an 11.6" display, deep memory up to 500 Mpoints, and exceptional signal integrity for embedded hardware, power electronics, and PMIC testing.

Saelig Launches RIGOL MHO900 Series Ultra-Portable Oscilloscopes for Advanced Signal Analysis

Saelig introduces RIGOL MHO900 Series Ultra-Portable High-Resolution Oscilloscopes with 350/500/800 MHz bandwidths (special MHO98 edition at 1GHz), featuring a 12-bit ADC and memory depths up to 500Mpts. The compact (10.5" x 6.4" x 3.0") instruments offer 4 analog channels, optional 16 digital channels, Bluetooth/Wi-Fi connectivity, and an integrated 2-channel AWG option in a single platform for comprehensive signal analysis and debugging.

ESA Honors Rohde & Schwarz for Three Decades of Contributions to European Satellite Navigation

The European Space Agency (ESA) has honored Rohde & Schwarz for its excellence, commitment, and long-standing partnership in European satellite navigation programs over the past three decades. The award, presented at ESA's 30-year celebration of European satellite navigation, recognizes the company's vital contributions to the development and operational success of Galileo and EGNOS systems.

Tektronix Unveils 7 Series DPO Oscilloscope with Breakthrough Signal Fidelity and Speed

Tektronix's new 7 Series DPO oscilloscope offers ultra-high-performance with industry-leading signal fidelity and breakthrough low-noise performance for complex signal analysis. The instrument features 8-25 GHz bandwidth, ultra-low random noise, exceptional ENOB, 10x faster data transfer via 10G SFP+ LAN, and a 15.6" touchscreen interface, designed for demanding applications in embedded systems and high-speed interface testing.

EOS/ESD Association Announces 2026 Leadership at Annual Symposium

EOS/ESD Association, Inc. has announced its 2026 elected officers and board members at its 47th Annual Symposium in Riverside, CA. The leadership includes newly elected Board members from Electro-Tech Systems, Thermo-Fisher Scientific, Teledyne, and Nexperia, plus an Executive Committee with Nate Peachey (Qorvo) as President, Robert Gauthier (IBM) as Senior VP, and Michael Khazhinsky (Silicon Laboratories) as VP.

ETSI Launches Technical Committee to Advance Quantum Communications and Security Standards

ETSI has approved the creation of a new Technical Committee on Quantum Technologies (TC QT) to develop specifications for quantum communications and networks across multiple sectors. The committee, which will hold its initial meeting in December 2025 under Mark Pecen of EigenQ, will focus on six key areas including quantum communications, networking, sensing, satellite communications, QRNGs, and quantum security while supporting European policy objectives and the EuroQCI.

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EMC BENCH NOTES

Pre-Compliance Testing for Conducted Emissions

Equipment Needs (AC Mains)

By Kenneth Wyatt

Pre-compliance testing aims to duplicate the test setup used by your third-party test lab. Fortunately, setting up a conducted emissions test in-house is relatively simple and can be performed on the benchtop (Figure 1).

Ideally, you should procure a copy of the appropriate EMC test standard used, depending on the product type. For example, for military testing, you'll need a copy of MIL-STD-461. For commercial, industrial or medical products, you'd use one of the IEC standards, such as IEC/EN 61326, IEC/EN 60601 or the generic IEC/EN 61000-6-3, which will refer back to CISPR 11 or CISPR 32. For automotive modules, you'll need a copy of CISPR 25. These will describe the equipment and setups and test limits required. I also have more detailed information in my EMC Troubleshooting Trilogy, Volumes 1 and 2 [Reference 1].

The purpose is to measure the noise voltages (as referenced to ground or chassis) for the line or neutral circuits. The return path for the common mode currents is shown, and we'll discuss this in a later article.

First, let's discuss the various noise voltages produced by common line-operated switch-mode power supplies. The conducted emissions test measures noise voltage EMI, that is, the emission voltages measured from line to ground (or chassis) and neutral to ground (or chassis). This is depicted in Figure 1 and is measured using a line impedance stabilization network, or LISN.

A typical conducted emission plot of a line-operated switch-mode power supply is shown in Figure 2. This was measured using an EMZER EMScope EMI receiver with built-in LISN.

EQUIPMENT REQUIRED

Let's start off with the basic equipment you'll need. This will include a good spectrum analyzer or EMI receiver, a line stabilization network (LISN) and a metallic ground plane over the top of a test bench or table for the equipment under test (EUT).

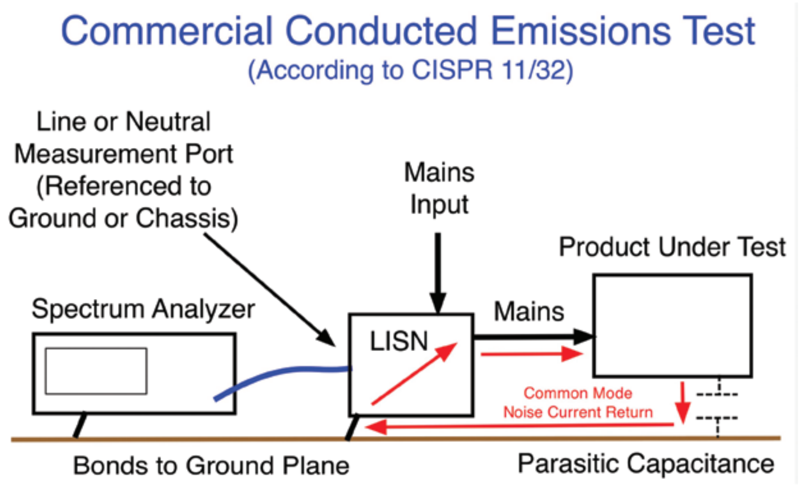

Figure 1: The commercial conducted emission measurement setup as specified by CISPR 11 or 32.

There's one caution regarding the more affordable analyzers. Because they rely on a common superheterodyne topology, they tend to have local oscillator leakage or feed through, which manifests as a large peak at the "zero" frequency and an associated "skirt" adjacent to it.

Ideally, the test should be conducted inside a shielded room in case of a strong nearby AM radio station transmitter or other nearby ambient transmission sources within the measurement sweep range. However, for troubleshooting or pre-compliance purposes, this is not required. Just be aware of any local transmitters that could appear in your plots.

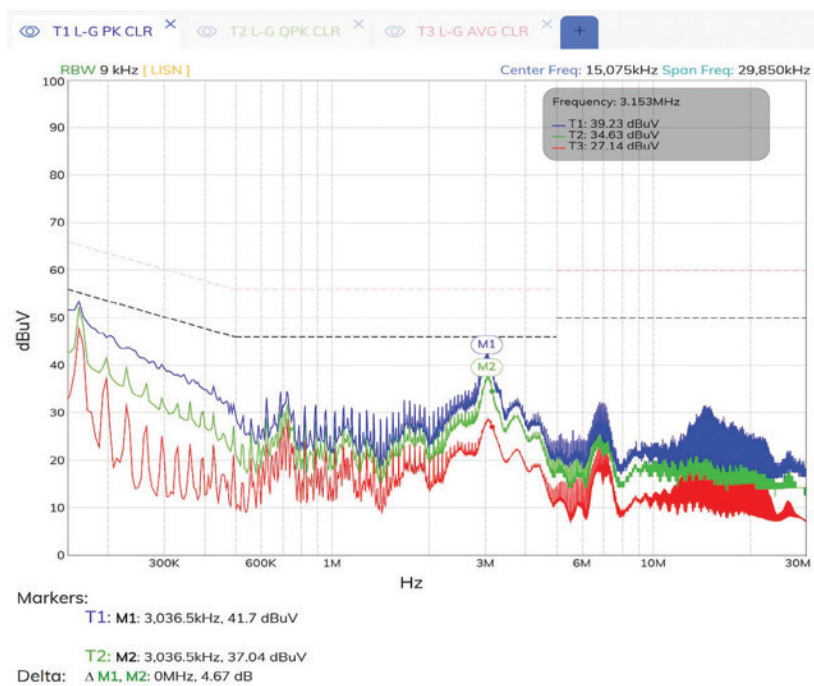

Figure 2: Typical conducted emission test plots for a line-operated switch-mode power supply. In this case, the line to ground noise voltages are compared to the CISPR 32 test limit. Peak (blue), quasi-peak (green), and average (red) plots are shown.

Spectrum Analyzer: Figure 3 shows an example of an affordable bench top spectrum analyzer. You'll want to specify an analyzer with the required test frequency range as specified in the appropriate standards your product requires. Most of the conducted emissions tests will start from 10 kHz (military) or 150 kHz (Commercial) and stop to at least 30 MHz (10 MHz for military).

There's one caution regarding the more affordable analyzers. Because they rely on a common superheterodyne topology, they tend to have local oscillator (LO) leakage or feed through, which manifests as a large peak at the "zero" frequency and an associated "skirt" adjacent to it. This skirt is caused by phase noise from the PLL local oscillator. The width of the peak and skirt depends on the resolution bandwidth (RBW). If you're testing to the military MIL-STD-461 starting at 10 kHz, this LO leakage may be an issue in resolving the lower emissions when using one of the affordable analyzers. Fortunately, a 9 or 10 kHz RBW tends to minimize this issue.

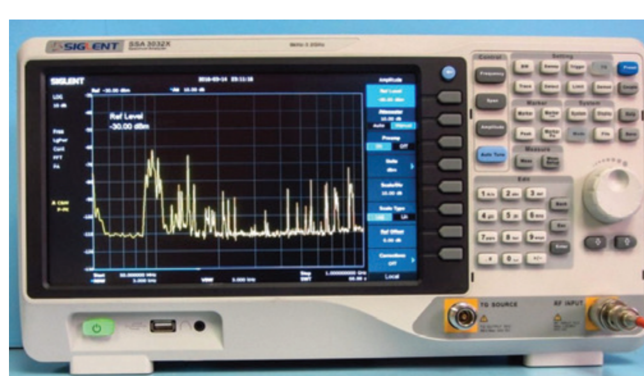

Figure 3: An example of an affordable spectrum analyzer usable for pre-compliance testing of conducted emissions.

For commercial testing, this is not nearly as much an issue, but you'll still see part of the peak (or associated skirt) at the 150 kHz start frequency. The lab-quality spectrum analyzers won't generally have this issue due to better internal shielding. In the case of conducted emissions, you definitely get what you pay for.

The example in Figure 4 shows an expanded plot from 9 kHz to 1 MHz showing the zero-frequency peak with associated phase noise "skirt." A Siglent SSA 3032X analyzer was used for the measurement. The marker at 150 kHz indicates the commercial starting frequency. Notice it's riding on top of significant phase noise, which appears as a rise in the noise floor of the measurement. Typically, the measurement of switch mode power supplies will be relatively large at this low frequency, so this rise in noise floor may not really be an issue.

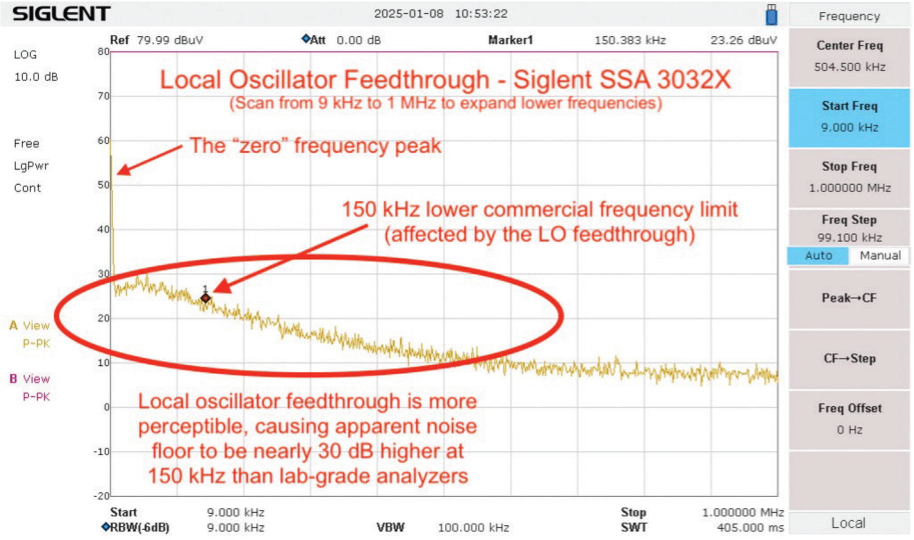

Figure 4: Expanding the lower frequency range for conducted emissions shows the "zero" frequency of the LO as well as the associated skirt that raises the noise floor by 30 dB at the 150 kHz commercial lower frequency limit.

Figure 5 shows the same frequency range but with a much-reduced phase noise. A lab-quality Signal Hound model BB60D was used. The 150 kHz marker is about 30 dB lower than that shown in Figure 4.

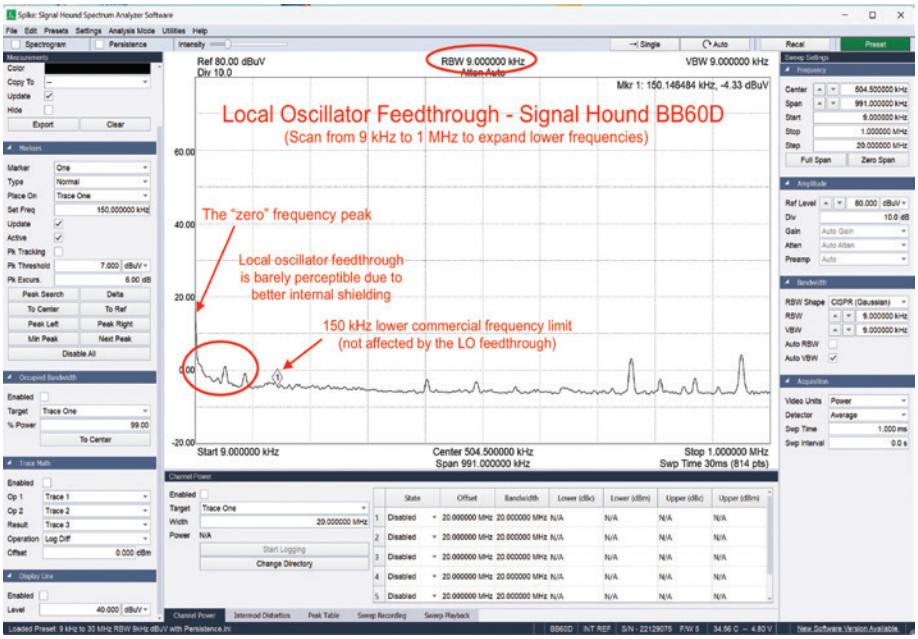

Figure 5: The same measurement setup as Figure 4, but using a lab-quality Signal Hound model BB60D analyzer. While you can still see the zero-frequency peak, the associated skirt is much less perceptible.

Line Impedance Stabilization Network (LISN): Line impedance stabilization networks (LISNs) are used to help match the power line impedance to 50 Ω for the purpose of measuring the conducted emissions emanating from DC or line-operated products. They come in AC 50 µH (90 to 270 VAC) and DC 5 µH (at up to 100 V or more).

The µH reference refers to the inductance used in the LISN. Most are designed to measure from 9 kHz to 30 (or 100) MHz.

Figure 6 shows the LISN (Tekbox TBCL08) I like to use for AC line-operated products. It has a switch for line and neutral measurements and can handle up to 8 amps of line current.

Ground Plane: For accurate measurements, you'll also need a ground plane under the test setup. In the past, I've simply used heavy-duty aluminum foil taped down to the benchtop. The LISN and spectrum analyzer should be bonded to this ground plane to allow the noise currents a return path back to the source.

Currently, I'm using a Tekbox model TBGP "roll up" ground plane over the top of my plastic table top. This comes in a 250 x 140 cm roll, and the 250 cm dimension nearly fits across my 6-foot table. I keep the excess rolled up behind the test setup. See Figure 7.

Isolation Transformer: Some standards require an isolation transformer be connected between mains power and the LISN. It is used to isolate the conducted emission measurement from local power line noise. While this is specified by some EMC standards, like MIL-STD-461, CISPR 11 or 32 does not specify one. I find it is optional for pre-compliance or troubleshooting tests on the benchtop. I'm using a Solar model 7032-3 for any serious military testing.

Transient Protector: A transient protector at the spectrum analyzer input is highly recommended to protect the sensitive RF front end from transients caused by applying or removing main power or when switching from line to neutral measurement. Many of these also include a 10-dB attenuator as extra protection. I like to use the Tekbox TBFL1.

Figure 6: An affordable LISN. It has a switch that measures either line or neutral noise voltages and also includes a built-in 10 dB attenuator and transient protector.

SUMMARY

This summarizes the most basic equipment needed for setting up your own commercial conducted emissions test. Use the References section to find out more about the products mentioned. See my previous article on how to use spectrum analyzers for EMC measurements (Reference 5).

REFERENCES

1. Wyatt, *EMC Troubleshooting Trilogy* (Volumes 1, 2 and 3)
2. Saelig Electronics (U.S. distributor for Tekbox and Siglent products)
3. Siglent Technologies
4. Tekbox Digital Solutions
5. Wyatt, "How to use spectrum analyzers for EMC," *In Compliance Magazine* website, March 7, 2024.

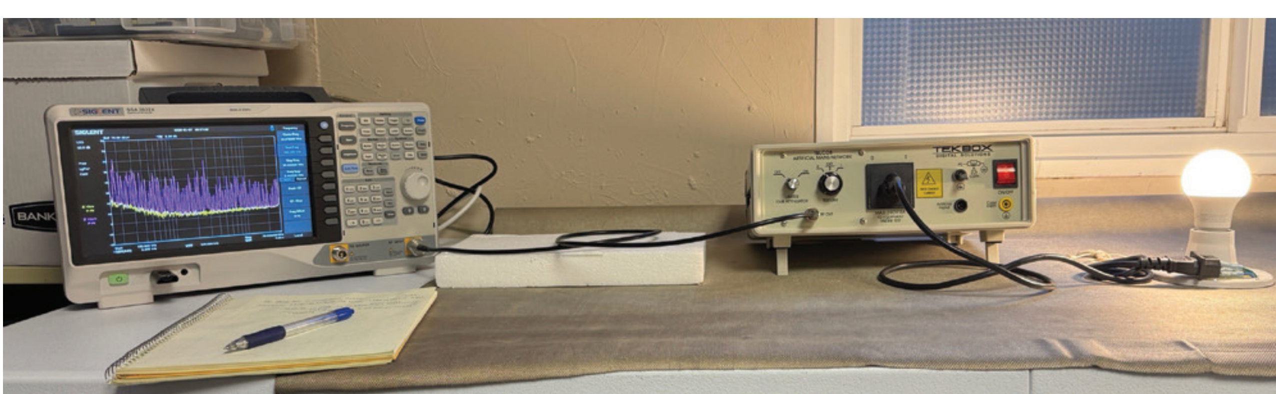

Figure 7: Here is my conducted emissions setup for measuring a common LED light bulb. The equipment is sitting on top of the Tekbox ground plane, and both analyzer and LISN are bonded to it.

PRACTICAL ENGINEERING

Introduction to Measurement Uncertainty in EMC Testing

By Don MacArthur

Measurement uncertainty is a crucial concept in the field of electromagnetic compatibility (EMC) testing. It refers to the doubt that exists regarding the result of a measurement. No measurement is perfect, and even the most precise instruments have some degree of uncertainty. This uncertainty can stem from various factors, including the measuring instrument, the environment, the operator, and the method itself. Understanding and accounting for measurement uncertainty is essential to ensure the test results are reliable and accurate.

In the context of EMC testing, accurate measurements are vital to determine whether electronic devices comply with regulatory standards. If the uncertainty in measurements is too high, it could lead to incorrect conclusions about a device's compliance, potentially resulting in either unnecessary redesigns or non-compliance with regulatory requirements.

SOURCES OF UNCERTAINTY IN RADIATED EMISSIONS TESTS

Several factors contribute to measurement uncertainty in radiated emissions tests:

1. Instrument Accuracy: The precision and calibration of the measuring equipment, including spectrum analyzers, antennas, and preamplifiers, play a significant role in measurement uncertainty. Regular calibration and maintenance are essential to minimize this source of uncertainty.
2. Environmental Conditions: The testing environment, including ambient temperature, humidity, and electromagnetic interference, can impact measurement accuracy. Conducting tests in controlled environments, such as anechoic chambers, helps to mitigate these effects.
3. Operator Proficiency: The skill and experience of the operator can influence the measurement results. Proper training and adherence to standardized procedures are crucial to reduce this source of uncertainty.
4. Test Setup: Variations in test setup, including the positioning of the device under test (DUT), cable routing, and grounding, can introduce uncertainties. Standardizing test setups and following best practices can help minimize these variations.
5. Measurement Methodology: The methods used to measure radiated emissions, including scanning techniques and averaging methods, can also contribute to uncertainty. Using standardized and validated methodologies is critical to ensure consistent results.

Measurement uncertainty is a fundamental aspect of EMC testing that cannot be overlooked.

PRACTICAL EXAMPLES OF MEASUREMENT UNCERTAINTY IMPACT

To illustrate the impact of measurement uncertainty, consider the following real-world examples:

1. Product A: A consumer electronics company is testing a new device for compliance with FCC radiated emissions

limits. Initial tests show that the device is close to the limit but within acceptable margins. However, when accounting for measurement uncertainty, the actual emissions could exceed the limit. This prompts the company to make design changes to ensure compliance, avoiding potential regulatory issues and market delays.

2. Product B: An automotive manufacturer tests an electronic control unit (ECU) for radiated emissions. The initial test results indicate compliance, but the measurement uncertainty is high due to environmental factors and operator variability. To mitigate this, the manufacturer conducts additional tests in a controlled environment and standardizes the test setup. The refined results confirm compliance with a lower uncertainty margin, ensuring the ECU meets stringent automotive standards.
3. Product C: A medical device company evaluates a new diagnostic tool for EMC compliance. The testing lab uses state-of-the-art equipment, but the operator is relatively inexperienced. The high measurement uncertainty results in a false non-compliance verdict. After retraining the operator and recalibrating the equipment, the subsequent tests show that the device meets all regulatory requirements, saving the company from costly redesigns and production delays.

CONCLUSION

Measurement uncertainty is a fundamental aspect of EMC testing that cannot be overlooked. By understanding the sources of uncertainty and implementing strategies to mitigate them, companies can ensure their products comply with regulatory standards, thereby avoiding costly redesigns and market entry delays. Accurate and reliable EMC testing not only ensures regulatory compliance but also enhances product performance and customer satisfaction.

This understanding and diligent management of measurement uncertainty are crucial for any organization designing, manufacturing, and testing electronic devices.

MILITARY AND AEROSPACE EMC

High Intensity Radiated Fields *Part 3*

By Patrick André

In Parts 1 and 2, we explored the need for testing HIRF, the assumptions that were made to determine the field strengths, and the environments they would apply to. There were four HIRF environments created:

- Fixed Wing Aircraft Severe HIRF (not used in FAA HIRF guidance AC 20-158B)
- HIRF Environment I: Aircraft Certification
- HIRF Environment II: Aircraft Normal
- HIRF Environment III Rotorcraft Severe HIRF

These environments are based on the type of aircraft and the potential for high-level exposure. For Fixed Wing Severe, these were the worst-case estimated field strengths that could be exposed to civil aircraft under Visual Flight Rules. With the potential of an exceptionally close approach to a transmitter, these levels exceed certification requirements.

For certification of Part 23 and Part 25 aircraft, HIRF I was established as suitable test levels. HIRF II was a subset of these levels, less severe, which may be encountered during normal flight operation of civil aircraft. The need for very high levels was found for Rotorcraft and established as HIRF III.

The levels shown are for field strengths exposed to the exterior of the aircraft in question.

To determine the proper category for a given system or function, the HIRF certification level (HCL) classification is assigned. FAA AC 20-158B, paragraph 7.3.1, states:

The HCL classification assigned to the system and functions may be different from the design assurance level assigned for equipment redundancy, software, and complex electronic hardware. This is because HIRF environments can cause common cause effects. The term "design assurance level" should not be used to describe the HCL because of the potential differences in assigned classifications for software, complex electronic hardware, and equipment redundancy. The HIRF safety assessment should include all electrical and electronic equipment, components, and electrical interconnections, and should assume that they are potentially affected by HIRF.

The system HIRF certification level is divided into three categories based on the severity of failure conditions:

- System Level A – Catastrophic – is for electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the rotorcraft/airplane.

- System Level B – Hazardous – is for electrical and electronic system that performs a function whose failure would significantly reduce the capability of the rotorcraft/airplane or the ability of the flight crew to respond to an adverse operating condition. This also applies for airplanes approved for instrument flight rules (IFR) operations.
- System Level C – Major – is for electrical and electronic system that performs a function whose failure would reduce the capability of the rotorcraft/airplane or the ability of the flight crew to respond to an adverse operating condition.

Since the levels given in Table 1 are for the outside of the aircraft, it is necessary to know the expected attenuation the aircraft may provide, also known as the transfer function of the aircraft. Generic values are provided in Appendix A.3 of the FAA circular. However, there may be benefits to the airframe manufacturer to know what the transfer function is for a particular aircraft. With improved attenuation, coupled fields internal to the airframe will reduce the fields exposed to avionics. Reduced fields can imply less need for high grade filters and shields, reducing weight and cost.

Frequency		**Fixed Wing Severe**		**HIRF I (Certification HIRF)**		**HIRF II (Normal HIRF)**		**HIRF III (Rotorcraft Severe HIRF)**	
Start	***Stop***	***Peak***	***Average***	***Peak***	***Average***	***Peak***	***Average***	***Peak***	***Average***
10 kHz	100 kHz	50	50	50	50	20	20	150	150
100 kHz	500 kHz	60	60	50	50	20	20	200	200
500 kHz	2 MHz	70	70	50	50	30	30	200	200
2 MHz	30 MHz	200	200	100	100	100	100	200	200
30 MHz	70 MHz	30	30	50	50	10	10	200	200
70 MHz	100 MHz	30	30	50	50	10	10	200	200
100 MHz	200 MHz	90	30	100	100	30	10	200	200
200 MHz	400 MHz	70	70	100	100	10	10	200	200
400 MHz	700 MHz	730	80	700	50	700	40	730	200
700 MHz	1 GHz	1400	240	700	100	700	40	1400	240
1 GHz	2 GHz	3300	160	2000	200	1300	160	5000	250
2 GHz	4 GHz	4500	490	3000	200	3000	120	6000	490
4 GHz	6 GHz	7200	300	3000	200	3000	160	7200	400
6 GHz	8 GHz	1100	170	1000	200	400	170	1100	170
8 GHz	12 GHz	2600	330	3000	300	1230	230	5000	330
12 GHz	18 GHz	2000	330	2000	200	730	190	2000	330
18 GHz	40 GHz	1000	420	600	200	600	150	1000	420

Table 1: HIRF Field Strengths Found in FAA Advisory Circular AC 20-158B

The FAA is aware of missing data in Table 3 of the circular. The above table is accurate.

STANDARDS PRACTICE

Bonding to the Ground Plane

By Karen Burnham

If you usually spend your time testing to one standard, it can be easy to forget about some of the little things that differ from standard to standard. One thing that's easy to overlook is the different ways that equipment under test (EUTs) are required to be bonded (or not bonded) to a ground plane. Let's start by looking at the difference between Figures 2 and 3 of MIL-STD-461 Rev G.

In both cases you have the EUT sitting directly on the surface of the test bench. In the first, the surface is metallic (usually copper), and in the second, it's non-conductive except for a small area where the LISNs sit.

This is a classic example of the Test Like You Fly (TLYF) principle. Whether the EUT is housed in metal or plastic, the assumption is that it will be mounted onto some platform, and the test setup should mimic the material of that platform. This has a huge impact on test results, as you can imagine, so you want to make sure you're testing in the correct environment.

What's mentioned in the text but not shown is the inclusion of more subtle aspects of mounting. It's not uncommon for a metal-housed unit to be installed on a metal chassis but conductively isolated from the chassis by some kind of standoff, either for thermal or mechanical reasons. If that's the case, those standoffs

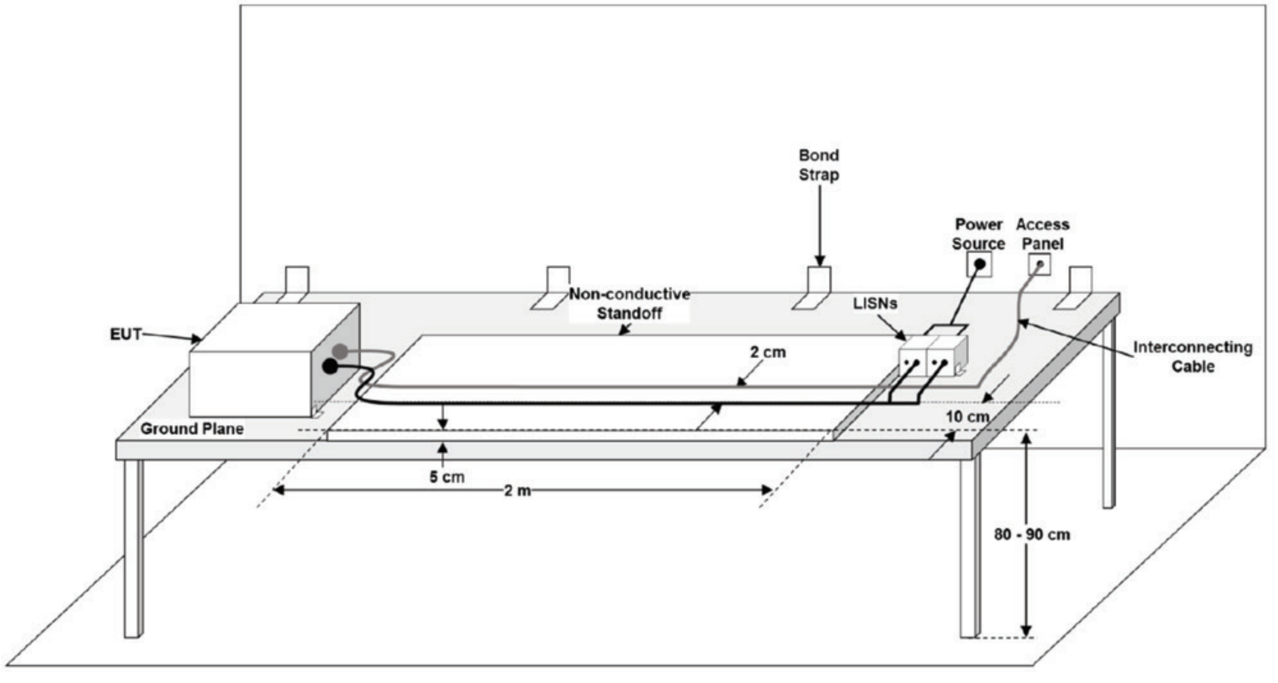

Figure 1: Figure 2 of MIL-STD-461 Rev G "General test setup"

should also be represented in the test setup, along with a bond strap to the chassis/surface if and only if a bond strap will be included in the final installation. (If unsure, or if there's a chance a bond strap may be removed from the installation for cost or weight concerns, I'd recommend testing without one and only adding one if poor test results require it. That way, you'll have solid data to either support or argue against the need for a bond strap in the installation.)

One thing that's easy to overlook is the different ways that equipment under test are required to be bonded (or not bonded) to a ground plane.

You can see the same Test Like You Fly/Drive principles at work in automotive testing. Looking at Figure 9 of CISPR 25, 4th edition, you'll see the EUT is isolated from the conductive test bench surface by 5 cm of dielectric. This represents the common situation where a unit housed in plastic is mounted near, but not directly to, the metal chassis of a vehicle. There's a dotted line connection from the EUT housing to the surface, indicating that a bonding connection should be included if the EUT is housed in metal and if it will be bonded to the chassis in installation. Similar considerations are included for the load simulator used in testing.

Finally, looking at ANSI C63.4 (the test method used for FCC compliance testing), there's no ground plane at all. The most common case for FCC testing is a stand-alone electronics unit that will be used in a residential or office environment, on a non-conductive desk or handheld, with no fixed installation and no assumption of nearby metal planes.

The presence or absence of a 5 cm gap between EUT and table surface or the inclusion/removal of a short bond strap can be easy to gloss over during testing. However, making sure that your test setup accurately captures the salient features of the EUT's final installation will ensure that your testing is the most efficient and effective it can be.

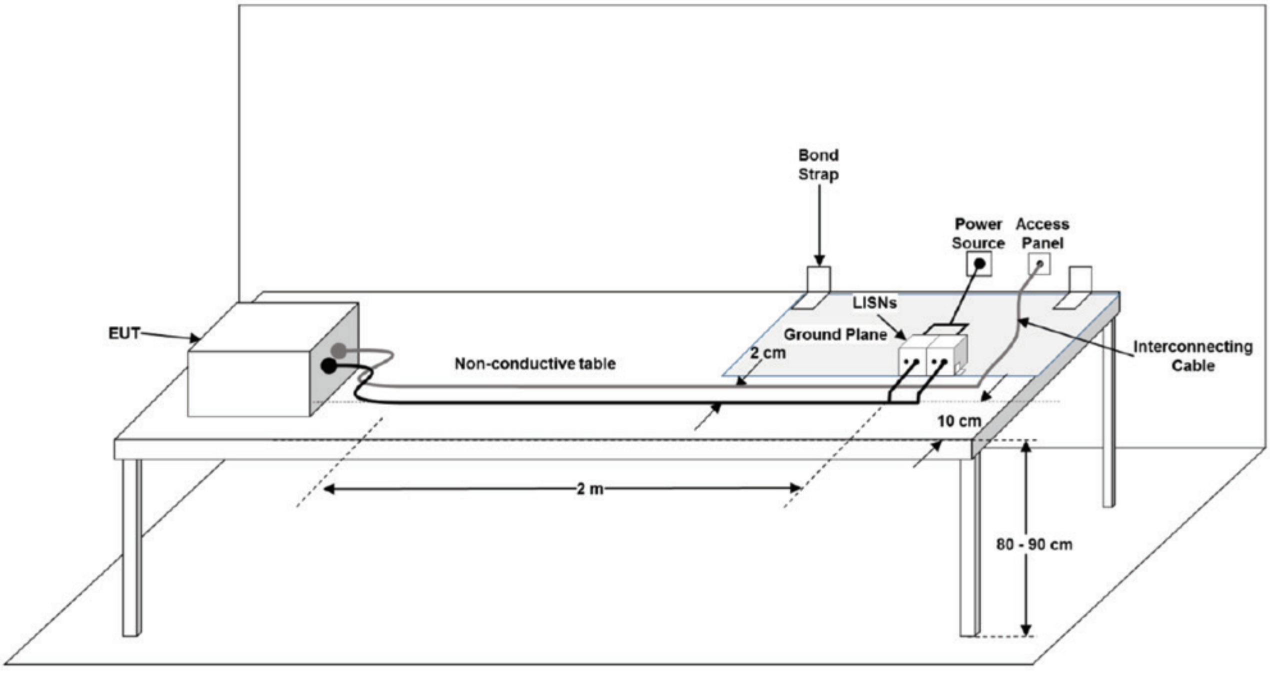

Figure 2: Figure 3 of MIL-STD-461 Rev G "General test setup for non-conductive surface mounted EUT"

RADHAZ-SAFE SEPARATION DISTANCE ASSESSMENT FOR PORTABLE TRANSMITTERS

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By Jeffrey Viel

In today's increasingly complex electromagnetic environments, the need for radiation hazards (RADHAZ) assessments and testing have reached critical importance. RADHAZ refers to the potential danger posed by radio frequency (RF) electromagnetic radiation. This term is commonly used in military, aerospace, and engineering contexts, especially in environments where high-powered RF transmitters are present. These dangers have traditionally been attributed to high-power intentional transmission equipment such as radars and long-range communications. However, low-power RF transmitters operating at close distances can also cause harm to personnel, ignite fuel, and initiate or disable electrically initiated explosive devices (EIDs).

This article will examine each of the three primary hazard areas covered by a RADHAZ assessment and dive into how these assessments are generally conducted. These hazard assessment areas cover:

- HERP (hazards of electromagnetic radiation to personnel)
- HERO (hazards of electromagnetic radiation to ordnance)
- HERF (hazards of electromagnetic radiation to fuel)

RADHAZ: SOME BACKGROUND

To illustrate the threat that RADHAZ presents, it is worth noting a historical incident that occurred during the late 1980s to early 1990s involving FLU-12 life vest incidents aboard Aegis-class ships. There were three documented incidents where FLU-12 life vest EIDs were susceptible to the shipboard radar system (SPY-1), causing the life vests to inflate unintentionally. HERO occurs when RF energy couples to sensitive EIDs, including weapons, rockets, explosives, squibs, flares, igniters, explosive bolts, electric primed cartridges, destructive devices, and jet-assisted take-off bottles. HERO may lead to triggering an unexpected explosion or disable the device, preventing it from performing as intended.

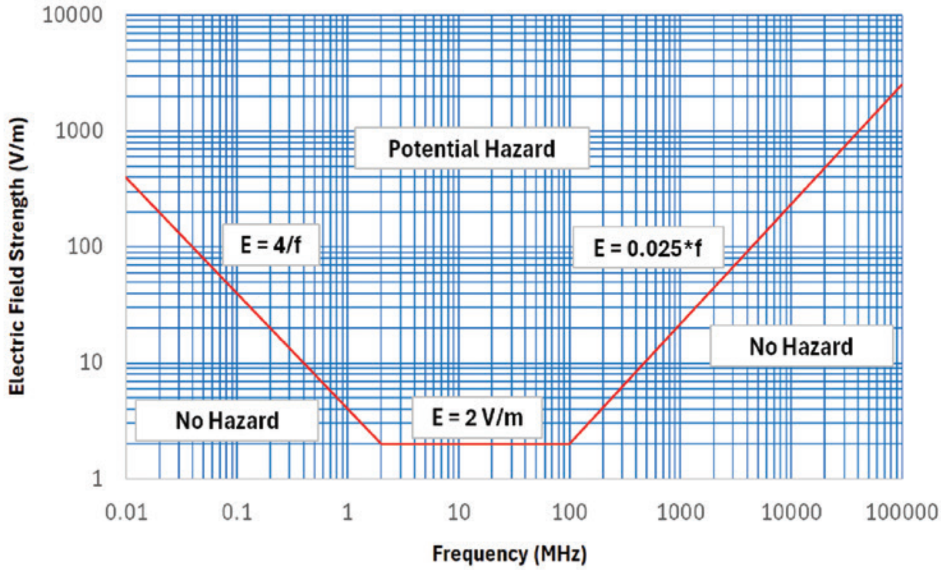
The life vest activations were reported during early operational deployments of these ships, suggesting the incidents likely occurred between 1987 and 1992, a period when HERO testing protocols were still evolving and the electromagnetic environment aboard Aegis ships was being actively characterized. While this event did not result in a catastrophic loss of life, it certainly depicts the threat electromagnetic radiation presents on ordnance devices, as well as the importance of well-executed modernized electromagnetic control plans.

Today, the HERO risk has evolved due to the gradual implementation of extremely powerful communications and radar equipment that radiate high levels of EM energy. This, coupled with the rapid deployment of advanced technologies consisting of EM sensitive, low-power electronics, is increasing HERO concerns to new levels. As a result of these growing risks, each service branch has placed an emphasis on verifying that all electrically initiated ordnance devices provide sufficient protection against their intended electromagnetic environment (EME), and that their performance is quantified through testing and/or analysis.

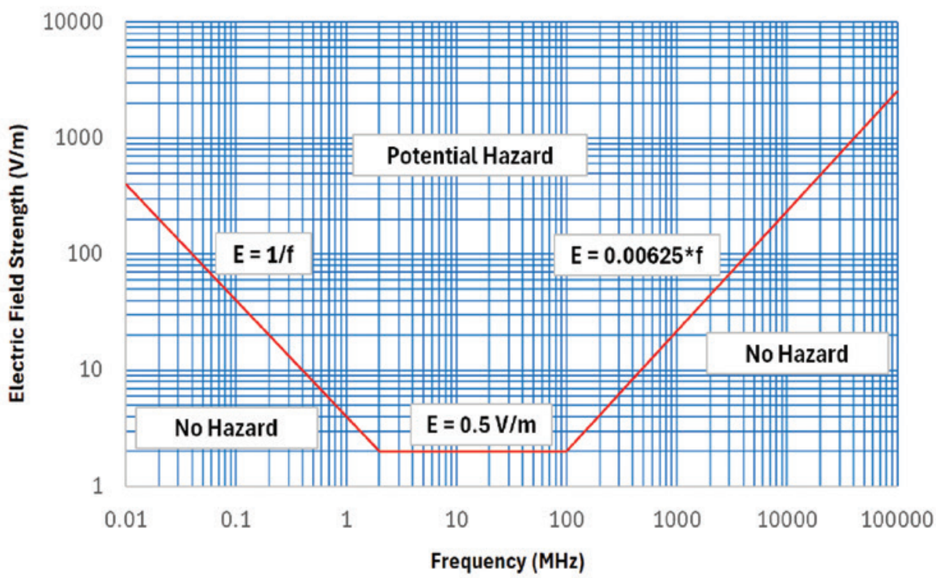
HERO CLASSIFICATIONS

There are four classifications pertinent to HERO, as follows:

- HERO SAFE ORDNANCE
- HERO SUSCEPTIBLE ORDNANCE
- HERO UNSAFE ORDNANCE
- HERO UNRELIABLE ORDNANCE



HERO SUSCEPTIBLE LIMIT



HERO UNSAFE/UNRELIABLE LIMIT

Frequency Range (MHz)	Distance Equations (meters)	Frequency Range (MHz)	Distance Equations (meters)
$0.01 \le f < 2.0$	$D = 1.37\, f \sqrt{P_T G_T}$	$0.01 \le f < 2.0$	$D = 5.5\, f \sqrt{P_T G_T}$
$2.0 \le f < 80.0$	$D = 2.74\, f \sqrt{P_T G_T}$	$2.0 \le f < 80.0$	$D = 18\, f \sqrt{P_T G_T}$
$80.0 \le f < 100{,}000$	$D = 219\, f^{-1} \sqrt{P_T G_T}$	$80.0 \le f < 100{,}000$	$D = 876\, f^{-1} \sqrt{P_T G_T}$

f f = Frequency (MHz)
D = Safe Separation Distance (meters)
P_T = Average Power Output of the transmitter (watts)
G_T = Numerical (Far Field) gain ratio

Figure 1: HERO safe separation distance limits and calculations

HERO classifications are based upon the degree of susceptibility experienced while the ordnance is in each of its stage-to-stockpile (S^4) configurations. In accordance with governing DoD standards such as MIL-STD-464, ordnance that meet this qualification criteria require no RF environment restrictions beyond the general HERO requirements, and are classified as HERO SAFE ORDNANCE. Alternatively, ordnance determined to be susceptible and that require moderate RF environment restrictions are classified as HERO SUSCEPTIBLE or HERO UNSAFE/UNRELIABLE. These may include items that have never been evaluated for HERO, or items that have been classified as HERO SAFE but that can have increased exposure to an RF environment when assembled or disassembled.

While basic HERO requirements for design and performance verification are found in MIL-STD-464 and other military standards, military service branches (Army, Navy, and Air Force) have developed unique approaches to deal with HERO problems over time. These approaches typically reflect other factors, such as how services store, transport, and use ordnance to minimize hazards.

When operational electromagnetic environment (EME) levels exceed susceptibility thresholds, the services can opt to use different risk-reduction measures. For

Despite these differences, there are common fundamentals applied to all HERO programs. Arguably, the most critical aspect is defining the sources contained within the EME for each platform, specifically, understanding the EME where ordnance will be used.

example, the Army or Air Force might stipulate a minimum separation distance between the susceptible ordnance and the offending transmitter, while limited space aboard naval platforms/systems might leave no other option for the Navy than to impose restrictions on the emissions of the offending transmitter.

Nonetheless, the service groups deploy many different methodologies to manage HERO while minimizing the operational restrictions, such as frequency management, reducing the transmitter output power, or limiting the antenna radiation zones.

HERO ASSESSMENT FUNDAMENTALS

Despite these differences, there are common fundamentals applied to all HERO programs. Arguably, the most critical aspect is defining the sources contained within the EME for each platform, specifically, understanding the EME where ordnance will be used. In many cases, the EME is very complex, consisting of a large number of sources over a broad frequency spectrum. RF surveys are routinely performed at all ordnance S^4 areas to keep this data up to date and allow it to be compiled into simple limit curves for use in HERO assessments.

The HERO SUSCEPTIBLE and HERO UNSAFE limit curves shown in Figure 1 (left) were derived from a tri-service effort; where the HERO test data for each of the services was used to develop composite "worst-case" curves that are now harmonized across all U.S. DoD service branches.

These curves represent the maximum allowable electromagnetic environment (MAE) for ordnance and are used to calculate the safe separation distance (SSD) between known transmitters and ordnance once the ordnance item is classified as either HERO SUSCEPTIBLE or HERO UNSAFE/UNRELIABLE. Specific details regarding the transmitter device must be known, including a list of transmit frequencies or transmit frequency bands used, as well as the average transmit power levels at each frequency. Selecting the lowest frequency for a

Traditionally, the founding philosophy of HERO was to ensure that a minimum ten-foot separation distance between all ordnance (including HERO SAFE ORDNANCE) and transmitters were maintained at all times.

given frequency band is permissible. But the gain of the transmitter at each selected transmit frequency is required. The effective isotropic radiated power (EIRP) is needed, but it can be calculated using the following formula:

$$EIRP = P_t - L_c + G_a$$

Where:

P_t = output power (dBm)

L_c = cable loss (dB)

G_a = antenna gain (dBi)

This data is generally gathered from the manufacturer's commercial EMI/EMC compliance test reports or through physical measurements. Additional information, such as transmitter type, modulation scheme, characteristics, antenna pattern plots, typical orientation, use, and modes of operation, is not required but can be useful supporting data when compiling the report.

Typically, HERO power density levels are exceeded by high-power intentional transmitters with high-gain antennas. The maximum power density at a given distance or maximum distance to a given power density can be calculated using these far-field equations. In the far-field region, the power density is calculated within the 3 dB beam width of the transmit antenna using the following formula:

$$P_d = \frac{P_T * G}{4 * \pi * r^2}$$

Where:

P_d = power density $\left(\frac{\text{watts}}{\text{meter}^2}\right)$

P_T = average or peak transmitter output power (watts)

G = numerical antenna gain (unitless)

r = distance from the antenna (meters)

Since most antennas used in these applications are aperture-type and the power density levels are only exceeded at near-field distances (where power distribution is a function of illumination taper), far-field calculations are often found to be excessive. Further guidance can be found in NAVSEA OP 3565 Volume 1 on how to calculate the near-field gain reduction factor.

CALCULATING HERO SAFE SEPARATION DISTANCES

Traditionally, the founding philosophy of HERO was to ensure that a minimum ten-foot separation distance between all ordnance (including HERO SAFE ORDNANCE) and transmitters was maintained at all times. This included large stational high-power systems as well as most portable, mobile, and handheld systems. Exceptions to this ten-foot rule have been made primarily due to the increased use of low-power RF transmitting devices needed at distances closer than ten feet from ordnance.

Examples of these RF devices include wireless laptops, handheld devices, tracking devices, and passive or active radio-frequency identification devices (RFID) using automatic identification technology (AIT) and operating at very low power (i.e., less than 1 watt). In these examples, relaxation of the standard ten-foot SSD distance down to a distance of zero feet between the antenna and ordnance item (excluding physical contact) can be determined using the HERO safe separation distance calculations shown in Figure 1.

HERF ASSESSMENT CONSIDERATIONS

HERF concerns the accidental ignition of fuel vapors by RF-induced arcs during fuel-handling operations. Fuel-handling is defined as the transferring of fuel from one container to another. While the probability of HERF occurring is not common, accidental combustion is still possible.

HERF concerns the accidental ignition of fuel vapors by RF-induced arcs during fuel-handling operations. Fuel-handling is defined as the transferring of fuel from one container to another.

There is not much information available with respect to HERF. However, guidance documents such as TO 31Z-10-4, and NAVSEA OP 3565 Volume 1 specify that areas where RF power densities exceed 5 W/cm^2 (50,000 W/cm^2) are considered to be hazardous areas for refueling operations regardless of the source of RF energy.

The SSD can also be calculated for HERF to establish the distance from a transmitting antenna where the power density will be approximately 5W/cm^2. Much like with HERO SSDs, the actual separation distance between the transmitter and fuel should be established at a greater distance than calculated to ensure that the power density in the fueling area will be less than 5W/cm^2.

The HERF SSD can be calculated using the following formula:

$$D = \sqrt{\frac{PG}{4 * \pi * PD}} = \frac{\sqrt{PG}}{792.7}$$

Where:

PD = desired power density (in W/m^2) = 5 W/cm^2 = 50,000 W/m^2

D = distance (meters)

P = peak power (Watts)

G = antenna gain ratio $\left(10^{\frac{Antenna\ Gain\ (dBi)}{10}}\right)$

An additional equation may be used to calculate the separation distance required to achieve a power density equivalent to that existing 50 feet from an antenna radiating 250 watts (equivalent to 0.009 mW/cm^2 or 0.09 W/m^2).

$$D = \sqrt{\frac{PG}{4 * \pi * PD}} = \frac{\sqrt{PG}}{1.06}$$

Where:

PD = desired power density (in W/m^2) = 5 W/cm^2 = 50,000 W/m^2

D = distance (meters)

P = peak power (Watts)

G = antenna gain ratio $\left(10^{\frac{Antenna\ Gain\ (dBi)}{10}}\right)$

HERP ASSESSMENT CONSIDERATIONS

The biological effects of non-ionizing (electromagnetic) radiation on personnel (HERP) can cause overheating of human body tissue. Overheating occurs when the body is unable to cope with or adequately dissipate heat generated by exposure to RF energy. However, the body's response is dependent on the energy level, time of exposure, and ambient temperature.

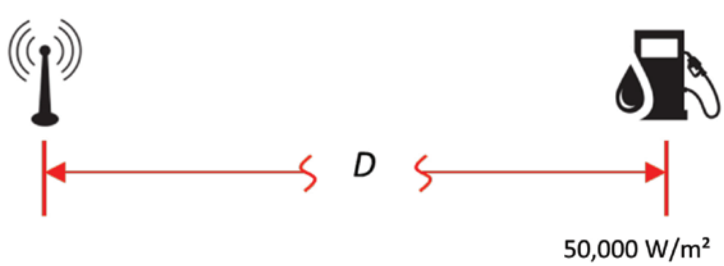


Figure 2: HERF safe separation distance calculation example

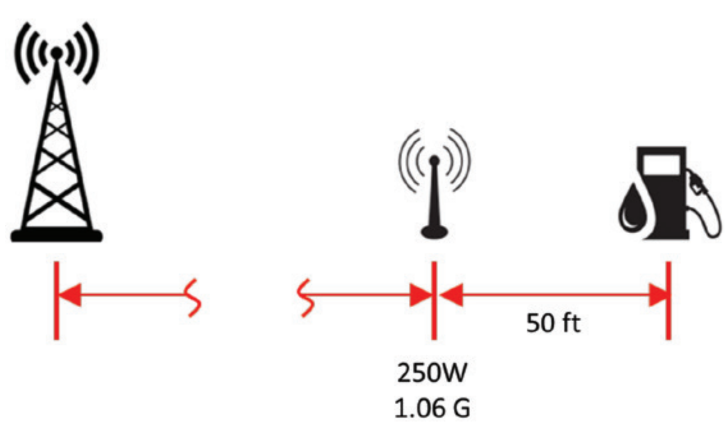
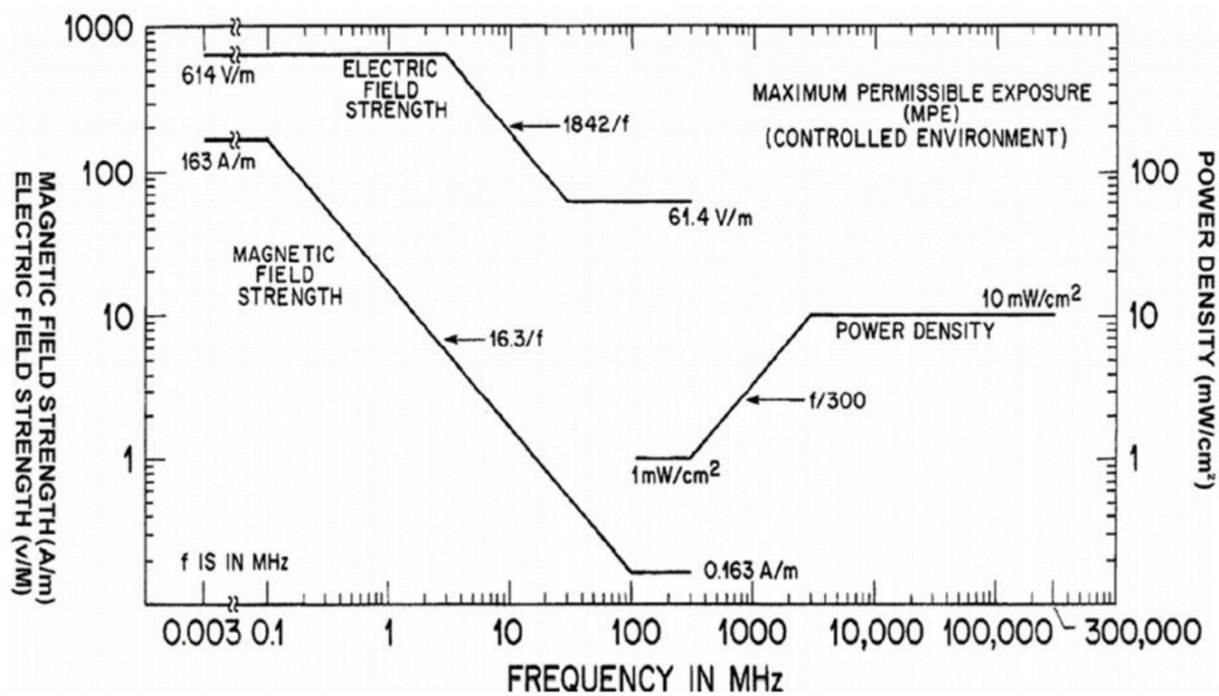


Figure 3: HERF safe separation distance based on 250W at 50 ft

Unlike ionizing radiation, no cumulative effects from repeated exposure or molecular changes that can lead to significant genetic damage to biological tissues have been proven. RF exposure guidelines and procedures have been adopted and promulgated to protect DoD personnel from the deleterious effects of RF exposure. DoDI 6055.11 implements the HERP criteria for military operations.

The transmitter must comply with the current DoD criteria for the protection of personnel against the effects of electromagnetic radiation. This DoD policy is currently found in DoDI 6055.11, and compliance is verified by test, analysis, or a combination of both.

Radar and ECM systems usually present the greatest potential personnel hazard due to their high transmit power levels and high-gain antenna characteristics, coupled with the potential of nearby personnel exposure. This poses the greatest risk to repair and facility maintenance personnel due to their frequent proximity to radiating elements and the need for rapid maintenance response.



Frequency Range (MHz)	Electric Field (V/m)	Magnetic Field (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
$0.1 - 1.0$	1842	$16.3/F_M$	$(900 * 100{,}000/F_M{}^2)^b$	6
$1.0 - 3.0$	1842/f	$16.3/F_M$	$(900/F_M{}^2 * 100{,}000/F_M{}^2)$	6
$30 - 100$	61.4	$16.3/F_M$	$(10*100{,}000/F_M{}^2)$	6
100 - 300	61.4	0.163	10	6
300 - 3000			$F_M/30$	6
3000 – 30,000			100	$19.63/F_G{}^{1.079}$
30,000 – 300,000			100	$19.63/F_G{}^{0.476}$
$F_M = Frequency\ MHz$ $F_{MG} = Frequency\ GHz$				

Figure 4: HERP upper tier MPE limits

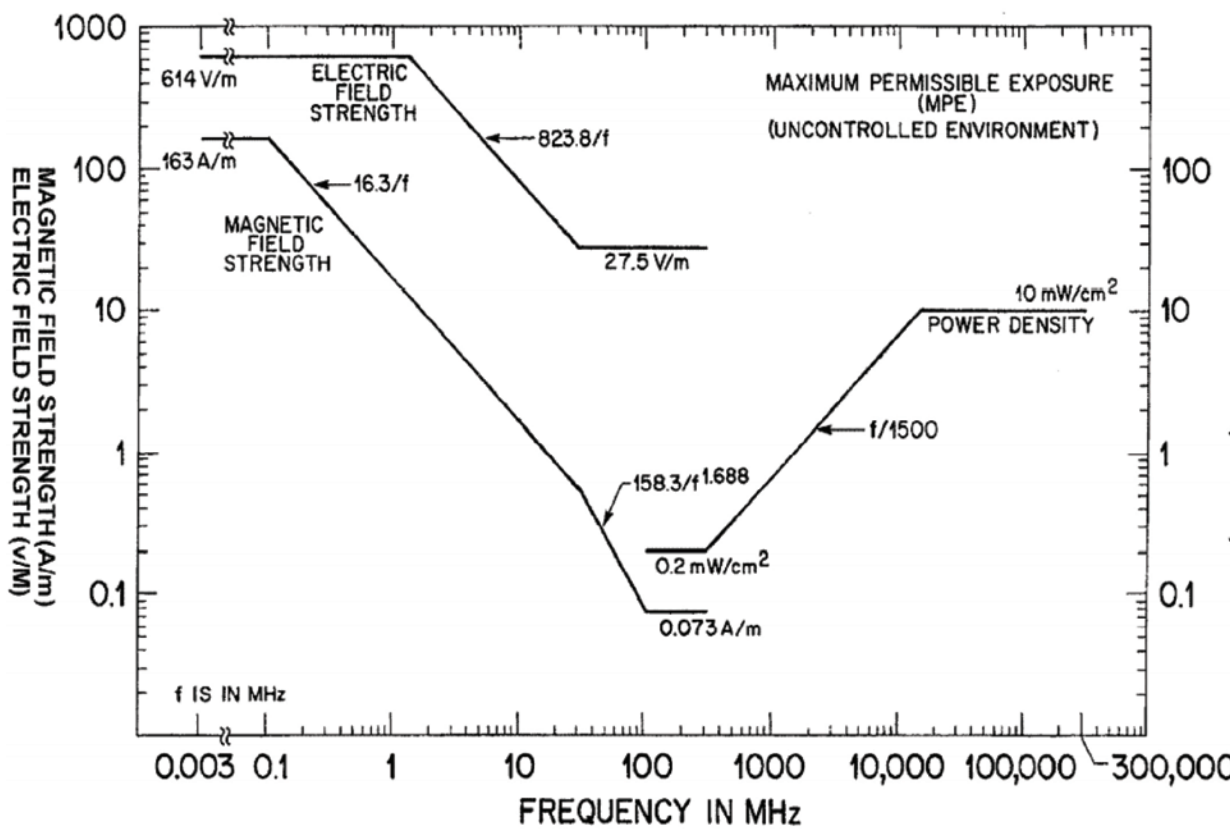
In accordance with applicable standards, an RF hazard evaluation may be performed first by determining the SSD for personnel via calculations based on RF emitter characteristics or through measurement. Once the distance has been determined, an inspection is typically conducted in personnel access areas where exposure to the antenna's main transmission beam is possible. Verification of appropriate warning signs, safety zones, and other precautionary measures, guidance manuals, and operating manuals is commonly required as part of the platform inspection process. Further technical guidance for assessing RF hazards can also be found in the Air Force AFRL-SA-WP-SR-2013-0003, Army TO 31Z-10-4, TB MED 523, and Navy NAVSEA OP 3565.

The HERP limits are established as MPE values based upon the basic restriction. The upper tier MPE limits shown in Figure 4 (left) are presented as a function of frequency, and their values have been based upon a whole-body specific absorption rate (SAR) of 0.4 W/kg (formerly known as "controlled"). The limits were developed to control human exposures to electromagnetic energy at frequencies ranging from 0 kHz - 300 GHz, and to limit the localized SAR occurring in the feet, ankles, wrists, and hands of personnel due to exposure to such fields or contact with objects exposed to such fields. MPEs are given in terms of rms electric (E) and magnetic (H) field strengths, equivalent plane-wave free space power densities (S), flux density (B), and induced currents (I) in the body.

The lower tier MPE limits shown in Figure 5 on page 28 are presented as a function of frequency and are based on a SAR of 0.08 W/kg lower tier (formerly known as "uncontrolled") exposures that can occur in areas where individuals would have no knowledge or control of their exposure. These locations would include living quarters or workplaces where there are no expectations that the exposure levels may be exceeded.

OTHER CONSIDERATIONS

HERP SSD may be validated through physical EMI survey measurements using specialized HERP/RADHAZ meters to ensure the proper tier limits are not exceeded. However, caution is needed to ensure that the field measurement probes used have peak



Frequency Range (MHz)	Electric Field (V/m)	Magnetic Field (A/m)	Power Density (W/m^2)	Averaging Time (minutes)
$0.1 - 1.34$	614	$16.3/F_M$	(1000 to 100,000/$F_M{}^2$)^c	6
$1.34 - 3.0$	$823.8/F_M$	$16.3/F_M$	(1800/$F_M{}^2$ to 100,000/$F_M{}^2$)	$F_M^2/0.3$ to 6
$30 - 30$	$823.8/F_M$	$16.3/F_M$	(1800/$F_M{}^2$ to 100,000/$F_M{}^2$)	30 to 6
300 - 100	27.5	$158.3/F_M{}^{1.668}$	2 to 9,400/$F_M{}^{3.336}$	30 to $0.0636F_M{}^{1.337}$
100 - 400	27.5	0.0729	2	30
400 - 2000	-	-	$F_M/200$	30
2000 – 5,000	-	-	10	$150/F_G$
5,000 – 30,000	-	-	10	$25.24/F_G{}^{0.476}$
30,000 – 100,000	-	-	10	$5048/[9F_G - 700)F_G{}^{0.476}]$
100,000 – 300,000	-	-	(90F_G-7000)/200	
$F_M = Frequency\ MHz$ $F_{MG} = Frequency\ GHz$				

Figure 5: HERP lower tier MPE limits

power limits above the expected peak and average levels at the SSD distance. This will prevent potential saturation and/or damage of the measurement device. This should include scenarios where multiple emitters are present and the emitters are not phase coherent (the usual case), causing spectrum power density. This is an important effect which should be considered for both calculation and measurement approaches.

In addition to the main beam hazards, localized hot spots produced by reflections and resonant standing waves occurring between metal structures and buildings is also an important consideration. It is common to encounter these scenarios in areas where general power densities are initially found to be less than the maximum permissible exposure limits. Therefore, a thorough understanding of the site and the surrounding electromagnetic environment is critical.

There are several guidance documents available to assist in EMI survey planning as well as typical test methodology and measurement equipment recommendations based on the platform and type of transmitter.

CONCLUSION

In summary, RADHAZ is a very important safety aspect of today's U.S military force, and assessment is typically required for any new RF transmission device prior to deployment, including those that are specifically intended for operation in proximity of ordnance, fuel, and personnel.

GLOBAL EFFORTS TO MAKE A SAFER AND BETTER INTERNET FOR CHILDREN

The Advancement of Age-Appropriate Design and Age Verification Standards

The IEEE Standards Association (IEEE SA) is a collaborative organization where innovators raise the world's standards for technology. IEEE SA provides a globally open, consensus-building environment and platform that empowers people to work together in the development of leading-edge, market-relevant technology standards, and industry solutions shaping a better, safer, and sustainable world.

By IEEE Standards Association

Children now make up roughly one-third of all internet users worldwide. Greater connectivity has enabled young people to benefit from educational content, communication tools, and entertainment, but it has also exposed them to harmful content, exploitation, data privacy risks, and potential addiction problems. The United Nations has confirmed that its Convention on the Rights of the Child[1] also applies to the digital world.

One area gaining strong focus is age verification. For policymakers, age verification is a critical tool to enforce child protection laws and uphold digital rights. For digital service providers, it's a strategic imperative for ensuring compliance, building trust, and protecting brand integrity.

The IEEE Standards Association has been at the forefront of age-appropriate design and age verification standards and certification. As technology advances, our commitment to safer and more responsible online spaces must grow too, in which accessing such spaces in an age-appropriate manner isn't just a legal requirement, but a social responsibility. IEEE standards provide a practical and implementable foundation for this.

AGE VERIFICATION IS NOT A NEW CALLING

The concept of verifying age to protect children began long before the advent of the internet. In the United States, for example, age verification was used as a tool to enforce child labor laws such as New York's 1903 labor law, which eventually led to federal birth certificate standards. Since then, other federal laws have been enacted that set age requirements for purchasing tobacco products, e-cigarettes, medical marijuana, and pharmaceuticals, or watching a movie in a theater, or gambling online.

Since the internet became widely available to the public in the early 1990s, society has gained incredible benefits but also inherited significant risks. Over the past two-plus decades, we have witnessed and perhaps experienced first-hand the rise of all types of cybercrimes against governments, businesses, and individuals, as well as online addiction and behavioral risks.

Unfortunately, these risks also apply to our most vulnerable, our children. Risks to minors include online grooming, exposure to inappropriate content, privacy violations, cyberbullying, manipulative advertising, and online addiction. Some laws have addressed these issues to some degree; one significant U.S. federal law is the Children's Online Privacy Protection Act (COPPA)[2]. COPPA, effective since 2000, establishes foundational rules for how online services must handle personal data from children under age 13. On April 22, 2025, the Federal Trade Commission (FTC) issued new amendments to COPPA, updating its requirements to reflect evolving digital practices, which took effect on June 23, 2025, and require full compliance by April 22, 2026.

At the federal level in the U.S., proposed legislation attempting to control online content and access of minors has failed. The roadblocks are tied to a complex mix of constitutional concerns, privacy risks, technical challenges, and political fragmentation. Defeats include the Communications Decency Act (1996), struck down by the U.S. Supreme Court in 1997, and the Child Online Protection Act (1998), which never went into effect due to ongoing legal challenges, as well as more current efforts, such as the Kids Online Safety Act (2023), have not passed.

Significant and effective efforts in the U.S. to enact online age verification mandates have fallen to the states, resulting in a patchwork of state-level laws

Enforcement and infrastructure vary widely. In many developing regions, such as parts of Africa and Southeast Asia, age verification laws are either absent or inconsistently enforced.

requiring age verification for access to adult content or social media platforms. Currently, about half of U.S. states have passed laws that are either in effect or await effective dates. These laws vary widely in scope and enforcement. For example, states such as Louisiana, Texas, Utah, and Arkansas require websites with sexually explicit content to verify users are 18 or older using government-issued ID or third-party services.

These state laws have met legal challenges. Notably, in June 2025, the U.S. Supreme Court upheld a Texas law[3] requiring age verification for access to websites hosting sexually explicit material. The Court ruled 6-3 that the law, House Bill 1181, does not violate the First Amendment, finding that the state's interest in protecting children from harmful content outweighs the burden on adults seeking access to such material. The ruling is significant because it marks the first time the Supreme Court has allowed age verification requirements on adult consumers to protect minors online.

Some states have passed laws focused on social media restrictions, imposing age verification and/or parental consent and other age-appropriate design features such as curfews, time limits, and privacy settings for children of various ages.

AGE VERIFICATION IS A GLOBAL ISSUE

In the European Union, policymakers have taken a more aggressive approach and made significant progress toward implementing harmonized age verification laws across member states. Like COPPA in the U.S. and the Online Safety Act (OSA) in the United Kingdom[4], the Digital Services Act in the European Union[5] officially recognizes minors as a distinct risk group that requires stronger safeguards.

In other parts of the world, countries are rapidly adopting online age verification laws. For example, Australia's eSafety Commissioner conducted age verification trials in 2023. A proposed ban on social media use by children under 16 is scheduled to take effect in December 2025, and industry age assurance codes to support enforcement are being drafted.

China requires real-name registration and facial recognition for youth gaming, limited to three hours of gaming per week. While pornography is banned, age verification is also applied to gaming and social platforms.

Japan uses the "My Number" system for age checks across games, manga, and video platforms. It also enforces limits on gacha microtransactions to protect minors. There is no blanket ban on social media use, but platforms engage in voluntary self-regulation.

However, enforcement and infrastructure vary widely. In many developing regions, such as parts of Africa and Southeast Asia, age verification laws are either absent or inconsistently enforced. This highlights the need for international cooperation and capacity building to ensure that children everywhere benefit from the same level of protection.

A STANDARD FOR AGE VERIFICATION: IEEE 2089.1-2024

Published in May 2024, the IEEE 2089.1™, Standard for Online Age Verification[6] was developed by industry experts from around the world. It is part of the IEEE 2089 series of standards, which was initiated by and based on the 5Rights Principles for children, focusing on age-appropriate design of digital services and helping to build a better digital world for children.

The IEEE 2089.1 standard was developed to provide a set of processes for digital services to verify or estimate a user's age or age range with a proportionate degree of accuracy and certainty in determining a child's age. This allows organizations to manage access to their products and services based on the suitability of age, keeping the rights and needs of children in mind.

Age verification can help digital services providers, policymakers, and regulators to address requirements from various jurisdictions around the world, including:

- Age-Appropriate Design Codes in the UK, California, and more;
- Europe's Digital Services Act, General Data Protection Regulation (GDPR), and Audiovisual Media Services Directive (AVMSD);
- US's Children's Online Privacy Protection Act (COPPA); and
- India's Digital Personal Data Protection Act (DPDPA)

These processes associated with digital services are essential in creating a digital environment that supports, by design and delivery, children's safety, privacy, autonomy, agency, and health. The program specifically provides a set of guidelines and best practices that offer a level of validation for Age Assurance decisions that may be either required by law or voluntarily implemented for business or social reasons.

A STEP FURTHER: AGE-APPROPRIATE DESIGN

Countries around the world are increasingly adopting age-appropriate design code policies inspired by pioneering frameworks such as the United Kingdom's Age-Appropriate Design Code and multiple similar frameworks based upon it. These policies aim to safeguard children's rights and well-being in digital environments by mandating privacy-by-design principles for online services likely to be accessed by minors. The UK's code, enacted in 2020 and enforceable since September 2021, set a global precedent with its 15 standards rooted in the UN Convention on the Rights of the Child, influencing similar initiatives in Ireland, Sweden, Indonesia, and Australia.

> The advancement of age-appropriate design and age verification standards by IEEE SA is helping stakeholders, including digital services providers, policy makers, and regulators, to address requirements from various jurisdictions around the world.

No federal policy exists in the United States. Therefore, it is up to the states to consider similar legislation, with California, Maryland and Vermont having modeled after the UK's Age Appropriate Design Code. These frameworks emphasize high privacy settings by default, age assurance, data protection impact assessments, and transparency tailored to children's understanding. As digital platforms increasingly shape young people's lives, these codes represent a growing global consensus on the need for robust, child-centric data governance.

The IEEE SA's focus on human-centric design and the need to protect children online has resulted in the development of advanced frameworks for the age-appropriate design of internet platforms[7] to support this growing demand. This community is helping organizations design and develop digital services that are age-appropriate and deliver against the cultural and legal privileges they are entitled to in digital environments.

Informed by the United Nations Convention on the Rights of the Child (CRC) and built upon the principles developed by the 5Rights Foundation[8], IEEE 2089-2021, Standard for Age Appropriate Digital Services Framework[9] establishes a recommended set of processes that help enable organizations to make their products and services age appropriate, including consideration of risk mitigation and management through the life cycle of development, delivery, and distribution.

IEEE SA recently launched the Technology Policy Collaborative to further leverage IEEE's neutral, trusted expertise to help governments address complex technical and societal challenges in strategic areas, such as digital governance. As a model for collaborative policy development, IEEE SA announced the culmination of its collaboration with policymakers in Indonesia[10] in May 2025 on the recently passed Indonesian Government Regulation, Governance of Electronic Systems in Child Protection.[11]

SEAL OF ASSURANCE: IEEE AGE VERIFICATION CERTIFICATION PROGRAM

The IEEE SA offers a globally- and industry-respected Age Verification Certification Program[12], which assesses the design, specification, evaluation, and deployment of age verification systems against the framework identified in the IEEE 2089.1, Standard for Online Age Verification. It is part of the IEEE 2089 series of standards deliverables, focusing on age-appropriate design of digital services and helping to build a better digital world for children.

The certification program provides technology organizations with the means to verify to regulators and consumers whether their age assurance systems work as intended. Governing bodies can also leverage the certification and standard when establishing age verification mandates. Online users and those responsible for the welfare of children can more easily identify brands and systems that are implementing age-appropriate measures that are compliant with the program's established framework.

LOOKING AHEAD

The advancement of age-appropriate design and age verification standards by IEEE SA is helping stakeholders, including digital services providers, policymakers, and regulators, to address requirements from various jurisdictions around the world.

While many digital service providers only implement age-appropriate design and age verification measures to comply with governmental mandates, the opportunity, standards, and certification process are available to those who are willing to do so proactively and show their commitment to helping create an online environment that is not only safer for children but also respects their rights.

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FAILURE TO FOLLOW WARNINGS AND INSTRUCTIONS

Is that Foreseeable?

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By Kenneth Ross, Senior Contributor

In previous articles I have written, I have talked about what is reasonably foreseeable misuse and how that should be taken into account during the design of the product,[1] how to navigate the safety hierarchy,[2] and how to create effective warnings and instructions.[3] All of these subjects merge when discussing the foreseeability of product users not following warnings and instructions.

WHAT IS FORESEEABLE MISUSE?

At the birth of product liability, the California Supreme Court in *Greenman v. Yuba Power Products, Inc.,* 377 P.2d 897 (Cal. 1963), limited the manufacturer's liability to a product that was "unsafe for its intended use." Section 402A of the Restatement (Second) of Torts, adopted shortly after *Greenman*, imposed no liability for injuries caused by consumer "mishandling," "over-consumption," and "excessive use."

While considerable confusion arose over the years about what effect these limitations had on liability, the concept of "misuse" as a defense or limitation on a manufacturer's duty became firmly entrenched in the law.

The Restatement Third, Torts: Products Liability (1998) ("Restatement 3d"), continued that precedent by confirming that a manufacturer is liable only when its product is put to reasonably foreseeable uses. If its use and the harm occurring during that use are reasonably foreseeable, then the manufacturer must design the product to eliminate or minimize the risk of the foreseeable use. In addition, the manufacturer must warn of known or reasonably foreseeable risks that remain in the product.

However, consistent with case law as it developed after 1965, the Restatement 3d also provided that a manufacturer can be liable for "foreseeable product misuse, alteration, and modification" (hereinafter "misuse"). Accordingly, a manufacturer must also design its product and provide warnings so that it is safe from foreseeable misuse.

Injury caused by misuse does not provide a separate theory of liability, per se, but instead relates to the issue of whether a product is defective and whether a causal connection exists between the defect and injury. Misuse, as a legal concept, is also relevant to the comparative fault doctrine, which can be used to reduce a manufacturer's liability based on the plaintiff's product misuse.

Setting aside the legal concept, though, the practical question for the manufacturer is what conduct will the courts and juries consider "misuse?" As one would suspect, the answers are all over the map. In fact, in a number of situations, similar conduct has been deemed foreseeable misuse in one court and unforeseeable misuse in another court. But there are some common themes that run through the cases that provide some guidance to manufacturers.

First, courts generally recognize that "nothing is unforeseeable" (especially in retrospect) and that the ways in which a product can be misused are "endless." To counter absolute liability for product-caused harms, however, courts have attempted to limit the foreseeability concept to that which is "reasonably foreseeable."

Recognizing this limitation, one court memorably stated: "Reasonably foreseeable … does not encompass the far reaches of pessimistic imagination".[4] While true, this limitation is not all that helpful as a guide to manufacturers because an event must occur before a jury gets to decide whether it was foreseeable, reasonably or otherwise.

Certainly, though, foreseeable use (or misuse) is broader than "intended use." One state statute defines "reasonably anticipated use" as any use or handling of the product that the manufacturer should reasonably expect of ordinary persons in the same or similar circumstances (see Louisiana Rev. Stat. § 2800.53). In addition, a technical standard for machine tools defines "reasonably foreseeable misuse" as unintended conduct that may result from "readily predictable human behavior" (see ANSI B11 (2008)).

In some situations, the manufacturer does something that increases the probability of unintended human behavior. For example, it may design a product in a way that increases the chance that the user will misuse or alter it because of some difficulty in using the product as originally designed. Or the product's marketing may invite misuse by showing unintended users or intended users using it in an unintended and unsafe way. In both situations, the user and the use would arguably be considered "reasonably foreseeable."

The difficulty is even greater in warnings cases. Is it foreseeable that a product user will ignore warnings and instructions? Of course it is. That is the reason that safety engineering principles, some case law, and the Restatement 3d all encourage manufacturers to design out a hazard or guard against it before, as a last resort, warning against it.

But assuming that the manufacturer designed or guarded its product as safely as reasonably possible, can it rely on a warning if it is foreseeable that users might ignore the warnings? Thankfully, yes, assuming that the warning was adequate, which will be discussed in more detail later. Judges and juries understand that manufacturers cannot make product users read and follow warnings. Any other answer would require manufacturers to sell products with no significant risk of harm based on their design and guarding. With most products, this is impossible to do.

THE SAFETY HIERARCHY

So, the first question is whether a warning is permissible instead of designing out the hazard or warning against it. The engineering concept is called the "safety hierarchy." It is also a legal concept that is described as follows:

> *…when a safer design can reasonably be implemented and risks can reasonably be designed out of a product, adoption of the safer design is required over a warning that leaves a significant residuum of such risks.*[5]

On this hierarchy, a court in Massachusetts said the following:

> *If a slight change in design would prevent serious, perhaps fatal, injury, the designer may not avoid liability by simply warning of the possible injury. We think that in such a case, the burden to prevent needless injury is best placed on the designer or manufacturer rather than on the individual user of a product.*[6]

So, before you can rely on a warning, the question is whether the manufacturer should instead make the design safer or whether a guard will minimize the risk better than relying on a warning or instructions that consumers can ignore. Assuming you can warn, then the question is whether the warnings and instructions are adequate.

FAILURE TO FOLLOW WARNINGS CASELAW

It is clear in the law that failure to follow warnings and instructions is a product misuse. Professor Owen said the following in his hornbook on Product Liability Law:

> *A user's failure to follow a manufacturer's warnings of danger or instructions on safe use provides a special form of misuse that ordinarily should bar recovery whenever the danger from non-compliance is evident, the non-compliance is a substantial cause of the plaintiff's harm, and there is no simple way or apparent reason for the manufacturer to design the danger out of the product.*

And Professor Owen quotes from the Restatement (Second) of Torts, which says:

> *Where warning is given, the seller may reasonably assume that it will be read and heeded; and a product bearing such a warning, which is safe for use if it is followed, is not in a defective condition nor is it unreasonably dangerous.*

In addition to the case law, a few states have laws that preclude liability for a manufacturer when the injured party ignores the warnings and instructions. Statutes in Arizona, New Jersey, North Carolina, and

Indiana provide protection against such a lawsuit. For example, the law of Indiana says:

> *It is a defense to an action under this article … that a cause of the physical harm is a misuse of the product by the claimant or any other person not reasonably expected by the seller at the time the seller sold or otherwise conveyed the product to another party.*[7]

And Indiana case law provides that misuse "is established as a matter of law when the undisputed evidence proves that plaintiff used the product in direct contravention of the product's warnings and instructions."

Using this law, the Indiana Court of Appeals held that the failure to follow warnings and instructions is unforeseeable product misuse and therefore the manufacturer is not subject to liability.[8] The court held that the product involved in the accident:

> *[w]as used in direct contravention of its label's prominent and explicit warnings regarding flammability and instructions regarding flame cutting an empty drum and/or exposing it to heat.*

Therefore, "the defense of misuse was established as a matter of law" because the defendant "could not have reasonably expected that it would be misused in the way that it was."

Specifically, the court said that "the large, prominent warning label on the top of the drum informed readers that the contents of the drum were flammable and explosive and would remain so even when drum was empty unless it had been reconditioned." The court also found that the label "specifically informed readers in no uncertain terms not to cut the drum with a flame even if empty, instructions which, if followed, would have avoided the danger posed by the drum altogether."

In conclusion, the court held that the evidence established that the warning label gave reasonable warnings about the dangers posed by the drum and how to avoid them, but that the decedent still ignored them.

So, while all misuse is foreseeable, it is not necessarily reasonably foreseeable. Thus, many courts have held that not following warnings and instructions is not reasonably foreseeable. In that case, the manufacturer would have a defense against that lawsuit.

CPSC'S POSITION ON FAILURE TO FOLLOW WARNINGS

Let's see what the U.S. Consumer Product Safety Commission (CPSC) has said about not following warnings and instructions. Not surprisingly, since they are not restricted by state laws, the Restatement language, or case law, some people at the CPSC take the position that, since it is foreseeable that users will not follow warnings and instructions, if the product could have been designed more safely, then the product could be considered defective and should be recalled. The CPSC has also taken the position, on occasion, that if the product can't be designed more safely, and warnings are not being followed, maybe the product should not continue to be sold.

Thought needs to be given to how to provide the most effective safety communications. On-product warnings and hard copy instructions are the typical ways to provide this information.

For example, the CPSC recently sued Leachco, a manufacturer of an infant lounger that caused several deaths after parents violated clear warnings and instructions about safe use. The Pacific Legal Foundation (PLF) that is defending Leachco just issued a white paper discussing this case and the CPSC's position on this subject.[9] PLF said:

> *Through its interpretive rules, the CPSC allows itself to consider any factors that the agency deems relevant when identifying a substantial product hazard. Most importantly here, the CPSC never identified any objective design or manufacturing defect with the product itself. Instead, using its "interpretive" rules, the agency claimed that the Podster was defective because it was "reasonably foreseeable" that parents and caregivers might ignore the Podster's warnings and misuse it.*

They also said:

> *The CPSC declared that consumer misuse could, by itself, render a product defective. In other words, product "defects" can include no defects at all—just the potential for or evidence of misuse, in the CPSC's judgment. Such an approach could be applied to every product on the market.*

PLF suggests that the following be done to fix this position of the CPSC:

> *Ultimately, Congress has the power, either by amending the Consumer Product Safety Act or through other legislation, to define terms such as "product defect" that remain statutorily undefined. Doing so could reduce vast agency discretion and establish more objective standards for determining substantial product hazards.*

WARNINGS ADEQUACY

So, let's assume that the product is designed as safely as possible and consumers are not following the clear, unambiguous warnings and instructions. Consumers usually have lots of excuses for why they did not follow the warnings. For example, the safety precautions are too hard to comply with, or they are too detailed or too general, too small, in the wrong location, unclear, or only in English, or that the design could have been made safer.

In a recent lawsuit against Tesla, the court said the following:

> *[Consumer's] failure to read the warnings in the Owner's Manual is not the end of the inquiry because "the mere existence of warnings in an instruction manual is not dispositive of the adequacy of the warnings . . . [given that a] warning may be defective not only by virtue of inadequate wording, but as a result of its location and the manner in which the warning was conveyed."*[10]

The same court also said:

> *Still, a plaintiff's failure to warn claim may still survive, notwithstanding the consumer's failure to read the warning, where the very nature of the defendant's breach is such that it causes the consumer to fail to read the warning that would have prevented the injury.*

Therefore, thought needs to be given to how to provide the most effective safety communications. On-product warnings and hard copy instructions are the typical ways to provide this information. But the manufacturer needs to think about location, accessibility, and conspicuity of this information in addition to the mere adequacy of the language.

In addition, the manufacturer must think about other ways to communicate safety information that may be more likely to be read or heard. For example, here are other possible ways to communicate:

- Instructions that appear on websites of manufacturers and retailers;
- Safety videos and safety manuals on manufacturer's websites, or that accompany the product;
- Training software that accompanies products or is online;
- Training at dealers', manufacturers', or retailers' facilities;

- Warnings and instructions at the point of sale and in marketing literature;
- Safety video shown at dealer location before delivery; and
- Require customers to confirm safety messages on delivery and confirm that anyone who will use the product is trained in safety.

That way, it is less likely for a court to hold that it was the manufacturer's conduct that caused the consumer to not see or follow the warnings and instructions.

CONCLUSION

So, while the law is helpful in arguing that not following warnings and instructions constitutes unforeseeable misuse, the courts and the CPSC may not be receptive to these arguments, especially when specific users, such as children, are injured.

If the product is designed as safely as possible and a number of consumers are ignoring the warnings and instructions and hurting themselves, it is hard for a manufacturer to argue that nothing needs to be done. At a minimum, they should report to the CPSC and maybe argue that the CPSC needs to issue a safety regulation that includes enhanced warnings to be publicized by the CPSC and the manufacturer.[11] This would hopefully prevent accidents, help in defending future product liability cases, and satisfy the CPSC's desire to do something.

The manufacturer must be able to defend the adequacy of the design and show that it was not feasible or cost-effective to make the design safer. And then show that the warnings provided were clear, complete, accessible to the user, could easily be followed and that the accident would not have occurred if the warnings had been followed.

If this can be proven to the court and jury, there is a good chance that the manufacturer will prevail in this case. It is also possible that the CPSC will agree that while a recall is not necessary, additional safety notices should be issued that strengthen the warnings provided by the manufacturer and better educate the user on how to safely use the product.

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SHIELDING TO PREVENT RADIATION

Part 5: Near-Field Wave Impedance of Electric and Magnetic Dipoles

By Bogdan Adamczyk

This is the fifth of seven articles devoted to the topic of shielding to prevent electromagnetic wave radiation. The first article [1] discussed the reflection and transmission of uniform plane waves at a normal boundary. The second article, [2], addressed the normal incidence of a uniform plane wave on a solid conducting shield with no apertures. The third article, [3], presented the exact solution for the shielding effectiveness of a solid conducting shield. The fourth article, [4], presented the approximate solution obtained from the exact solution. Both the exact and approximate solutions were derived for a good conductor in the far field of the radiating source. This article begins by discussing the topic of shielding effectiveness in the near field by introducing the concept of wave impedance.

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NEAR-FIELD SHIELDING

Note: The following derivations are valid under the assumption that the shield made of a good conductor is much thicker than the skin depth, at the frequency of interest.

The total shielding effectiveness in the near field is:

$$S_{dB} = R_{dB} + A_{dB} \tag{1}$$

just like it was in the far field, but the reflection loss for electric sources is different from the reflection loss for magnetic sources (in the far field, the reflection loss for the two sources was the same).

The absorption loss in the near field is the same for the electric and magnetic sources and is the same as it was in the far field. That is:

$$A_{dB} = 20 \log_{10} e^{\frac{t}{\delta}} \tag{2}$$

Thus, the shielding effectiveness in the near field for electric sources is:

$$S_{dB,e} = R_{dB,e} + A_{dB} \tag{3}$$

while the shielding effectiveness in the near field for magnetic sources is:

$$S_{dB,m} = R_{dB,m} + A_{dB} \tag{4}$$

Near-field shielding formulas for the reflection loss can be derived using the far-field shielding results for the reflection loss, and the concept of the *near-field wave impedance* for the electric and magnetic sources.

HERTZIAN (ELECTRIC) DIPOLE AND NEAR-FIELD WAVE IMPEDANCE

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 Hertzian dipole complete fields at a distance r from the origin can be obtained from the vector magnetic potential ***A*** shown in Figure 1 (see [5] for the derivations), and can be expressed as [6]:

$$\hat{E}_r = 2\frac{I_0 l}{4\pi}\eta_0\beta_0^2 \cos\theta \, \hat{K}_r e^{-j\beta_0 r} \tag{5a}$$

where:

$$\hat{K}_r = \left(\frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right) \tag{5b}$$

$$\hat{E}_\theta = \frac{I_0 l}{4\pi}\eta_0\beta_0^2 \sin\theta \hat{K}_\theta \, e^{-j\beta_0 r} \tag{6a}$$

where:

$$\hat{K}_\theta = \left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right) \tag{6b}$$

$$\hat{H}_\phi = \frac{I_0 l}{4\pi}\beta_0^2 \sin\theta \, \hat{K}_\phi e^{-j\beta_0 r} \tag{7a}$$

$$\hat{K}_\phi = \left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right) \tag{7b}$$

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:

$$\hat{Z}_{w,e} = \frac{\hat{E}_\theta}{\hat{H}_\phi} \tag{8}$$

Using Equations (6) and (7) in Equation (8), we get [6]:

$$\hat{Z}_{w,e} = \frac{\eta_0\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right)}{\left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right)} \tag{9}$$

At a small distance from the antenna, $\beta r << 1$, the term $1/(\beta r)^2$ will dominate the term $1/(\beta r)$, and the term $1/(\beta r)^3$ will dominate the term $1/(\beta r)^2$.

Thus, the wave impedance in Eq. (9) can be approximated by:

$$\hat{Z}_{w,e} \cong \eta_0 \frac{\left(-j\frac{1}{\beta_0^3 r^3}\right)}{\left(\frac{1}{\beta_0^2 r^2}\right)} \tag{10}$$

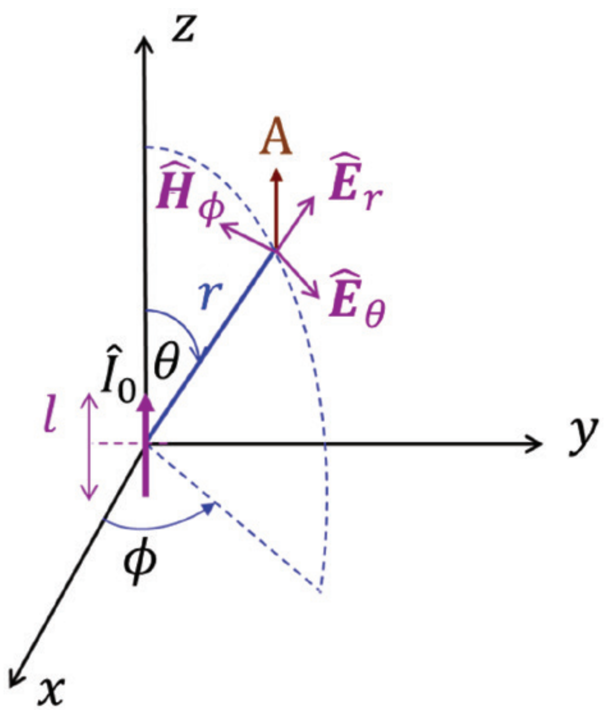

Figure 1: Hertzian dipole

or

$$\hat{Z}_{w,e} \cong \eta_0\left(\frac{-j}{\beta_0 r}\right) \tag{11}$$

The magnitude of this wave impedance is:

$$\left|\hat{Z}_{w,e}\right| \cong \frac{\eta_0}{\beta_0 r} \tag{12}$$

In the very near field:

$$\beta_0 r \ll \eta_0 \quad \Rightarrow \quad \left|\hat{Z}_{w,e}\right| \gg \eta_0 \tag{13}$$

For that reason, we refer to the electric dipole as a high-impedance source. Since $\beta_0 = 2\pi/\lambda_0$, we have:

$$\left|\hat{Z}_{w,e}\right| \cong \frac{\eta_0}{\frac{2\pi}{\lambda_0}r} = \frac{120\pi}{\frac{2\pi}{\lambda_0}r} \tag{14}$$

or

$$\left|\hat{Z}_{w,e}\right| \cong 60\frac{\lambda_0}{r} \tag{15}$$

In the next article, we will use this expression to evaluate the reflection loss $R_{dB,e}$ and the shielding effectiveness in the near field for electric sources, using Eq. (3), repeated here:

$$S_{dB,e} = R_{dB,e} + A_{dB} \tag{16}$$

MAGNETIC DIPOLE AND NEAR-FIELD WAVE IMPEDANCE

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

The magnetic dipole complete fields at a distance r can be expressed as [6]:

$$\hat{E}_\phi = -j\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4} \sin\theta\, \hat{K}_\phi e^{-j\beta_0 r} \tag{17a}$$

where:

$$\hat{K}_\phi = \left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2}\right) \tag{17b}$$

$$\hat{H}_r = j2\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4\eta_0} \cos\theta\, \hat{K}_r e^{-j\beta_0 r} \tag{18a}$$

where:

$$\hat{K}_r = \left(\frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right) \tag{18b}$$

$$\hat{H}_\theta = j\frac{\omega\mu_0 I_0 a^2 \beta_0^2}{4\eta_0} \sin\theta\, \hat{K}_\theta e^{-j\beta_0 r} \tag{19a}$$

$$\hat{K}_\theta = \left(j\frac{1}{\beta_0 r} + \frac{1}{\beta_0^2 r^2} - j\frac{1}{\beta_0^3 r^3}\right) \tag{19b}$$

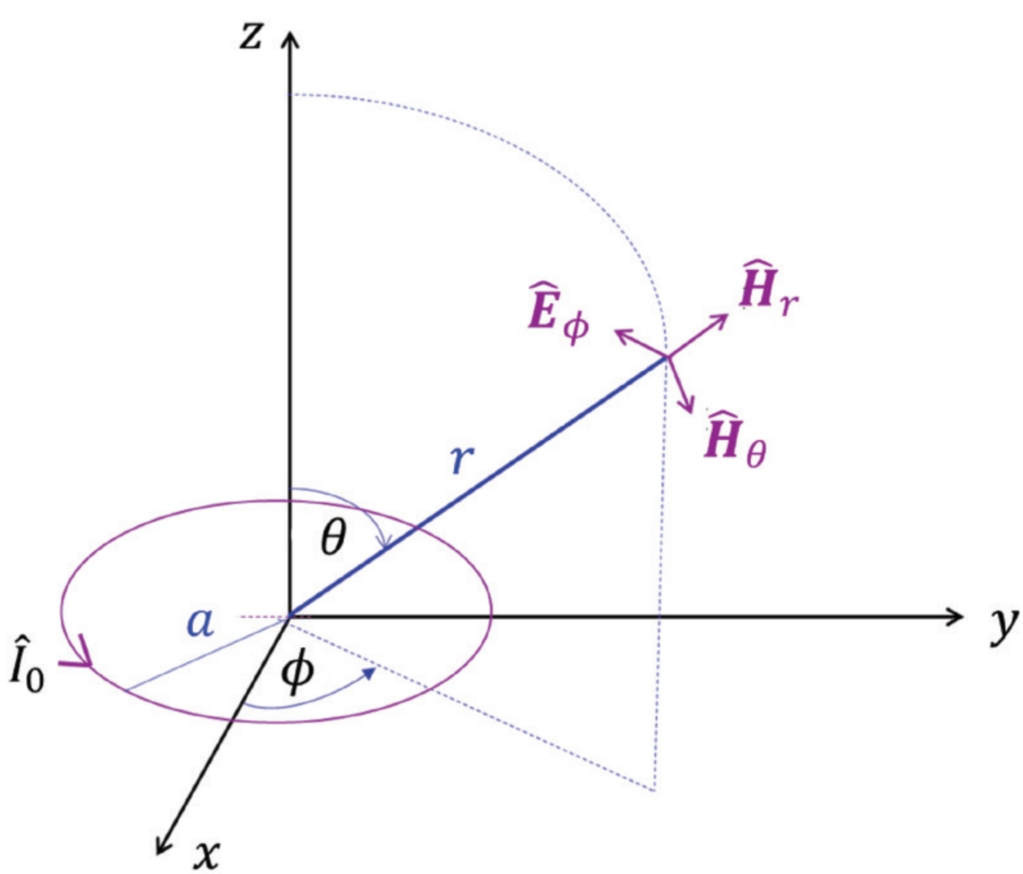

Figure 2: Magnetic dipole

The wave impedance for the magnetic dipole is defined as:

$$\hat{Z}_{w,m} = \frac{\hat{E}_\phi}{\hat{H}_\theta} \tag{20}$$

Using Equations (17) and (19) in Equation (20) we get:

$$\hat{Z}_{w,m} = -\eta_0 \frac{\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}\right)}{\left(j\frac{1}{\beta_0 r}+\frac{1}{\beta_0^2 r^2}-j\frac{1}{\beta_0^3 r^3}\right)} \tag{21}$$

At a small distance from the antenna, $\beta r << 1$, the term $1/(\beta r)^2$ will dominate the term $1/(\beta r)$, and the term $1/(\beta r)^3$ will dominate the term $1/(\beta r)^2$.

Thus, the wave impedance in Eq. (23) can be approximated by:

$$\hat{Z}_{w,m} \cong -\eta_0 \frac{\left(\frac{1}{\beta_0^2 r^2}\right)}{\left(-j\frac{1}{\beta_0^3 r^3}\right)} \tag{22}$$

or

$$\hat{Z}_{w,m} \cong j\eta_0\beta_0 r \tag{23}$$

The magnitude of this wave impedance is:

$$\left|\hat{Z}_{w,m}\right| \cong \eta_0\beta_0 r \tag{24}$$

In the very near field:

$$\beta_0 r \ll 1 \quad \Rightarrow \quad \left|\hat{Z}_{w,m}\right| \ll \eta_0 \tag{25}$$

For that reason, we refer to the magnetic dipole as a low-impedance source. Since $\beta_0 = 2\pi / \lambda_0$, we have:

$$\left|\hat{Z}_{w,m}\right| \cong (120\pi)\left(\frac{2\pi}{\lambda_0}\right) r = 240\pi^2 \frac{r}{\lambda_0} \tag{26a}$$

or

$$\left|\hat{Z}_{w,m}\right| \cong 2369 \frac{r}{\lambda_0} \tag{26b}$$

In the next article, we will use this expression to evaluate the reflection loss $R_{db,m}$ and the shielding effectiveness in the near field for magnetic sources, using Eq. (4), repeated here:

$$S_{dB,m} = R_{dB,m} + A_{dB} \tag{27}$$

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ON-CHIP ESD PROTECTION FOR MULTI-GBPS AUTOMOTIVE APPLICATIONS

By Shudong Huang for EOS/ESD Association, Inc.

The increasing demand for advanced driver assistance systems (ADAS) in road vehicles is fueling the development of high-speed automotive serial links. ADAS features such as adaptive cruise control, lane-keeping assistance, and parking assistance rely heavily on cameras, sensors, and radar. To support high image resolution and video frame rates, state-of-the-art automotive I/O may operate at data rates higher than 10 Gbps [1]. Automotive ICs are rated for system-level ESD robustness, rather than only component-level ESD, which makes ESD protection design for high-speed automotive I/O more challenging than for most other high-speed I/O. Specifically, in addition to component-level ESD qualification tests like human body model (HBM) and charged device model (CDM), many automotive products need to pass ISO-10605 qualification [2], which is a test standard for road vehicles based in part on the similar but more general IEC 61000-4-2 standard. Figure 1 shows an example of an 8kV discharge current waveform. The near-30-A peak current is well above the magnitude of the HBM and CDM.

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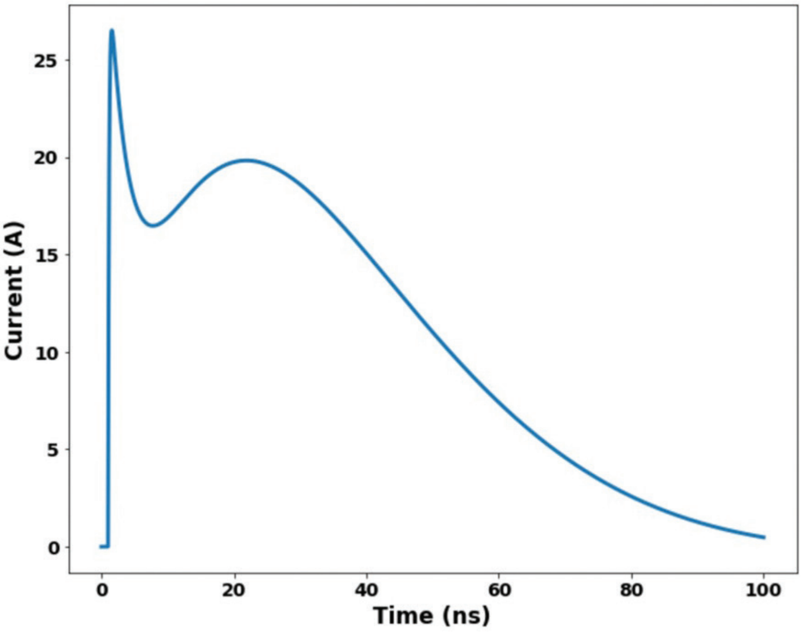

Figure 1: 8-kV ISO-10605 discharge current waveform into a low impedance load.

Conventionally, transient voltage suppressor (TVS) devices may be placed on a PC board to sink the system-level ESD current [3] [4] as shown in Figure 2. While it is a widely adopted protection scheme for relatively low-speed interfaces such as the controller area network (CAN) bus, the impedance discontinuity introduced by the on-board TVS makes it challenging to meet both the ESD requirements and the performance specifications.

One way to address the challenge is to place the ESD protection on-chip as shown in Figure 3, which allows the large ESD capacitance to be absorbed into a circuit network that will compensate for it. It is therefore highly desirable that the IC manufacturers of these receiver (RX) and transmitter (TX) chips integrate the ESD protection on-chip. System designers incorporating these chips into a complete system no longer need to worry about onboard ESD protection.

Figure 4 shows the schematic of the ESD-protected receiver front-end reported in this work [5]. Primary and secondary ESD clamps are embedded in a T-coil circuit, which is commonly used in broadband I/O circuits for impedance-matching and bandwidth extension. The T-coil is composed of two coupled inductors. The primary ESD protection, an efficient bidirectional SCR [6], is used to sink most of the ESD current. It is connected to the center tap of the T-coil. The input port of the T-coil is connected to the I/O Bump, and the output port of the T-coil is connected to a 50-Ω on-die termination (R_{ODT}) resistor. An AC-coupling capacitor C_{AC} provides a bridge between the ODT and the first stage of the receiver circuit (RX), typically a continuous time linear equalizer (CTLE). Secondary and auxiliary dual-diodes are placed at the ODT side and RX side of C_{AC}, respectively. The secondary ESD protection

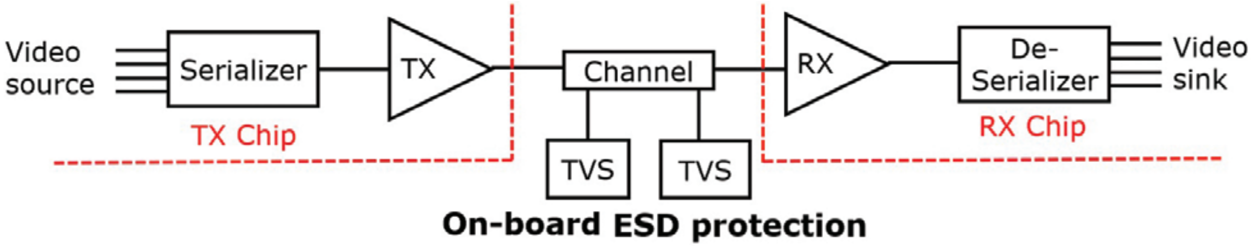

Figure 2: Illustration of the conventional on-board system-level ESD protection with TVS devices

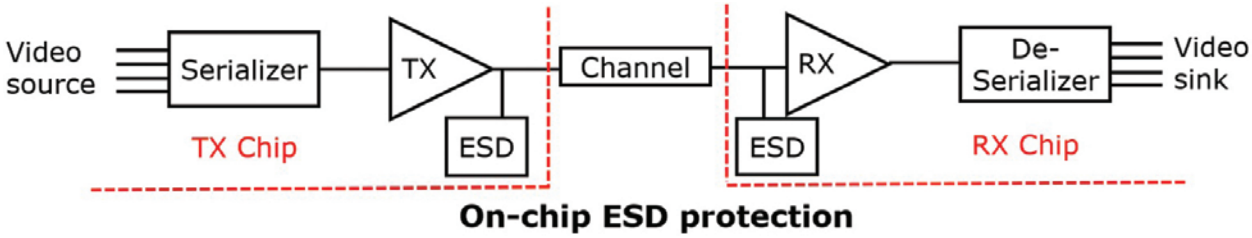

Figure 3: Illustration of the conventional on-chip system-level ESD protection

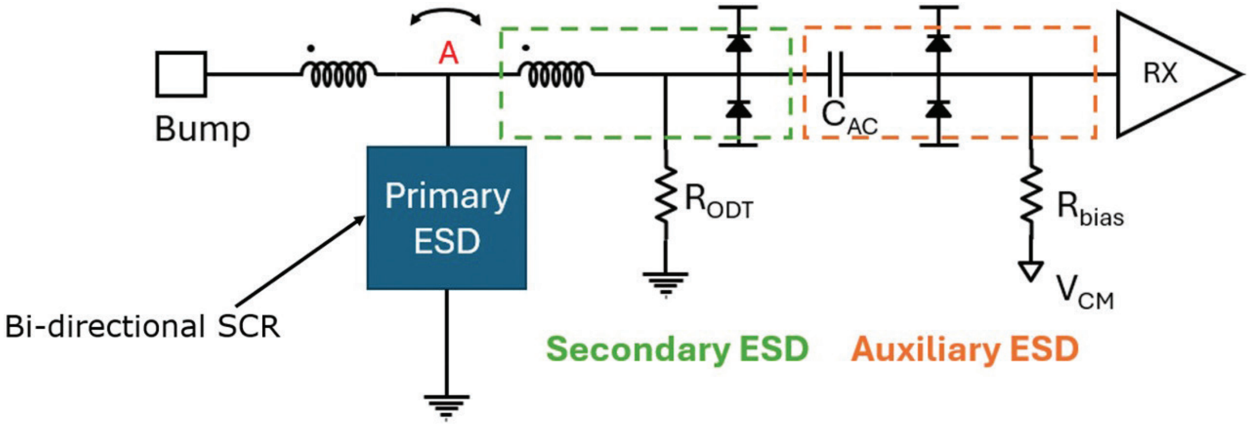

Figure 4: Schematic of the ESD-protection architecture of the receiver front-end

utilizes the impedance of the T-coil to first reduce the stress seen at the ODT. The auxiliary ESD protection stage further reduces the stress seen at the RX as demonstrated in [5] and [7].

As reported in [5], the proposed on-chip protection architecture can achieve up to 8kV ISO system-level protection. The measured and simulated return loss and insertion loss are plotted in Figures 5a and 5b, respectively. The return loss and insertion loss serve as good performance indicators of the ESD-protected frontend network. The measured return loss remains below -13 dB, and the normalized insertion loss is less than 1 dB all the way to 18 GHz, indicating excellent impedance matching and bandwidth extension. The achieved bandwidth supports 36/72 Gbps data rates (NRZ/PAM4) and beyond, which is well above the data rate of today's state-of-the-art automotive links.

In the future, automotive I/O will become faster with the integration of more ADAS features. Meeting the ESD robustness requirements of these systems will require careful co-design of system-level ESD protection and analog front-end circuits.

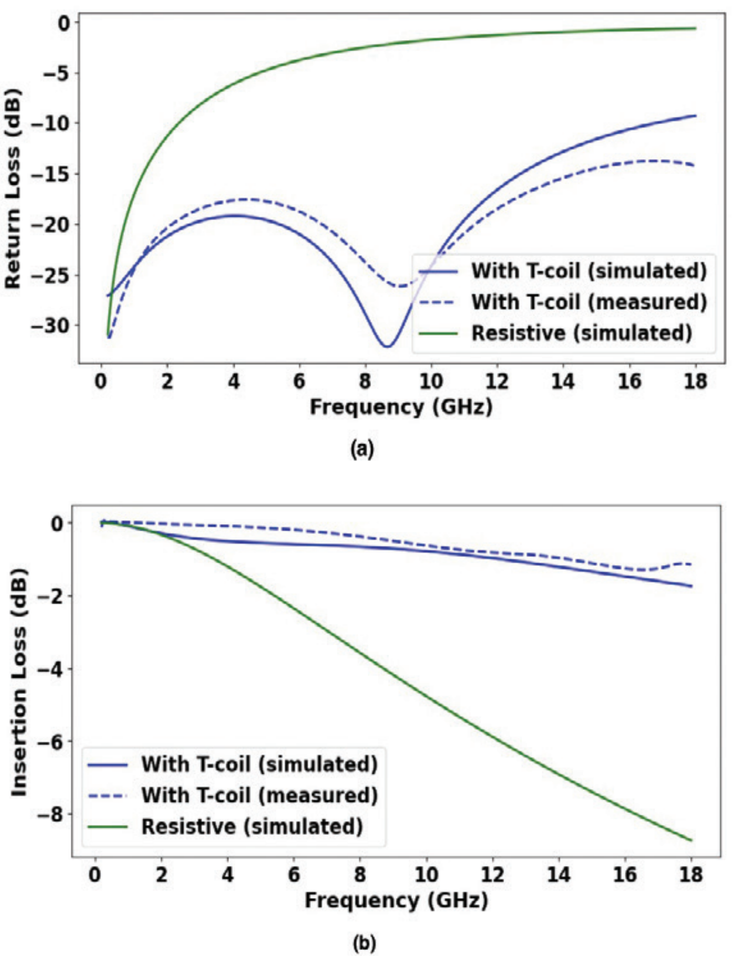

Figure 5: Measured and simulated (a) return loss and (b) insertion loss of the test structure.

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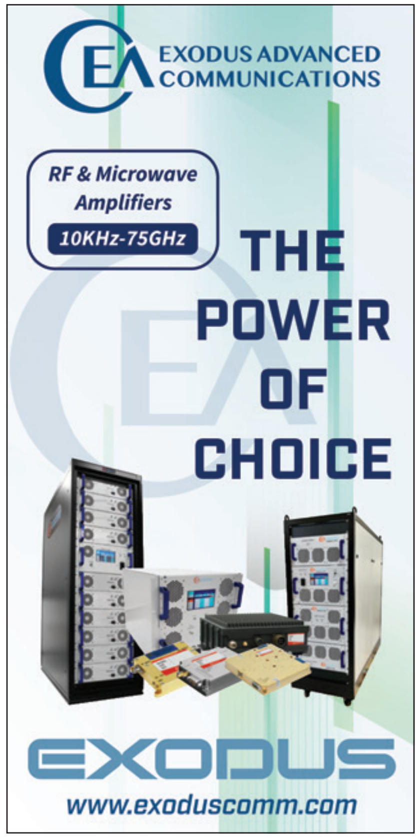

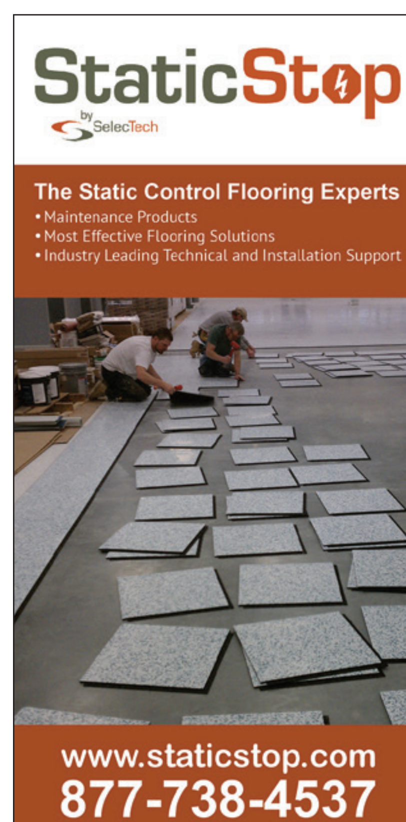

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