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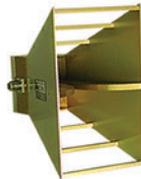
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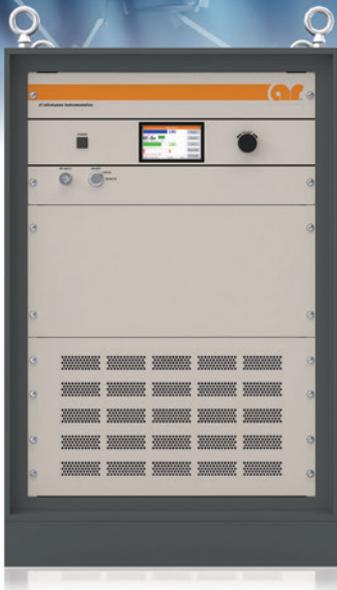
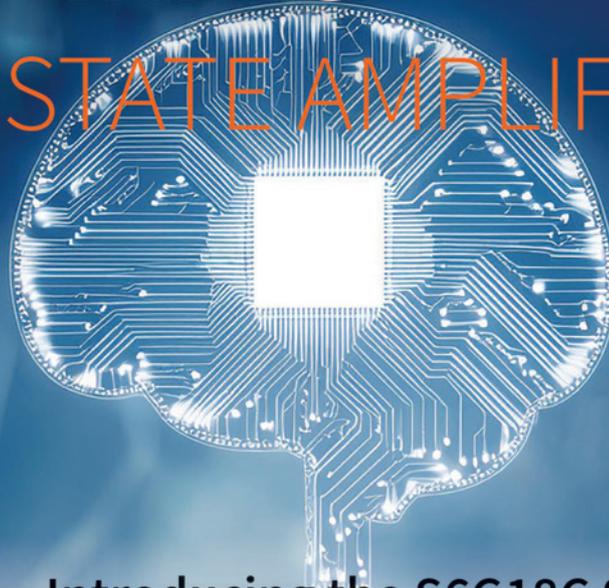
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white paper

Fundamentals of Electrical Safety Testing

This white paper explores the evolution and critical role of advanced hipot testers in ensuring product safety. It details how modern testers perform dielectric withstand, insulation resistance, and ground bond tests, complying with global standards like IEC and UL. The paper emphasizes the necessity of reliable, accurate testing in manufacturing and certification processes.

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guide

VSWR Explained

This resource traces VSWR from telegraph linemen using light bulbs to detect transmission line faults to modern RF measurements. It explains how improper line termination creates reflected signals that combine with forward waves, forming standing wave patterns. The evolution demonstrates how VSWR became a standard parameter for measuring reflected power in RF systems.

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white paper

How To Work Safely With High-Voltage Test & Measurement Equipment

When working with high-voltage test and measurement equipment, electrical and test engineers strive to achieve precise readings while also maintaining a safe work area. They employ external probes such as high-voltage dividers, but these instruments have drawbacks and are prone to errors. This white paper describes an alternative approach to high voltage calibration.

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RF Signal Generation Primer

Siglent's RF signal generation capabilities extend into complex IQ signals with wide bandwidth and fast symbol rates. Learn more about the capabilities and functions of RF signal generators, including the newest SSG6082A-V 8 GHz Vector Signal Generator.

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white paper

Reverberation Chambers

A technical overview of reverberation chamber design for EMC radiated immunity testing. Covers mode density, tuner efficiency, chamber Q, and validation methods in accordance with IEC, MIL-STD, and RTCA guidelines.

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FCC Issues Annual Internet Access Services Report

The U.S. Federal Communications Commission (FCC) has recently released its annual report on access to Internet connections in the U.S., including information on the gap between current service levels and the benchmark Internet connection speeds recommended under the Commission's National Broadband Plan.

According to the Commission's report, entitled *Internet Access Services: Status as of June 30, 2024*, approximately 97% of residential fixed Internet connections had a speed of at least 10 megabits per second (Mbps) downstream and 1 Mbps upstream by the end of the reporting period, with 94% of residential connections having a speed of

at least 25 Mbps downstream and 3 Mbps upstream. These results easily surpass the target set in the National Broadband Plan of 3 Mbps downstream and 768 kilobits per second (kbps) upstream.

Without accounting for speed, the total number of Internet connections remains strong. As of June 30, 2024, there were more than 548 million Internet connections operating at speeds over 200 kbps, slightly more than the 544 million recorded the previous year. And, once again, modern Internet connections are dominated by mobile technologies, which account for more than 75% of all Internet connections.

FDA to Address Data Integrity Concerns with Third-Party Testing Labs

The U.S. Food and Drug Administration (FDA) is raising concerns about the integrity of data submitted by two China-based testing laboratories in support of recent premarket medical device submissions.

Detailed in a press release, the FDA's Center for Devices and Radiological Health (CDRH) has issued General Correspondence Letters to Mid-Link Technology Testing Company, based in Tianjin, China, and the Sanitation & Environment Technology Institute of Soochow University in Suzhou, China. The FDA's communications inform the testing laboratories that it has been unable to "ensure the reliability and validity of biocompatibility testing and animal safety

and performance testing studies" conducted at their respective laboratories.

As a result, the CDRH says that it will reject data generated by those two testing laboratories for use in premarket device submissions "until the two firms have adequately addressed these issues."

The FDA has previously raised concerns about the operations of these two testing laboratories. In September 2024 warning letters sent to each laboratory, the FDA identified "laboratory oversight failures and animal care violations" that raised questions about the quality and integrity of data generated by the testing laboratories.

FCC Issues Annual Voice Telephone Services Report

The Federal Communications Commission (FCC) has released its most recent report on voice telephone services available to consumers in the United States.

The report, titled "Voice Telephone Services: Status as of June 30, 2024," shows the continued decline in the use of legacy wireline technologies in favor of mobile wireless technologies. By the end of the reporting period, wireline technologies accounted for just over 18% of the 471 million retail voice telephone service connections in the U.S., with

mobile voice subscriptions equaling more than 82% of total service connections.

Further, the report highlights the continued shift toward mobile wireless technologies. According to the report, during the three years from June 2021 through June 2024, mobile voice subscriptions increased at a compound annual growth rate (CAGR) of 2.8%, while interconnected VoIP (wired) subscriptions declined at a CAGR of 1.3% and retail switched access (wired) lines declined at a CAGR of 17.8%.

Editorial Clarification

The article "Preparing for the EU's New RED Cybersecurity Requirements" (June 2026) was published later than intended, resulting in outdated information that did not reflect the current regulatory landscape. We apologize for any confusion that this article may have created for our readers. Rather than retracting this article, we will be publishing an updated companion piece that covers the latest developments in EU RED Directive implementation, including the finalized harmonized standards, in an upcoming issue.

FDA Expands Unannounced Inspections of Foreign Manufacturing Facilities

The U.S. Food and Drug Administration (FDA) is stepping up its use of unannounced inspections at foreign manufacturing facilities that produce medicines and other medical products.

According to a press release, the FDA currently conducts about 12,000 domestic facility inspections and 3000 foreign facility inspections each year, covering more than 90 countries around the globe. However, U.S.-based manufacturing facilities are typically inspected without prior notice, while foreign-based facilities are usually given advanced notice of plans for inspections.

The FDA says that these different inspection protocols give foreign-based facilities ample time to prepare for their inspection and provide a theoretical advantage over domestic facilities in the FDA's oversight process. It also provides those facilities with an opportunity to falsify records or find ways to conceal potential violations of FDA requirements ahead of the actual inspection.

Going forward, the FDA says it plans to expand its use of unannounced inspections to include foreign-based facilities as well. These steps will "provide real-time evidence and insights that are essential for making fact-based regulatory decisions to protect public health."



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ACB Celebrates 25 Years as Leading Wireless Certification Authority

American Certification Body, Inc. (ACB) reached its 25th anniversary milestone in wireless certification this year, marking a quarter-century of service to the compliance community since its founding in 1999. The company holds accreditations as an FCC Telecommunications Certification Body (TCB), ISED Foreign Certification Body (FCB), and EU Notified Body, providing wireless compliance services across North America and Europe. ACB has worked with wireless equipment manufacturers worldwide throughout its 25-year operating history in the certification industry.

ATEC Hosts San Diego Test Equipment Symposium 2025

Advanced Test Equipment Corporation (ATEC) will host its annual San Diego Test Equipment Symposium on October 14, 2025, targeting engineers, technicians, and compliance professionals. The event will feature demonstrations, presentations, and product displays from manufacturers in RF, EMC, power, environmental, and electrical safety testing sectors. Technical sessions will cover applications including PC-based digitizers in medical acoustic microscopy for ultrasonic imaging.

32 Years of Dedicated Service at Elite: Celebrating Kathy Barri

For more than 32 years as Elite's receptionist and office assistant, Kathy Barri has been the face of the company, greeting nearly every visitor and handling countless phone calls. Beyond reception duties, Kathy served as administrative assistant to finance, supported sales with proposals, managed tradeshow logistics, organized safety training, and even helped with manufacturing tasks. She fostered company culture by planning events and parties. Kathy takes pride in Elite's family atmosphere and watching colleagues' families grow. The company appreciates her warm, welcoming presence and congratulates her on her dedicated career of service. We wish her a happy retirement!

EMC Society Completes Historic 50-Year Digital Archive

The EMC Society's History Committee has successfully completed the Legacy III project, digitizing five decades of European EMC conference papers now available on IEEE Xplore. The comprehensive archive includes papers from the Zurich EMC Symposiums (1975-2005), EMC Europe International Conferences (1994-2010), and Wroclaw, Poland

International Symposiums (1972-2006). Approved and funded by the EMC Society Board of Governors in 2024 after nearly a decade of planning, the project was executed by IEEE eXpress Conference Publishing Department.

EOS/ESD Association Collaborates with SRF Technologies

EOS/ESD Association Services, LLC has formed an alliance with SRF Technologies to provide ESD and EOS diagnostic and resolution services. The partnership offers testing, consulting, failure analysis, design corrections, and damage diagnosis services, including specialized support for HBM, CDM, and IEC test diagnostics. The collaboration combines the resources of both organizations to address electrostatic and electrical overstress issues across various industries.

ETS-Lindgren Unveils Model 5903-HST Ultra-High Speed Reverberation Tuner System

ETS-Lindgren has released the Model 5903-HST Reverberation Tuner System, operating at 20-100 RPM for electromagnetic testing applications. The system supports ISO 11451-5, Annex G compliance testing and can

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collect multi-axis data from up to eight probes when used with the company's EMCenter EM8 and EMSense Platinum Probes. ETS-Lindgren also offers the 5902-STD (2-16 RPM) and 5904-SST (0.1-5.8 RPM) models for different EMC testing requirements.

Leader Tech Introduces Thermally Conductive Absorber Series

Leader Tech has introduced its Thermally Conductive Absorber (TCA) Series, a composite material designed to address heat dissipation and electromagnetic interference in electronics applications. The material features thermal conductivity and broadband EMI absorption capabilities in a flexible, compressible format with adhesive backing. The product targets applications in RF modules, power electronics, and communication devices where space constraints require dual-function solutions.

Retlif Testing Laboratories Earns DLA Approval

Retlif Testing Laboratories received approval as a Defense Logistics Agency testing facility, adding to its 45-year history in defense testing services. The family-owned company operates three facilities in the northeast, providing testing and engineering services for commercial aviation, aerospace, rail, transit, maritime, military, and wireless industries. The certification enables Retlif to conduct equipment and materials testing for military operational requirements.

Rohde & Schwarz Introduces FSX Signal Analyzer

Rohde & Schwarz introduced the FSX signal and spectrum analyzer, featuring multiple input ports and an internal multi-path architecture with cross-correlation capabilities. The instrument offers 8 GHz internal bandwidth, multiple synchronous input ports with 4 GHz analysis bandwidth each, and operates on a Linux-based system.

Compact High-Current Protection for the Next Generation of Humanoid Robotics

SCHURTER introduced the UHP high-current SMD fuse for humanoid robotics applications, featuring current ratings up to 100A and breaking capacity of 2000-3000A. The component operates in temperatures from -55°C to +125°C and provides protection for battery systems, DC/DC converters, and motor controllers in robotic environments. The fuse is available in tape-and-reel packaging and meets UL and RoHS compliance standards.

Spectrum Instrumentation Announces New AWGs

Spectrum Instrumentation announced four new Arbitrary Waveform Generators (AWGs) with output rates up to 10 GS/s, 16-bit vertical resolution, and bandwidths reaching 3.9 GHz. The instruments are available in PCIe and Ethernet/LXI form factors with single or dual channels, targeting applications in wireless communications, radar development, quantum research,

and aerospace testing. The AWGs feature up to 8 GSample memory per channel, multi-channel synchronization capabilities, and include software support for Windows, Linux, and multiple programming languages.

Spira Manufacturing Partners with Integrated Polymer Solutions

Spira Manufacturing Corporation, founded in 1978, has entered into a partnership with Integrated Polymer Solutions, Inc. (IPS) after 45 years in the EMI shielding industry. The company will maintain its California-based manufacturing operations and continue producing spiral EMI gaskets with its existing team. The partnership provides Spira access to expanded resources and manufacturing capabilities while continuing its current operations.

Würth Elektronik Launches Compact Flat-Wire Inductors

Würth Elektronik introduced the WE-PMFI Power Molded Flat-Wire Inductor series, measuring 2.0 × 1.6 × 1.0 mm with 4.8 mΩ resistance and 48V operating voltage. The components use flat-wire technology and operate in temperatures from -55°C to +150°C, with inductance values ranging from 100 nH to 4.7 μH. The inductors are designed for DC/DC converters in smartphones, tablets, and portable electronics applications.

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EMC BENCH NOTES

Pre-Compliance Testing for Radiated Emissions

Part 2: Making the Measurement

By Kenneth Wyatt

Last month, we introduced you to radiated emissions pre-compliance testing and what equipment is required. This month, we'll show you how to actually make the measurement for commercial, industrial, and medical products, including all the system gains and losses. Once we complete the calculation for each dominant harmonic, you can directly compare it to the appropriate test limit. Next month, we'll cover some details for automotive modules and military pre-compliance testing.

The generalized test setup for pre-compliance testing is shown in Figure 1. The unit under test (EUT) is placed on an 80 cm high non-conductive table, which ideally should be able to rotate. However, a good estimate with fixed tables is to measure at least every face of the EUT in order to maximize the dominant harmonics. The preamplifier may not be required, as most modern analyzers have a 20-dB broadband preamp built in, if needed, to boost signal levels. The attenuator (usually 3 or 6 dB) is fixed to the antenna port to level out the impedance closer to 50Ω.

Notice that with a reflective floor, there will be a direct and reflected wave. In the official commercial compliance test, the antenna is raised or lowered between 1 and 4 m in order to find the point where the direct and reflected waves add up to a maximum.

In reality, most pre-compliance setups simply adjust the antenna height to some nominal height, say 1.2 or 1.5m, depending on the tripod design.

An additional point is that for most temporary pre-compliance test setups, there will not be a very good reflective floor, so it may not be necessary to adjust the antenna height anyway. You'll have seen this in the example setups shown in Part 1 of this series, published last month.

FINDING TEST LIMITS

The test limits will be located in the appropriate EMC standard used for your product type. Most commercial or medical products will use one of the IEC or European EN standards, which will refer to CISPR 11 or CISPR 32. For automotive modules, you'd refer to CISPR 25 (usually Class 5), and for military or aerospace ground equipment, MIL-STD-461. Limits for commercial aircraft are found in DO-160, which often refers to MIL-STD-461.

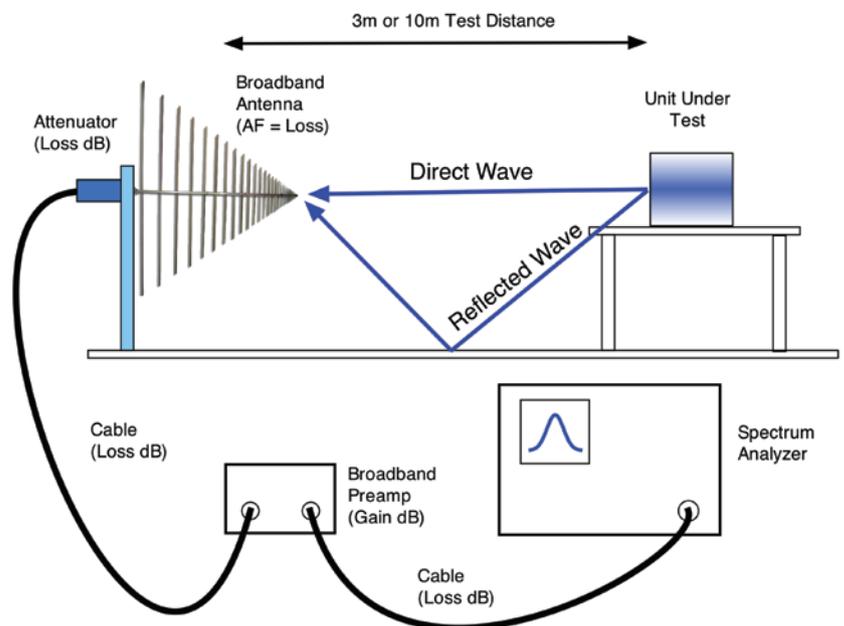


Figure 1: The physics of radiated emission measurement. Ideally, the antenna height should be adjusted to maximize the direct and reflected emission for the worst-case emissions.

PRE-TEST CALIBRATIONS

Before you're ready to make an actual measurement, you'll need to have characterized the gain versus frequency for any broadband RF preamplifiers (if used), the fixed attenuator (if used), plus the total loss in coax cables.

The best way to perform this measurement is to use either a spectrum analyzer with a tracking generator (Reference XX) or an XXX network analyzer (VNA). This data will be used in the system gain/loss calculation.

ANTENNA FACTOR

One important loss is the antenna factor (AF). Antenna factor is merely the transfer function of incident E-field impinging at the antenna versus the voltage measured at the antenna port. The unit will be 1/m. Calibrated antennas will come with a calibration chart of frequency versus AF. This will usually be in steps of 5 MHz or greater. If the harmonic lies between two calibration factors, you'll need to interpolate an AF.

MAKING THE MEASUREMENT

You can calculate the E-field (dBμV/m) by recording the dBμV reading of the spectrum analyzer and factoring in the coax loss, external preamp gain (if used), any external attenuator (if used), and antenna factor (from the antenna calibration provided by the manufacturer). See Figure 2 for the gain and loss diagram.

This calculation can then be compared directly with the 3m or 10m radiated emissions test limits using the formula:

$$\begin{aligned} \text{E-field (dB}\mu\text{V/m)} = & \\ \text{SpecAnalyzer (dB}\mu\text{V)} - \text{PreampGain (dB)} & \\ + \text{CoaxLoss (dB)} + \text{AttenuatorLoss (dB)} & \\ + \text{AntFactor (dB/m)} & \end{aligned}$$

For practical reasons, most pre-compliance setups will use a 3m test distance. In this case, you can directly compare with the 3m limit chart. This must be done for each harmonic to be measured.

Note that when comparing 3m to 10m test limits, the calculated difference in test limits is actually about 9.5 dB, with the 10m test limit lowered by that much from the 3m limits. For practical reasons, the regulatory authorities simply use a 10 dB difference. The same 10 dB difference is used when comparing Class A or Class B test limits for either 3m and 10m test distances.

To see where the test limit is on the spectrum analyzer, we simply rearrange the equation above. The E-field (in dBμV/m) is taken from the desired test limit. This is the method used to plot test limit lines on your analyzer.

$$\begin{aligned} \text{SpecAn (dB}\mu\text{V/)} = \text{E-field (dB}\mu\text{V/m)} & \\ + \text{PreampGain (dB)} - \text{CoaxLoss (dB)} & \\ - \text{AttenLoss (dB)} - \text{AntFactor (dB)} & \end{aligned}$$

While we can manually calculate each harmonic in question, plugging the measured gains and losses versus frequency into pre-compliance software helps automate

this measurement. Most software will also perform the interpolation calculation if a measured harmonic lies between two calibration frequencies. We'll be discussing and comparing pre-compliance software next time.

Example Calculation - For example, if we're measuring a harmonic at 50 MHz at a 3m test distance, then the FCC Class A limit is 50 dBμV/m. For a coax loss of 1 dB, an antenna factor of 9 dB, and no external preamp or attenuator, the signal on the spectrum analyzer of 40 dBμV would be right at the limit.

Calculating Limits for Distances Other Than for 3m or 10m - If we didn't have enough space and were to set the antenna-to-product distance at 2m rather than 3m, we would merely raise the displayed limit by $20\log(3/2)$, or 3.5 dB. An easy way to remember whether to add or subtract this correction factor is when the antenna gets closer to the product, the harmonics get higher, and so does the regulatory limit (and vice versa).

Once you've calculated this limit at the harmonic frequency of concern, you can either move the display line (see below) to that amplitude or use the custom limit feature of your spectrum analyzer. I prefer to use the display line, as it's faster. Note that if you're using the built-in preamplifier, it's not necessary to plug the (typical) 20 dB gain into the equation because the analyzer already compensates for the gain, leaving the signal amplitudes the same and effectively lowering the noise floor by the gain factor.

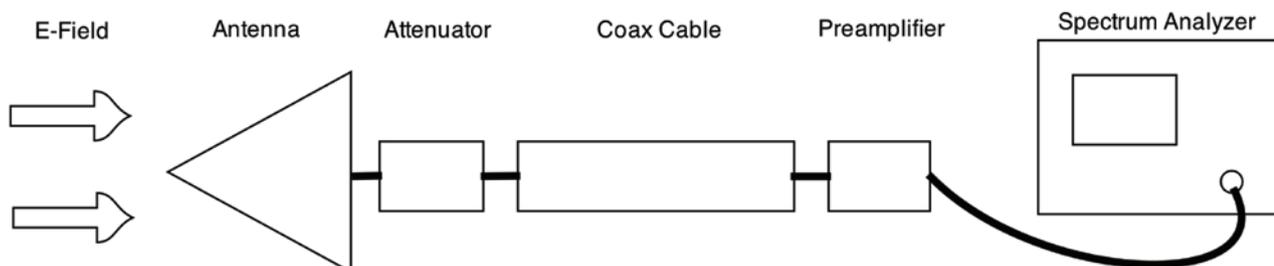


Figure 2: A block diagram of the system gains and losses used to calculate the E-field at the antenna.

PERFORMING THE COMMERCIAL TEST

Typically, this test will be in accordance with CISPR 11 or 32. Ideally, the antenna height should be adjusted between 1 and 4m so the vector sum of the direct and reflected emissions are maximized and the EUT rotated to at least all faces at each harmonic frequency.

For pre-compliance testing, antenna height adjustment and EUT rotation are usually limited. Set the test distance between EUT and antenna to 3m. Most companies try to set up the test in an area clear of other equipment or reflecting metal objects. Several examples are shown below.

Set up your spectrum analyzer as follows:

1. Frequency 30 MHz to 1,000 MHz (or higher, as specified by the standard)
2. Resolution bandwidth = 120 kHz, per the standard, or 100 kHz is close enough
3. Preamp = Off (turn on if you need to boost the signal more)
4. Set the vertical units to dB μ V
5. Adjust the Reference Level so the highest harmonics are displayed and the vertical scale is reading in even 10 dB increments
6. Use peak detection initially and quasi-peak detection on any over-limit peaks later
7. Internal attenuation — start with 20 to 30 dB at first and adjust for the minimum attenuation required for the best display without overload.

I prefer setting the vertical units from the default dBm to dB μ V so the displayed numbers are positive. Then, adjust the Reference Level for even increments along the vertical axis. This is also the same unit used in the test limits of most EMI standards. I also like to set the horizontal scale from linear to log (if possible) so frequencies are easier to read out. Now, start measuring!

If you observe a harmonic above the limit, try zeroing in on it using a span of 1 MHz (Figure 3). You can usually ignore the ambients and measure with some accuracy. By accounting for the antenna factor, coax loss, and preamp gain using the above equation, set the Display Line option (if available) to the calculated limit at that frequency. That will show you the margin below or above the limit.

Alternatively, you can set the display line to the harmonic amplitude as a reference while troubleshooting, comparing progress against the display line. This is a fast and efficient way to troubleshoot and keep track of progress (or lack of)!

Once you've identified the peaks over the limit, if any, the next step is to use the Quasi-Peak detector as required by CISPR 11/32. You'll need to refer to the user manual as to how to set this up on your analyzer. Some of the affordable analyzers may not have this option built in but may be available as an extra-cost option. Quasi-peak detection

uses an averaging method that can reduce the amplitude for non-CW harmonics. However, the measurement takes much longer than an ordinary peak measurement. Typically, you'd make this measurement only for the harmonics over the limit as measured in Peak mode.

Figure 4 shows one good example of a permanent radiated emissions pre-compliance test setup built in a client's basement. The antenna uses a commercial mast that can raise and lower the antenna, plus turns it from vertical to horizontal polarization. The 12-inch floor tiles were removed to allow 4 x 8-foot sheets of aluminum panels to be set in. They were copper taped together. The turntable was simply a "lazy Susan" placed on top of a roll-around cart. Marks were placed on the floor to indicate a 3m test distance and the product under test was manually rotated and antenna height adjusted for maximum emissions. Despite other racks of equipment in the room, they were able to make reasonable measurements and at least identify "red flags."

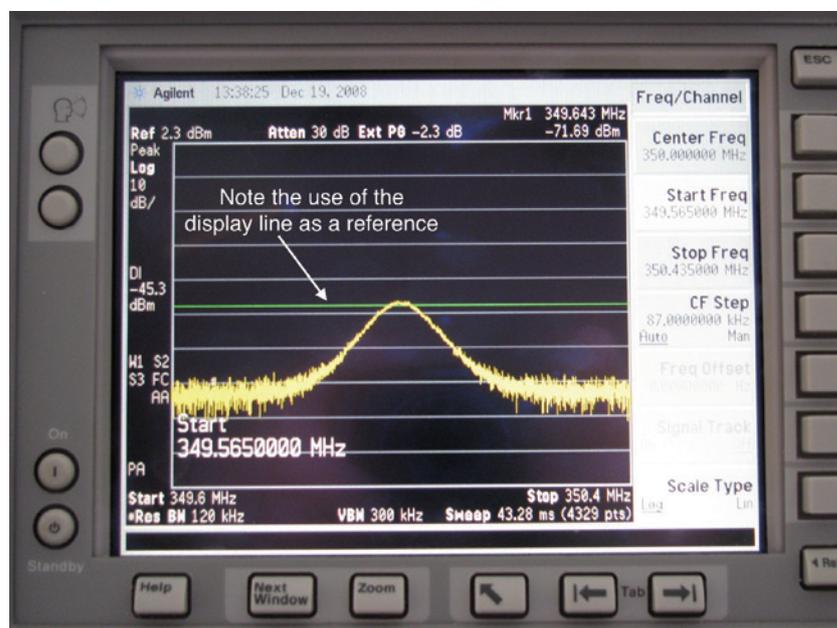


Figure 3: A large harmonic being measured using the 3m range set up in the conference room. Note the use of the display line feature for use as a reference during troubleshooting.

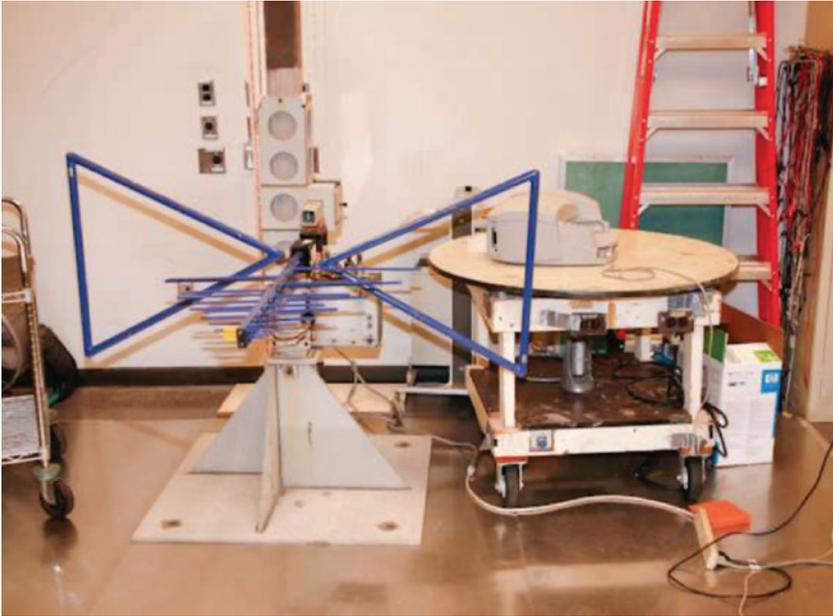


Figure 4: An example of a more permanent pre-compliance test setup

DEALING WITH AMBIENT TRANSMISSIONS

One problem you'll run into immediately when testing radiated emissions outside of a shielded room, is the number of ambient signals from sources like FM and TV broadcast transmitters, cellular telephone, and two-way radio. This is especially an issue when using external antennas.

I'll usually run a baseline plot on the analyzer using "Max Hold" mode for a couple minutes to build up a composite ambient plot. Then, I'll activate additional traces for the actual measurements. For example, I often have at least two plots or traces on the screen; the ambient baseline and the actual measurement. It greatly helps if you become familiar with the RF spectrum usage in your area.

It's also a bonus if you already know the top harmonic frequencies already, because it's easier to identify product emissions from the ambient noise. I often "zero in" by reducing the frequency span on a high harmonic while performing a measurement.

Fortunately, there are three ways around this:

1. In most cases, you'll observe a range of product emissions in a harmonic relationship. Very often, these harmonics are created from the same source and if one, or more, are masked by ambient signals, then working on the others that are more visible will generally bring the whole batch down, as well.
2. In some cases, there will be a critical harmonic masked by an ambient transmitter. A common example is a 100 MHz harmonic hidden underneath a strong FM broadcast station at the 99.9 MHz channel. In this case, I'll try reducing the resolution bandwidth from 100 or 120 kHz down to as little as 1 kHz, or less. This often "filters out" the modulation from the FM station, allowing you to observe the hidden harmonic. This also presumes the harmonic is an unmodulated continuous wave (CW) signal. Just be sure reducing the RBW doesn't also reduce the harmonic amplitude. If your harmonic is modulated,

this may not work, so you could try selecting a higher related harmonic, as in (1) above.

3. Move your testing well away from urban transmitters (easier said than done these days) or test in the early morning hours.

Remember that strong nearby transmitters can affect the amplitude accuracy of the measured signals, as well as create mixing products that appear to be harmonics, but are really combinations of the transmitter frequency and mixer circuit in the analyzer. You may need to use an external bandpass filter at the desired harmonic frequency to reduce the effect of the external transmitter. An example would be an FM broadcast band "stop band" filter.

SUMMARY

Very few companies today can afford permanent EMC test facilities, and I hope this has given you some ideas for performing pre-compliance testing at your own facility. While ambients are particularly difficult to deal with and can hide important harmonics, it is still possible to use these temporary sites for troubleshooting and a certain level of pre-compliance testing. This could save you thousands of dollars in wasted testing at your local compliance test facility.

Next month, we'll cover test setups for automotive modules and MIL-STD-461, which are similar in that both are tested at a distance of 1m from the test table. We'll also explain why the short distance! [C](#)

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MILITARY AND AEROSPACE EMC

High Intensity Radiated Fields (HIRF)

By Patrick André

Under the heading of radiated susceptibility (RS) testing is the category of High Intensity Radiated Fields, or HIRF. What is HIRF and why does anyone need to test to these high levels?

NASA/TP-2001-210831, In-Flight Characterization of the Electromagnetic Environment Inside an Airliner[1], has this definition (*emphasis mine*):

HIRF encompasses man-made sources of electromagnetic radiation generated external to

the aircraft considered as possibly interfering with safe flight. The easiest way to distinguish HIRF from other types of EMI is to state what it is not. HIRF *does not* include interference among on-board systems; this type of interference is referred to as an Electromagnetic Compatibility or EMC issue. HIRF also *does not* include EMI effects caused by portable electronic devices (PEDs) carried by passengers, such as cellular telephones, laptop computers, and portable radios. ...

HIRF *does not* include the effects of lightning, *nor* the effects of static electricity generated on the airplane; this is called Electrostatic Discharge or ESD. The effect of lightning on aircraft and avionics systems is similar to that produced by low frequency HIRF (kHz frequency range).

HIRF sources are intentionally generated, man-made radio frequency emissions. They are very intense and often come from ground radars, radio transmitters, and the like.



Figure 1: The Trestle, Kirtland Air Force Base, with B-52

These transmitters are typically friendly, however, HIRF has military applications that are used to intentionally disrupt electronics.

HIRF effects are real. And they are dangerous. HIRF has been known to cause many incidents, several crashes, and, sadly, loss of life. Reports of HIRF effects go back to the early 1980s and likely before. In 1972, the U.S. Air Force built ATLAS-I, the world's largest all-wood structure known as "The Trestle," at Kirtland Air Force Base in Albuquerque, New Mexico. Designed for EMP testing, the high frequency and high intensity fields had application to HIRF design and shielding.

Research into HIRF effects was performed in parallel by several agencies. These include the military and the FAA, working with the SAE, the EUROCAE and others. The Federal Register on HIRF states:

In 1987, the FAA contracted with the Department of Defense Electromagnetic Compatibility Analysis Center (ECAC) (currently the Joint Spectrum Center) to research and define the U.S. HIRF environment to be used for the certification of aircraft and the development of Technical Standard Orders. In February 1988, the FAA and the Joint Aviation Authorities (JAA) tasked the Society of Automotive Engineers (SAE) and the European Organization for Civil Aviation Equipment (EUROCAE) to develop guidance material and acceptable means of compliance (AMC) documents to support FAA and JAA efforts to develop HIRF certification requirements.[2]

The SAE sub-committee AE-4R with the EUROCAE Working Group WG-33 recognized the contribution of over 500,000 radio, television, radar, and other transmitters in just Western Europe and the USA which were causing the issues which were found.

The next step was to document the contribution of each of these transmitters – their frequency range, transmitting power, beamwidth, and similar information. With the data provided, the frequency ranges for each of the spectral envelopes were created. The following 17 ranges are now commonly used to define each of the HIRF environments:

10 kHz - 100 kHz
 100 kHz - 500 kHz
 500 kHz - 2 MHz
 2 MHz - 30 MHz
 30 MHz - 70 MHz
 70 MHz - 100 MHz
 100 MHz - 200 MHz
 200 MHz - 400 MHz
 400 MHz - 700 MHz
 700 MHz - 1 GHz
 1 GHz - 2 GHz
 2 GHz - 4 GHz
 4 GHz - 6 GHz
 6 GHz - 8 GHz
 8 GHz - 12 GHz
 12 GHz - 18 GHz
 18 GHz - 40 GHz

Some assumptions used to derive the amplitude in each range included that any reflection, say off the ground from an airport radar, was in phase with the direct transmitted amplitude. The amplitude was assumed to be at the closest approach to the transmitter by the aircraft or helicopter. The maximum amplitude in each of these frequency bands was used to determine the peak and average field strength. The average field strength was derived from the modulation (typically pulse modulation) for that transmitter, but it was noted that a transmitter with a wider pulse width might have a higher average energy than a high peak amplitude transmitter with a very short pulse width. Thus, the maximum amplitude for either condition was used, though it



Figure 2: Fiberglass and wood bolts and nuts

may not be from the same transmitter. What was not considered was the total illumination time, the frequency of the modulation (although the pulse width was used), nor the cumulative effect from multiple transmitters.

In the next article, we will continue with HIRF, what considerations were used to define these environments, and how commercial and military applications use them.

Fresh out of college with my physics degree, I had an opportunity to visit the structure, even before I knew how to spell EMI. They were changing out the metal bolts and holding them together, one at a time, to fiberglass and wood since the metal bolts were resonant structures at higher frequencies. [📄](#)

ENDNOTES

1. Karl J. Moeller et al., In-Flight Characterization of the Electromagnetic Environment Inside an Airliner, Langley Research Center, Hampton, Virginia, March 1, 2001. Work of the US Gov. Public Use Permitted.
2. Federal Register, Volume 71, No. 21, Wednesday, February 1, 2006, Proposed Rules, Docket No. FAA-2006023657; Notice No. 06-01, page 5555.

THE STATE OF IEEE EMC STANDARDS IN 2025

There's a Lot of Exciting Activity Going On In IEEE EMC Standards Development



Karen Burnham is the President and Chief Engineer of EMC United. She has over two decades of experience in the aerospace, defense, automotive, and other industries and is currently the Vice President of Standards for the IEEE EMC Society. You can reach her with any questions or discussion at karen@emcunited.com.



By Karen Burnham

Within the IEEE, the EMC Society “punches above its weight class” in terms of standards development.

We’re a small-to-mid-sized society (< 4000 members) with a fairly large portfolio of standards (> 25). That’s not too surprising, since most readers of this magazine know that EMC engineers live and die by the requirements imposed by different standards documents.

In this article, I hope to do three things:

1) describe the standards development process within the IEEE EMC Society and encourage you to get involved; 2) provide updates on areas of active development; and 3) provide a list of currently available EMC standards.

One interesting thing that people may not know is that you don’t have to be an EMC Society member, or even an IEEE member, to participate in a standards working group.

THE EMC SOCIETY’S INFRASTRUCTURE FOR STANDARDS DEVELOPMENT

Before diving into specifics, let me introduce you to the infrastructure the EMC Society has in place to support standards development. All the work gets done in individual standards working groups (WGs), which may be supported in three ways: 1) by a Technical Committee that coordinates with the

WG in their area of expertise; 2) by a Continuity Group; and 3) by the Standards Development and Education Committee (SDECom).

A Technical Committee (TC) is made up of members who are all interested in a particular technical area and can provide advice as well as a path for prospective future members for a standard’s WG. Thus, the standards dealing with shielding that we discuss in this article are largely sponsored by TC4, which has a focus on electromagnetic interference (EMI) control.

In addition, we’ve formed certain Continuity Groups (CGs) to monitor standards *after* they’re published, of which the most active is the Shielding CG. These groups meet once or twice a year to keep an eye on how the associated technology is evolving and when standards will need to be updated. The CGs field any concerns and feedback from users of the standards. This helps ensure that when a WG is formed to renew a standard, they won’t be starting from square one.

SDECom serves a different purpose, primarily to educate WG chairs about the process and to coordinate with the IEEE Standards Association (IEEE SA) on bringing new and renewed standards to full, official publication. SDECom helps WGs make sure all the procedural boxes are checked with the full help and support of IEEE SA personnel. IEEE SA is the entity that officially manages all IEEE standards, including balloting.

One interesting thing that people may not know is that you don’t have to be an EMC Society member, or even an IEEE member, to participate in a standards working group. The only membership requirement is that you have to be an IEEE and/or IEEE SA member to vote in a balloting group for a particular standard.

A typical SACCcom meeting will have representatives from IEEE societies, CISPR, ISO, ANSI, AIAA, IEC, and others. There isn't any better way to get an overview of the state of EMC standards than to attend (or call in!) one of SACCom meetings held each year.

The EMC Society has one other standing committee for standards, and that is the Standards Advisory and Coordination Committee (SACCom). SACCom brings together representatives from worldwide standards development organizations (SDOs) to discuss what they're working on, see if there are opportunities for collaboration, and to make sure there isn't too much redundancy of effort.

A typical SACCcom meeting will have representatives from IEEE societies, CISPR, ISO, ANSI, AIAA, IEC, and others. There isn't any better way to get an overview of the state of EMC standards globally than to attend (or call in! all EMC Society standards meetings are virtual or hybrid to the extent possible) one of the two or three SACCom meetings held each year.

EMC STANDARDS UNDER DEVELOPMENT/REVISION

With that background in place, let's look at the standards that are currently in the active phase of their lifecycle. This includes brand-new standards being written (Table 1) and standards being renewed (Table 2). Each of these will have a "P" in front of the standards number, indicating that it is an approved "Project" under the umbrella of the IEEE SA.

IEEE 299 on measurement of shielding effectiveness is probably the most widely used of all IEEE EMC standards, so we're excited to be starting on the renewal effort. Its companion standard, IEEE 299.1, on measuring small enclosures, should benefit immensely from technological advancements since it was first published in 2013. Both of these efforts are just getting underway, so it is a great time to get involved if these have relevance for your technical work.

Other committees that are nearer to the beginning of the process are IEEE 1560 on power line filters, IEEE P2710 on measuring shielding effectiveness of flexible RF protective pouches (such as those used to shield and isolate cell phones), and IEEE P1848.1 on extending the risk management approach of IEEE 1848 to the machine sector.

The way to get involved is to register interest through the IEEE SA myProject system (<https://development.standards.ieee.org>). You may need to create a free myProject account, but a paid IEEE membership is not required. Once you have registered interest, you should get notices for upcoming WG meetings. You can introduce yourself to the chair, and after attending a few meetings, the chair can determine

Number	Title	Status
P1848.1	Standard for Techniques & Measures to Manage Functional Safety and Other Risks With Regard to Electromagnetic Disturbances – Machinery Sector	WG drafting
P2710	Recommended Practice for Techniques to Evaluate the Performance of Enclosures and Other Methods for Electromagnetically Shielding Portable Electronic Devices	WG drafting
P2838	Standard for Aircraft Component Lightning Strike Direct Effects Qualification	WG nearing draft submission
P2855	Recommended Practice for the Electromagnetic Characterization of Cable/Connector Assembly Shielding Effectiveness in Frequency Range of Direct Current to 40 GHz	WG nearing draft submission

Table 1: New standards under development by WGs sponsored by the IEEE EMC Society

Number	Title	Status
P299/P299.1	Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures/Having all Dimensions between 0.1 m and 2 m	WG to kickoff Summer of 2025
P473	Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz)	Balloting completed
P1128	Recommended Practice for Radio-Frequency (RF) Absorber Evaluation in the Range of 30 MHz to 5 GHz	WG nearing draft submission
P1560	Standard for Methods of Measurement of Radio Frequency Power Line Interference Filter in the Range of 100 Hz to 10 GHz	WG kicked off efforts in Winter 2025
AIAA-S-121	Electromagnetic Compatibility Requirements for Space Equipment and Systems	Effort to make this a joint AIAA/IEEE standard is with the lawyers

Table 2: Standards currently being renewed

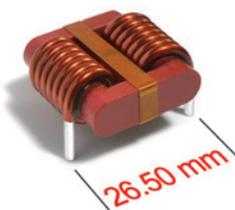
whether to admit you as an official WG member. The WG is where all the technical work gets done, including responding to comments from the voters in the balloting group. So that’s where your involvement and technical expertise will matter most.

STATUS OF OTHER EMC STANDARDS

In Table 3 on page 20, we summarize the remaining IEEE EMC standards and their status. If I’ve missed any, please let me know—some older standards aren’t always categorized correctly in the IEEE SA system.

The WG is where all the technical work gets done, including responding to comments from the voters. So that’s where your involvement and technical expertise will matter most.

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Number	Title	Status
139	Recommended Practice for the Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises	Inactive
187	Standard for Measurement of Emissions from FM and Television Broadcast Receivers in the Frequency Range of 9 kHz to 40 GHz	Expiring 2028
370	Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz	Expiring in 2030
377	Recommended Practice for Measurement of Spurious Emission from Land-Mobile Communication Transmitters	Inactive
475	Standard Measurement Procedure for Field Disturbance Sensors 300 MHz to 40 GHz	Inactive
1140	Standard Procedures for the Measurement of Electric and Magnetic Fields from Video Display Terminals (VDTs) from 5 Hz to 400 kHz	Inactive
1309	Standard for Calibration of Electromagnetic Field Sensors and Probes (Excluding Antennas) from 9 kHz to 40 GHz	Inactive
1597.1	Standard for Validation of Computational Electromagnetics Computer Modeling and Simulations	Expiring in 2032
1597.2	Recommended Practice for Validation of Computational Electromagnetics Computer Modeling and Simulations	Inactive
1642	Recommended Practice for Protecting Publicly Accessible Computer Systems from Intentional Electromagnetic Interference (IEMI)	Expiring in 2025
1688	Standard Requirements for the Control of Electromagnetic Interference Characteristics of Replaceable Electronic Modules	Expiring in 2025
1848	Standard for Techniques and Measures to Manage Functional Safety and Other Risks with Regard to Electromagnetic Disturbances	Expiring in 2030
1897	Recommended Practice for Location of Power Line Gap Interference Sources	Newly published in 2024
2665	Recommended Practice for Statistical Process Control for EMC Test Laboratories	Expiring in 2032
2715	Guide for the Characterization of the Shielding Effectiveness of Planar Materials	Expiring in 2033
2716	Guide for the Characterization of the Effectiveness of Printed Circuit Board Level Shielding	Expiring in 2032
2717	Recommended Practice for Passive Intermodulation Test Methods for Wireless Systems in Low Noise Environments	Newly published in 2024
2718	Guide for Near Field Characterization of Unintentional Stochastic Radiators	Expiring in 2033

Table 3: IEEE EMC standards not currently in active development

IEEE standards are on a ten-year renewal cycle, so standards published last year will likely start the renewal process in 2031 or 2032. It should be noted that the standards labeled “inactive” in Table 3 are still available for purchase from the IEEE SA and for use and application.

In most cases, the reason for the inactive label isn't technical. Since the IEEE SA does not have a stabilization process as many other SDOs do, renewing a standard requires as much effort and paperwork as generating a new standard (forming a new WG, submitting drafts for approval, new balloting, etc.). In some cases, it is easier to allow a standard to go inactive, knowing that it is still available to the public.

CONCLUSION

I hope this article gives you a good sense of what we're doing in the world of IEEE EMC standards, and a standing invitation to get involved. EMC engineers are deeply affected by the quality of standards out there, and it's particularly easy to get involved in the IEEE process. We rely on high quality volunteers with a wide variety of experiences to write high quality standards that benefit the entire community. [©]



Military Test for MIL-STD-461F/G CS106, CS114, CS115, CS116 And MIL-STD-1275F



- ★ **TPS-CS106 Power Leads Spike Pulse Generator**
Standard: MIL-STD-461F CS106
Test voltage: 0~1000V (continuous adjusting)
Repetition rate: max. 100Hz
EUT current: max. 300A
- ★ **CST-CS114 RF Conducted Susceptibility Test System**
Standard: MIL-STD-461 E/F/G CS114
Frequency: 4kHz~400MHz
Output power: 200W
- ★ **TPS-CS115 Fast Square Wave Pulse Generator**
Standard: MIL-STD-461 E/F/G CS115
Max. current: ≥5A (loop impedance: 100Ω)
Repetition rate: 1~50Hz
- ★ **DOS-CS116 High Frequency Damping Transient Pulse Generator**
Standard: MIL-STD-461 E/F/G CS116
Oscillation Frequency: 10kHz, 30kHz, 100kHz, 300kHz, 1MHz, 3MHz, 10MHz, 30MHz, 100MHz
- ★ **VSS 1275F Spike Surge Voltage Simulator**
Standard: MIL-STD-1275F
Surge Voltage: 30V~230V
Spike Voltage: 50V~300V
The product can be extended to 400A by DM 400 and LISN ML 400.
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ESD Footwear: The Hidden Variable in Flooring Audits

When ESD flooring audits fail, it's often for a simple reason: the footwear used during qualification testing isn't the footwear worn on the production floor. ANSI/ESD STM 97.1 (system resistance) and STM 97.2 (body voltage) treat the operator, footwear, and floor as a single conductive system. Change any part of the chain and performance changes.

Considerations

In electronics manufacturing, ESD footwear is an essential part of the flooring/footwear system. It forms the critical connection between the body and floor, safely discharging static to ground. Common options include toe straps, heel straps, sole straps, and ESD shoes.

ESD tile dissipates static through carbon granules or veins, which vary significantly in density – by as much as a factor of 10 between brands. Floors with sparse carbon paths require a larger conductive footprint, in which case ESD shoes may be necessary.

If a floor is qualified using ESD shoes then later used with heel straps, resistance can increase by a full order of magnitude—enough to fail an audit.

Four-Step Qualification Checklist

1. Document footwear: brand, model, size.
2. Test worst-case: 12% RH, minimal contact area.
3. Measure resistance and body voltage.
4. Build a test area before committing to a full installation.

Footwear isn't a detail: it's a variable. If a spec doesn't list the footwear used in tests, request full 97-series test results and the exact test interface. Without full transparency, a compliant floor may deliver non-compliant results. Always verify the system, not just the spec. 

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Navigating Product Cybersecurity:

What Manufacturers Need to Know About RED, PSTI & CRA

As the use of smart, “connected devices” across our homes, workplaces, and cities increases, the cybersecurity risks tied to these products continue to grow. In response, the UK’s Product Security and Telecommunications Infrastructure (PSTI) regime, updates to the EU’s Radio Equipment Directive (RED), and the upcoming EU Cyber Resilience Act (CRA) have emerged to ensure connected products are secure and remain secure throughout their lifecycle.

This article outlines the key requirements, scope, and timelines of each framework and offers guidance for manufacturers preparing to meet their obligations.

Why Product Cybersecurity Matters

While most companies already implement cybersecurity policies to protect internal systems, not all have applied the same rigor to the devices they manufacture. With consumer products increasingly connected to networks and the internet, attackers can exploit security flaws to access sensitive data, compromise systems, or launch widespread cyberattacks. Legislation is now catching up to close this gap.

- At the core of new laws are these principles:
- Eliminating known vulnerabilities at launch
- Default secure configurations
- Secure update mechanisms
- Access controls and data protection
- Responsible vulnerability disclosure

UK PSTI Regime: A Baseline for Connected Products

Effective from April 2024, the UK PSTI Regime was the world’s first legislation mandating Cybersecurity for consumer connectable products. It applies to internet-

and network-connectable devices such as smart TVs, doorbells, and routers.

Core Requirements

The PSTI Regime outlines just four key obligations:

1. Unique or user-defined passwords for each product
2. Clear vulnerability reporting processes
3. Published minimum update periods that cannot be shortened later
4. A statement of compliance, similar to CE or UKCA documentation

Supporting Standards

The legislation is closely aligned to ETSI EN 303 645, covering basic protections for consumer IoT products, and TS 103 701 for testing methodologies. These standards are freely available and form the technical benchmark for compliance.

EU Radio Equipment Directive (RED): Cybersecurity by Category

While the RED has long governed radio, safety, and electromagnetic compatibility, from August 1, 2025, it will enforce three new cyber-related essential requirements:

- Article 3(3)(d): Prevent harm to communication networks
- Article 3(3)(e): Protect personal data and privacy
- Article 3(3)(f): Guard against financial fraud

These apply only to internet-connected radio equipment, depending on how the device operates and what data it processes.

Whether you're preparing for RED changes in 2025 or the CRA rollout in 2027, engaging with experts early can streamline compliance and reduce costly delays.

Conformity Assessment & Standards

Three harmonised standards (EN 18031 series) have been cited to meet RED's new requirements, but all carry usage restrictions. For example, products that allow users to bypass password setup or lack parental controls won't benefit from automatic conformity.

If these standards can't be fully applied, manufacturers must undergo more rigorous third-party assessments, such as EU-Type Examination or Full Quality Assurance, involving a Notified Body.

EU Cyber Resilience Act (CRA): Raising the Bar Across the Board

Coming into full force by December 11, 2027, the CRA introduces the most comprehensive set of obligations yet. It applies to any product with a digital element that connects to other devices or networks.

Key Provisions

The CRA mandates:

- Cyber risk assessments at all stages of product development
- Conformity assessment based on risk category (basic, important, critical)
- Ongoing security updates and vulnerability disclosure procedures
- Incident reporting to ENISA, CSIRTs, and affected users within 24 hours (from September 2026)

Standards & Certification Pathways

While no specific standards yet exist for CRA, the European Commission has requested the development of 41 new standards by ETSI, CENELEC, and CEN. These will eventually provide the basis for demonstrating compliance, possibly alongside a new **European Cybersecurity Certification Scheme (EUCC)**.

Assessment pathways will vary depending on whether a product is classified as "important" or "critical," and whether harmonised standards or "Common Specifications" have been fully applied.

Understanding the Assessment Process

A Cybersecurity assessment typically includes:

- **Documentation Review:** Compliance documentation such as Implementation Conformance Statements (ICS), Implementation Extra Information for Testing (IXIT), and decision trees (especially for RED-related assessments).
- **Functional Sufficiency Testing:** Verifies that claimed protections work in practice (e.g., encryption is applied, PIN locks activate).
- **Completeness Check:** Ensures no undocumented features or interfaces exist.
- **Penetration Testing:** While not required under RED or CRA, some manufacturers may choose to conduct penetration tests for additional assurance.

Test labs play an important role in verifying documentation and performing assessments. Though third-party testing isn't mandatory under all regimes, many manufacturers prefer external expertise—particularly when Notified Bodies are required.

How Element Can Help

Element Materials Technology provides full lifecycle support for Cybersecurity compliance:

1. **Advisory Services** – Developing tailored test plans, conducting risk assessments, providing training and reviewing compliance documentation.
2. **Cyber Testing Services** – Element performs Cybersecurity assessments to EN 303 645 and EN 18031.
3. **Certification Body Services** – EU type examination certification for cyber security, as well as all other articles of the RED (radio, EMC, safety).

Whether you're preparing for RED changes in 2025 or the CRA rollout in 2027, engaging with experts early can streamline compliance and reduce costly delays. 

CISPR 11—A HISTORICAL AND EVOLUTIONARY REVIEW

Including an Update on the Seventh Edition of the Standard



***Editor’s Note**—This article was originally published in 2010 and 2016 in In Compliance Magazine and has been updated to include recent progress on the development of Edition 7.0 of CISPR 11.*

CISPR is the International Special Committee on Radio Interference which was founded in 1934. The International Standard for electromagnetic emissions (disturbances) from industrial, scientific, and medical (ISM) equipment is CISPR 11. The official title of the standard is “Industrial, Scientific, and Medical Equipment – Radio-Frequency (RF) Disturbance Characteristics – Limits and Methods of Measurement.”

The premiere edition of the standard was released in 1975, and the current edition (seventh edition) was released in 2024. The standard includes both limits and methods of measurement for conducted emissions and radiated phenomena. This article details the most recent Edition and retroactively traces the history and development of the content of the standard over the last 50 years.

SEVENTH EDITION – 2024

The Seventh Edition cancels and replaces the sixth edition

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By Daniel D. Hoolihan

published in 2015, Amendment 1: 2016, and Amendment 2: 2019. It constitutes a technical revision. The most significant technical changes with respect to the sixth edition are:

1. Introduction of limits for radiated disturbances in the frequency range above 1 GHz for group 1 equipment in line with the requirements given in the generic emission standards;
2. Introduction of limits for conducted disturbances on the wired network port in line with the requirements given in the generic emission standards;
3. Introduction of requirements for equipment which incorporates radio transmit/receive functions;
4. Introduction of definitions for various types of robots; and
5. Consideration of some particular conditions when measuring robots, such as measurement setups and operating modes of robots.

TECHNICAL DETAILS OF THE SEVENTH EDITION

The first significant technical change adds limits on radiated emissions (disturbances) above 1 GHz for group 1 equipment. Table 11 in the standard summarizes the limits (see Table 1).

The second significant technical change added new limits for conducted emissions (disturbances) on the wired network port. Table 7 in the new standard details the new limits (see Table 2 on page 28).

The third significant technical change deals with equipment incorporating radio transmit/receive functions, which have

not been covered in earlier versions of CISPR 11. They are addressed in the Scope, Paragraph 7.1, and Annex F.

The Scope says:

“Industrial, Scientific, and Medical (ISM) equipment which incorporates radio transmit/receive functions (host equipment with radio functionality) is included in the scope of this document, see Annex F. However, the emission requirements in this document are not intended to be applicable to the intentional transmissions from a radio transmitter as defined by the International Telecommunications Union (ITU) including their spurious emissions.”

Paragraph 7 (Measurement Requirements) and 7.1 (General) say: “For equipment with radio functionality, the additional requirements of Annex F shall apply.”

Annex F is Normative (Required) and is titled: “Additional requirements for equipment with radio functionality.” It addresses: 1) configuration of the equipment under test (EUT) during emissions tests; 2) radiated emissions; 3) conducted emissions; and 4) Table F.1 – Disturbance voltage and current limits for group 1 and group 2 equipment measured on a test site (antenna port).

Frequency Range	Class A	Class A	Class B	Class B
	Peak	Average	Peak	Average
1 to 3 GHz	76	56	70	50
3 to 6 GHz	80	60	74	54

Table 1: Table 11 in CISPR 11, Seventh Edition, on “Electromagnetic disturbance limits for group 1 equipment measured on a test site – Limits for a measurement distance of 3 meters in decibels above one microvolt per meter (dBuV/m)”

Frequency Range	Class A	Class A	Class A	Class A	Class B	Class B	Class B	Class B
	QP	AVE	QP	AVE	QP	AVE	QP	AVE
	dBuV	dBuV	dBuA	dBuA	dBuV	dBuV	dBuA	dBuA
0.15 to 0.5 MHz	97 to 87	84 to 74	53 to 43	40 to 30	84 to 74	74 to 64	40 to 30	30 to 20
0.5 to 30 MHz	87	74	43	30	74	64	30	20

Table 2: Table 7 in CISPR 11, Seventh Edition, on “Limits for conducted disturbances measured on a test site (wired network port)”

The fourth significant change introduces definitions for various types of robots. They include:

1. *3.1.30 – robot* – programmed actuated mechanism with a degree of autonomy to perform locomotion manipulation or positioning;
2. *3.1.20 – industrial robot* – automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or fixed to a mobile platform for use in automation applications in an industrial environment; and
3. *3.1.22 – medical robot* – robot intended to be used as medical electrical equipment or medical electrical system.

The fifth significant technical change is consideration of measurement setups and operating modes of robots. This is covered in two paragraphs, four figures, and two tables.

Paragraph 7.5.4 is titled “Measurements of Robots,” and it addresses radiated emissions, EUT arrangements, fixed robots, and mobile robots. Example setups for floor-standing robots are shown in Figures 6 and 7 in the Seventh Edition of CISPR 11 (conducted and radiated emission measurements, respectively). Figures 8 and 9 in the standard show an example of a combination EUT (floor-standing and tabletop/wall-mount units).

Paragraph 7.6.11 (Robots) initially states “Robots shall be tested in operating modes and under load conditions which are representative of normal use in the intended application according to the instruction manual.”

OTHER DETAILS IN THE SEVENTH EDITION

Product Family EMC Standard

The new Edition has the status of a Product Family EMC Standard in accordance with IEC Guide 10-7, *Electromagnetic Compatibility – Guide to the drafting of electromagnetic publications (2014)*.

CISPR Recommendation No. 39/2

The main content of the Seventh Edition is based on CISPR Recommendation No. 39/2 – *Limits and Methods of Measurement of Electromagnetic Disturbance Characteristics of Industrial, Scientific, and Medical (ISM) Radio-Frequency (RF) Equipment*, which states:

Operation Mode	Description
Mode 1	The robot is powered on but in its idle mode of operation (static state)
Mode 2	Normal operation mode at rated load, rated speed, defined maximum pose and trajectory (e. g., cube location which refers to l6,8 of ISO 9283:1998)
Mode 3	Similar to Mode 2., but with all corresponding parameters (e.g., load) set at approximately the middle of their specified range.

Table 3: Table 22 in CISPR 11, Seventh Edition, “Operation Modes for Fixed Robots”

Operation Mode	Description
Mode 1	Batter Charging Mode: the battery charging level is less than or equal to 20% of the test and remains less than 80% for the entire duration of the test; the robot is in charging mode , with its main function idle.
Mode 2	Normal separation mode at rated load and at rated speed. If the robot cannot operate at the same time at its rated load and rated speed, these two modes shall be evaluated in turn.
Mode 3	Similar to Mode 2, but with all corresponding parameters (e.g.,load) set at approximately the middle of their specified range.

Table 4: Table 23 in CISPR 11, Seventh Edition, “Operation Modes for Mobile Robots”

“The CISPR, considering:

- a. That ISM RF equipment is an important source of disturbance;*
- b. That methods of measuring such disturbances have been prescribed by the CISPR; and*
- c. That certain frequencies are designated by the International Telecommunication Union (ITU) for unrestricted radiation from ISM equipment,*

Recommends that the latest edition of CISPR 11 be used for the application of limits and methods of measurement of ISM equipment.”

CISPR 11, EDITION 6.0

Amendment 2 to CISPR 11, Edition 6.0, 2019-01

Amendment 2 combines two principal changes to Edition 6.0. One addresses semiconductor power converters (SPC) and the other “improvement of repeatability for measurements in the frequency range 1 – 18 GHz.”

Type test requirements were added for two SPC systems: 1) power conversion equipment intended for assembly line photovoltaic power generating systems, such as grid connected power converters (GCPCs) and direct current to direct current converters; and 2) GCPCs intended for assembly into energy storage systems.

The improvement of measurements in the 1 to 18 GHz range involves group 2 equipment operating at frequencies above 400 MHz. The measurements can be made with two different weighting functions: the traditional “LogAV detector” with a video bandwidth of 10 Hz and the new amplitude probability distribution (APD) method.

Amendment 1 to CISPR 11, Edition 6.0, 2016-06

This Amendment introduced the fully-anechoic room (FAR) for measurements of the disturbance field strength in the range 30 MHz to 1 GHz on equipment in the scope of CISPR 11. It contains the complete set of requirements for measurement of radiated disturbances from equipment fitting into the validated test volume of a given FAR. It specified a separation distance of 3 meters and restricts use of the FAR to measurements on table-top equipment.

CISPR 11, Sixth Edition, 2015-06

The sixth edition cancelled and replaced the fifth edition published in 2009 and its Amendment 1 published in 2010. It constituted a technical revision. It introduced type testing of components of power electronic equipment, systems, and installations. Its emission limits were newly applied to low voltage (LV) alternating current and direct current power ports, irrespective of the direction of power transmission.

Several limits were adapted to the practical test conditions found at test sites. They are also applicable to power electronic ISM RF equipment used for wireless power transfer (WPT), for instant power supply and charging purposes.

The limits in the range 1 to 18 GHz were applied to continuous wave (CW)-type disturbances and to fluctuating disturbances in a similar, uniform, and



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technology-neutral way. The measurements may be made with traditional Log-AV or the newer (APD) method.

For measurements at (LV) direct current power ports of power electronic equipment, a modern

implementation of the 150-ohm delta-network specified in CISPR 16-1-2 has been made available.

The Sixth Edition also included general maintenance items to address other technical issues in the fifth edition of the standard.

CISPR 11 – Edition 1 – 1975	CISPR 11 – Edition 5 - 2009
Foreword	Foreword
Preface	Introduction
1 – Scope	1- Scope
2 – Object	2 – Normative References
3 – Definitions	3 – Terms and Definitions
4 – Limits of Interference	4 – Frequencies Designated for ISM Use
5 – Methods of Measurement	5 – Classification of ISM Equipment
6 – Safety Precautions	6 – Limits of Electromagnetic Disturbance
Appendix A – Precautions to be taken in the use of a Spectrum Analyzer	7 – Measurement Requirements
Appendix B – Propagation of Interference from industrial RF equipment at frequencies between 30 MHz and 300 MHz	8 – Special Provisions for Test Site Measurements (9 kHz to 1 GHz)
Appendix C – Artificial Mains Networks for currents between 25 amps and 100 amps	9 – Radiation Measurements – 1-18 GHz
	10 – Measurements in situ
	11 – Safety Precautions
	12 – Assessment of Conformity of Equipment
	13 – Figures and Flowcharts
	Annex A (Informative) – Examples of Equipment Classification
	Annex B (Informative) – Precautions to be taken in the use of a Spectrum Analyzer (see 6.3.1)
	Annex C (Normative) – Measurement of Electromagnetic Radiation disturbances in the presence of signals from radio transmitters
	Annex D (Informative) – Propagation of Interference from industrial radio frequency equipment at frequencies between 30 MHz and 300 MHz
	Annex E (Informative) – Recommendations of CISPR for protection of certain radio services in particular areas
	Annex F (Informative) –Frequency Bands allocated for safety-related radio services
	Annex G (Informative) – Frequency Bands allocated for sensitive radio services
	Bibliography

Table 5: Comparison of the first and fifth editions of CISPR 11

FIFTH EDITION—2009

Released in 2009, the Fifth Edition of CISPR 11 continued the long-standing practice of Group 1 and Group 2, Class A and Class B equipment classifications. The limits stated in the Fifth Edition were similar to the limits found in the Fourth Edition.

Table 5 presents a side-by-side comparison of the table of contents for the first edition and the fifth edition of CISPR 11, which clearly shows the growth in the length and complexity of the standard over a period of 35 years.

Clause 6 in the Fifth Edition represented a major overhaul from that in the Fourth Edition. Its main clause and sub-clause headings are as follows:

- Clause 6 – Limits of Electromagnetic Disturbance
 - 6.1 – General
 - 6.2 – Group 1 Measured on a Test Site
 - 6.3 – Group 2 Measured on a Test Site
 - 6.4 – Group 1 and Group 2 Class A Measured *in situ*
- Clause 7 added a new Sub-clause 7.1 (“General”) and a new Sub-clause 7.7 (“Recording of Test Site Measurement Results”).
- Clause 12 (“Assessment of Conformity of Equipment”) added a new Sub-clause 12.1 (“General”) and then the next three Sub-clauses were the same as Sub-clauses 11.1–11.3 in the fourth edition.
- Clause 13, titled “Figures and Flowcharts,” was new to this edition, as was Annex E.

The entire Fifth Edition was written to provide a more transparent structure. Table 17 in the standard was added with a title of “Electromagnetic Radiation Disturbance Limits for Class A (Group 1) Equipment Measured *in situ*.” It specifically addressed equipment with input power greater than 20 KVA.

Amendment 1 to the fifth edition was released in 2010. It created a new subset of equipment, “Small Equipment.” Small Equipment is defined as “equipment, either

positioned on a tabletop or standing on the floor which, including its cables, fits in a cylindrical test volume of 1.2 meters in diameter and 1.5 meters above the ground plane.”

Using this definition, Tables 4, 5, 9, 10, and 11 in the standard were modified to allow testing of Class A and B products meeting the small equipment definition to be tested at a three-meter test distance. The limit at three meters would be extrapolated from the typical test distance of 10 meters using an inverse-distance fall-off assumption (free-field).

FOURTH EDITION—2003

The Fourth Edition of CISPR 11 was published in March 2003. The fourth edition superseded the third edition (1997), along with its first amendment (1999) and its second amendment (2002).

There were a limited number of changes in the Fourth Edition from the Third Edition. The first two sentences in Clause 4 were changed to read:

“...the manufacturer and/or supplier of ISM equipment shall ensure that the user is informed about the class and group of the equipment, either by labeling or by the accompanying documentation. In both cases, the manufacturer/supplier shall explain the meaning of both the class and the group in the documentation accompanying the equipment.”

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Clauses 7.1 and 7.2 were interchanged from the Third Edition.

Clause 6.2.5 (“Artificial Hand”) was added to the Fourth Edition, as well as Figure 6 (“Artificial Hand, RC Element”). The concept of an artificial hand was introduced to simulate the effects of the user’s hand during the conducted emission measurements

The definitions of Group 1 ISM equipment, Group 2 ISM equipment, Class A equipment, and Class B equipment remained basically the same as that in the Third Edition.

With respect to limits of electromagnetic disturbance, Class A equipment could once again be measured either in a testing laboratory or *in situ* (as preferred by the manufacturer). However, the Fourth Edition continued to require Class B equipment to be measured in a testing laboratory.

The limits of terminal disturbance voltage (conducted emissions) gave the manufacturer two choices: 1) meet the average limit with an average detector and the quasi-peak limit with a QP detector; or 2) meet the average limit when using a QP detector. This was the same as stated in the Third Edition.

For radiated disturbances from 150 kHz to 1000 MHz, the limits stayed basically the same as those found in the Third Edition. Measurements were allowed at closer distances than the specified distances under certain considerations. In case of dispute, however, Class B (Group 1 and Group 2) and Class A (Group 1) were to be measured at a distance of 10 meters, while Class A (Group 2) were to be measured at a distance of 30 meters.

Receivers used for the measurements were expected to meet the criteria of CISPR 16-1. Requirements for the artificial mains network (LISN) remained the same as those in the third edition, that is, a 50 ohm/50 microhenry V-Network as specified in CISPR 16-1. The antennas used for measuring CISPR 11 products were also expected to meet CISPR 16-1 requirements. In a testing laboratory, the antenna must be raised and lowered from one to four meters in the frequency range 30 MHz to 1000 MHz. For measuring products *in situ*, the antenna’s center must be fixed at two meters above the ground.

Amendment 1 to the fourth edition was released in 2004. Primarily, Amendment 1 replaced Table 6 in the Fourth Edition with a new table that addressed Group 2 (Class A and Class B) ISM equipment producing CW type disturbances and operating at frequencies above 400 MHz.

Amendment 2 added CISPR 16-4-2:2003 to the Normative References. It also added a new Table 2c for mains terminal disturbance voltage for induction cooking appliances. It also modified Clauses 6.5.4 (microwave cooking appliances) and 6.5.6 (single and multiple-zone induction cooking appliances) to more closely match the IEC Product Standard. Amendment 2 also added Clauses 6.6 (“Recording of test-site measurement results”), 6.6.1 (“Conducted Emissions”), and 6.6.2 (“Radiated Emissions”).

Also, Clause 11.4 (“Measurement Uncertainty”) was added, stating that “determining compliance with the limits in this standard shall be based on the results of the compliance measurement, not taking into account measurement instrumentation uncertainty.” However, results of measurements of emissions from ISM equipment were supposed to reference the measurement uncertainty considerations contained in CISPR 16-4-2.

THIRD EDITION—1997

The Third Edition of CISPR 11 was also developed by CISPR Subcommittee B and was released in 1997. It replaced the second edition and its two amendments.

The third edition of the standard reorganized the first Clause, changing it from “Scope and Object” to “General,” and comprised of two Sub-clauses, “Scope and Object,” and “Normative References.”

Clause 6 of the second edition was renumbered as Clause 11 in the third edition, and Sub-clause 6.1, “Equipment in series production,” was replaced with Sub-clause 11.2, “Equipment in small scale production.”

A new Sub-clause 5.4, “Provisions for Protection of Specific Sensitive Radio Services,” was added in Clause 5, “Limits of Electromagnetic Disturbance.”

Clause 7 in the second edition became Clause 6 in the third edition; Clause 8 became Clause 7, Clause 9

became Clause 8, Clause 10 became Clause 9, and Clause 11 became Clause 10.

Annexes A – D remained the same in the third edition as in the second. Two new annexes were added, Annex E, “Safety-Related Service Bands,” and Annex F, “Sensitive Service Bands.”

The classification of equipment remained the same from the second to the third edition, that is, Group 1 and Group 2, and Class A and Class B.

With respect to the limits of electromagnetic disturbance, Class A equipment could still be tested either at a testing laboratory or *in situ*, while Class B equipment had to be measured in a testing laboratory.

The limits for conducted emissions on the power leads were measured from 150 kHz to 30 MHz using a 50-ohm/50-uH network. The limits remained the same for Class A and Class B equipment from the second edition of the standard, except that another category was added for Class A-Group 2 equipment for mains supply currents in excess of 100 amps per phase when using the CISPR voltage probe. The limits for this special case are shown in Table 6.

However, new limits were added in Table 2c in the standard (“Mains terminal disturbance voltage for inductive cooking appliances”) for Group 2-Class B equipment for both domestic and commercial cooking appliances.

Table 3 in the standard (“Electromagnetic radiation disturbance limits for group 1 equipment”) had a major change, as the measurement distance for Group 1-Class A equipment was changed from 30 meters to 10 meters with a corresponding increase in limits of 10 dB (assuming an inverse distance fall-off of the radiated electromagnetic field).

Clause 5.2.2 of the third edition also introduced the concept of measuring products at shorter distances than the specified measurement distances for radiated disturbances. For example, it allowed Group 2-Class A equipment to be measured at a distance of between 10 and 30 meters instead of 30 meters. Also, it allowed Group 1 and 2-Class B, equipment to be measured at antenna distances between three and 10 meters. However, it stated that “in case of dispute, Class A-Group 2 equipment shall be measured at a distance of 30 meters; Class B-Group 1, Class B-Group 2, and Class A-Group 1 equipment shall be measured at a distance of 10 meters.”

Tables 3a and 3b were added in the third edition to cover Group 2 induction cooking appliances for Class B and Class A, respectively. Table 3a (“Limits of the magnetic field induced current in a 2-m loop antenna around the device under test”) was intended to use the Van Veen Loop Method measurement method as per CISPR 16-2. Table 3b (“Limits of the magnetic field strength”) is measured at a three-meter antenna distance with a 0.6 meter loop antenna as described in CISPR 16-1.

Table 4 in the standard (“Electromagnetic radiation disturbance limits for Group 2-Class B equipment measured on a test site”) added a new column of requirements, that the quasi-peak magnetic field (measured at three meters) will not exceed 39 dBuAmp/meter decreasing linearly with the logarithm of the frequency to 3 dBuAmp/meter from 150 kHz to 30 MHz.

Table 5 in the standard changed the measurement distance from 30 meters to 10 meters and increased the limits by 10 dB from the limits found in the second edition.

Frequency Band – MHz	Class A – Group 2 Equipment Limit - dBuV	Class A - Group 2 Equipment Limit - dBuV
	<i>Quasi-Peak</i>	<i>Average</i>
0.15 – 0.50	130	120
0.50 – 5.0	125	115
5.0 - 30	115	105

Table 6: Special case limits for conducted emissions, CISPR 11, Third Edition

Table 6 was added to the third edition of CISPR 11. It was entitled “Electromagnetic radiation disturbance peak limits for Group 2-Class B ISM equipment producing CW-type disturbances and operating at frequencies above 400 MHz.” Table 7 (“Electromagnetic radiation disturbance peak limits for Group 2-Class B ISM equipment producing fluctuating disturbances other than CW and operating at frequencies above 400 MHz”) and Table 8 (“Electromagnetic radiation disturbance weighted limits for Group 2-Class B ISM equipment operating at frequencies above 400 MHz”) were also added.

Clause 5.4 (“Provisions for protection of specific sensitive radio services”) was added to the third edition. It referenced a new Annex F which gave examples of bands to be protected.

The same general measurement conditions existed as in the previous edition which is that Class A equipment could be measured at a test lab or *in situ*. Class B equipment had to be measured on a test site (in a test lab).

For equipment on a turntable, the distance to the antenna was measured from the center of the turntable. For equipment not on a turntable, the distance to the antenna was measured from the edge of the equipment.

Paragraph 6.5.6 (“Single and multiple-zone induction cooking appliances”) was added to the third edition.

Amendment 1 to the Third Edition added requirements for ISM lighting apparatus operating in the frequency bands of 915 MHz, 2.45 GHz, and 5.8 GHz. It also added IEC 60705:1999 (“Household microwave ovens – methods for measuring performance”) to the normative standards. It also added new words in Clause 5.2.2 (discussed earlier) and it added a new Table 5 (“Electromagnetic Radiation disturbance limits for Group 2 – Class A equipment”). All new wording was added to Clause 5.2.3 by Amendment 1. In Clause 6.2.1, it added the requirement that “for measurements at frequencies above 1 GHz, a spectrum analyzer with characteristics as defined in CISPR 16-1 shall be used.” Additionally, in Clause 6.2.4, it added the words “for measurements at frequencies above 1 GHz, the antenna used shall be as specified in CISPR 16-1.” Also, Clause 6.5.4 (“Microwave cooking appliances”) was added by Amendment 1.

An important (and somewhat controversial) Sub-clause was added by Amendment 1 in Clause 7.1.3 (“Radiation measurements [9 kHz to 1 GHz]”). It added two sentences that impacted the third edition and subsequent editions. The first sentence said “for the test site measurements, an inverse proportionality factor of 20 dB per decade shall be used to normalize the measured data to the specified distance for determining compliance.” Also, it added the parenthetical sentence, “care should be taken in measuring a large test unit at 3 meters at a frequency near 30 MHz due to near-field effects.” It deleted a key sentence from the second edition that said “at the closer measurement distance the electromagnetic disturbances measured shall not exceed the limit values specified in Clause 5.” In Sub-clause 8.2 it added the sentence “the distance between the receiving antenna and the EUT shall be 3 meters.” Sub-clauses 8.3 (“Validation and calibration of test site”) and 8.4 (“Measuring Procedure”) were completely rewritten. Finally, Amendment 1 added Figure 5 (“Decision tree for the measurement of emissions from 1 GHz to 18 GHz of Class B-Group 2 ISM equipment operating at frequencies above 400 MHz”).

Amendment 2 replaced “spark erosion equipment” with “electro-discharge machining (EDM) and arc welding equipment.” It also made additional editing changes to several Sub-clauses.

SECOND EDITION—1990

The Second Edition of CISPR 11 was released in 1990, and it contained numerous changes from the original 1975 Edition, as well as two amendments.

In this Edition, ISM Equipment was divided into two groups and two classes. Group 1 equipment included all ISM equipment that used RF energy only for internal functioning of the equipment, while Group 2 equipment included ISM equipment used for external treatment of material and similar processes. Class A equipment is equipment suitable for use in all establishments other than domestic buildings, while Class B equipment is equipment suitable for use in domestic surroundings.

The frequency bands for conducted emissions were stated as covering 150 kHz to 30 MHz. The second edition included new separate limits for Class A and

Class B equipment. The Class A-equipment limits in dBuV are shown in Table 7.

The Class B-equipment Limits in dBuV are shown in Table 8.

Electromagnetic radiation disturbance limits in dBuV/m for Group 1 equipment in Edition 2 are shown in Table 9.

There were additional limits for radiated emissions for Group 2 equipment. In the frequency range 1 GHz to 18 GHz, the limit for radiation disturbance power was 57 dB above a picowatt (effective radiated power), referred to a half-wave dipole in the narrow frequency range 11.7 GHz to 12.7 GHz.

The standard used statistics for compliance conclusions. Clause 6.1 stated “it cannot be shown that equipment in series production fails to meet the requirements of this publication without a statistical assessment of compliance being carried out.”

In the General Measurements Requirements clause, the standard provided for the measurement of Class A equipment either on a test site or *in situ* as determined by the manufacturer. However, the standard mandated that Class B equipment be tested and measured in a testing laboratory only.

Measuring equipment used by a testing lab had to comply with CISPR 16. Receivers needed both average and quasi-peak capability. An artificial mains network (LISN) was needed for conducted emissions, and it was a 50 ohm-50 microhenry network. Antennas used included a loop antenna below 30 MHz and a balanced-dipole antenna from 30 MHz to 1000 MHz. Measurements were made in both horizontal and vertical polarizations. Class A equipment was measured with the center of the antenna three meters above ground while, for Class B equipment, the center of the antenna had to be adjusted to between one and four meters.

Frequency Band – MHz	Group 1 – Quasi-Peak	Group 1 - Average	Group 2 – Quasi-Peak	Group 2 - Average
0.15 - 0.50	79	66	100	90
0.50 - 5.0	73	60	86	76
5 - 30	73	60	90 decreasing with logarithm of frequency to 70	80 decreasing with logarithm of frequency to 60

Table 7: Class A limits for conducted emissions, CISPR 11, Second Edition

Frequency Band – MHz	Quasi-Peak	Average
0.15 – 0.50	66 decreasing with logarithm of frequency to 56	56 decreasing with logarithm of frequency to 46
0.50 – 5	56	46
5 – 30	60	50

Table 8: Class B limits for conducted emissions, CISPR 11, Second Edition

Frequency Band – MHz	Group 1 – Class A – 30 meters	Group 1 – Class B – 10 meters	Group 1 – Class A – 30 meters from wall
0.15 – 30	X	X	X
30 -230	30	30	30
230 – 1000	37	37	37

Table 9: Electromagnetic radiation disturbance limits, CISPR 11, Second Edition

The testing laboratory had to meet special provisions for measuring radiated emissions, including a minimum-sized ground plane, and an area free of reflecting structures and also large enough to allow for the appropriate separation of the equipment under test and the receiving antenna.

Amendment 1 to the second edition was released in March of 1996. It changed some conducted emission limits, especially for Class A equipment. Amendment 2 was also released in March of 1996 and it contained limits for induction cooking appliances for both conducted limits and radiated magnetic field limits. Amendment 2 also modified radiation limits for Group 2 equipment.

FIRST EDITION—1975

The title of the Premiere Edition was “Limits and Methods of Measurement of Radio Interference Characteristics of Industrial, Scientific, and Medical (ISM) Radio-Frequency (RF) Equipment (Excluding Surgical Diathermy Equipment).” It summarized the technical content of a significant number of CISPR publications, recommendations, and reports over a period of eight years, from 1967 to 1975.

The frequency range covered by the first edition of the standard was 150 kHz to 18 GHz. The terminal voltage limits were quoted in millivolts and covered the frequency range 150 kHz to 30 MHz. Terminal

Frequency Range – MHz	Limits in millivolts (mV) for microwave ovens with RF power of 5 kW or less	Limits in millivolts (mV) for all other ISM equipment
0.15 – 0.20	2	3
0.20 – 0.50	2	2
0.50 – 5.0	1	1
5.0 – 30.0	2	1

Table 10: Terminal voltage limits, CISPR 11, First Edition (Table I)

Frequency Range – MHz	On a Test Site, at a distance from the equipment of 30 m	On a Test Site, at a distance from the equipment of 100 m	Not on a Test Site, at a Distance of 30 m from the boundary of user’s premises	Not on a Test Site, at a Distance of 100 m from the boundary of user’s premises	Not on a Test Site, at a Distance of 300 m from the equipment
0.15 – 0.285	-	50 uV/m (34 dBuV/m)	-	50 uV/m (34 dBuV/m)	-
0.285 – 0.49	-	250 (48)	-	250 (48)	-
0.49 – 1.605	-	50 (34)	-	50 (34)	-
1.605 – 3.95	-	250 (48)	-	250 (48)	-
3.95 – 30	-	50 (34)	-	50 (34)	-
30 – 470	30 (30) – In TV Bands 500 (54) – Outside TV Bands	-	30 (30)*	50 (34)**	200 (46)
470 - 1000	100 (40) – In TV Bands 500 (54) – Outside TV Bands	-	100 (40)* 500 (54)**	-	200 (46)

* - Compliance with these limits is required only for the TV channels in use at any time at the site

** - Limits for use outside the TV channels in use at the time at the site

Table 11: Table 2 in the Standard, based on Limits of radiation, CISPR 11, First Edition (Table II)

voltage limits from the first edition are reproduced in Table 1 of the standard (see Table 10).

The radiated limits were quoted in microvolts per meter for the frequency range 0.150 MHz to 1000 MHz. They were quoted at antenna-measurement distances of 30, 100, and 300 meters from the equipment or 30 meters or 100 meters from the boundary of the users' premises. Limits of radiation in microvolts/meter and decibels (uV/m)] from the first edition was recreated in Table 2 in the standard.

There was a special limit for radiation from microwave equipment used for heating and medical purposes in the frequency range from 1-18 GHz; it was 57 dB above a picowatt effective radiated power (ERP), referred to a half-wave dipole.

Methods of measurement quoted CISPR Publications 1, 2, and 4 for quasi-peak measuring sets. Measurement of the radio-frequency voltage on supply mains (AC voltage lines) was conducted with a V-network with an intrinsic impedance of 150 ohms.

Magnetic field measurements are made with a balanced loop antenna below 30 MHz. For signals greater than 30 MHz, an "electric aerial" would be used as per CISPR Publications 2 and 4. The center of the "aerial" would be 3 meters above the ground.

Above 1 GHz, the "receiving aerial" was to be made with a directive aerial of small aperture capable of making separate measurements of the vertical and horizontal components of the radiated field. The height of the aerial had to be the same as the height of the approximate radiation center of the equipment under test.

CONCLUSION

The CISPR 11 standard for measuring disturbances (emissions) from ISM equipment has been in existence for 50 years. It has grown from a simple document to a complex document involving several types of products. It has grown from measuring products at a larger distance (100 meters and 30 meters) for Class A equipment to measuring them at three meters. Class B equipment measurement distances have shrunk to three meters, the distance used in the U.S. since the release in 1979 of FCC's rules on personal computer emissions. 



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MINIMIZING RISK WHEN BUYING OR SELLING A COMPANY

The Use of Product Safety Experts is Imperative



Over the years, I have been involved in a number of situations involving product liability issues arising out of the purchase or sale of a business or product line. In my experience, either the buying company (“buyer”) or the selling company (“seller”) does not perform adequate due diligence when analyzing risks. They always use experienced merger and acquisition counsel who can advise on how to structure the deal and generally the kind of due diligence that should be performed. But they rarely retain a product liability and product safety lawyer to help evaluate certain pre-transaction and post-transaction risks and make recommendations on the specifics of the sales contract.

This article will discuss this subject from the perspective of the buying company, as well as the selling company.

BUYER

First, let us talk about the risks of acquiring a business or product line.

As the head product liability lawyer in a Fortune 500 company, I was periodically asked to evaluate a potential acquisition from a product liability standpoint. This usually just involved reviewing the list of product liability cases that have been brought against the company over the past few years. I was

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By Kenneth Ross, Senior Contributor

not asked to delve into the safety of a product and the way they did business to try to identify potential legal problems before they arose.

In addition, after I entered private practice, I served as an expert witness in litigation involving the acquisition of a manufacturer. Shortly after the acquisition, the buyer had to undertake a recall of the product. The buyer sued the seller and alleged that the seller hid the fact that the product would have to be recalled.

I represented the seller. While the buyer did use competent product liability counsel to help evaluate future product liability risks involving these products, I testified that this counsel did not see or appreciate disclosed information that would have indicated that a recall at some point in the future would need to be considered and possibly undertaken. I testified that the documentation that the seller provided to the buyer was sufficient to alert them to this possibility and that the seller was not hiding anything.

These experiences have made me sensitive to the necessity to be proactive during the due diligence process and to be sure that the buyer and seller understand the short-term and long-term risks of proceeding with the transaction and the ways that risk can be minimized.

No matter what analysis is performed pre-acquisition, it is possible that the buyer may assume liabilities that even the selling company is not aware of. And rarely are experienced product safety lawyers asked to audit a selling company's product line or corporate structure to help determine if the products they have been selling are reasonably safe and have minimal risks.

So, in addition to reviewing the facts surrounding the disclosed incidents and lawsuits, product liability or product safety counsel, along with experienced safety

professionals, should also review the design process, the warnings and instructions, the sales and purchase contracts for the product, the marketing, the insurance contracts in place, any recalls or safety campaigns that have been taken by the seller, and the product safety policies and procedures of the seller and the major suppliers to the seller applicable to safety-critical components or raw materials.

Examples of Buyers' Exposure

Some of the problems with disclosed and undisclosed product liability risks assumed by acquiring companies are legendary. There have been many stories of large, sophisticated companies that have purchased product lines or companies and were then hit with huge product liability problems. One recent situation that comes to mind is 3M's purchase of Aearo Technologies in 2007. Aearo sold combat arms earplugs to the military from 2003 until 2015. These earplugs allegedly caused injuries to thousands of service members. 3M settled a good chunk of these cases for \$6 billion in 2023, but many cases remain. And 3M attempted to have Aearo file for bankruptcy to get rid of the remaining cases, but the courts have rejected this attempt.

In the 1980s, Monsanto purchased G.D. Searle, a manufacturer of the Copper-7 IUD. Litigation against IUD manufacturers was just starting and expanding as there was other litigation involving the Dalkon Shield, an IUD made by A.H. Robins, which bankrupted the company. As a result of hundreds of lawsuits, G.D. Searle stopped the sales of this IUD in 1986. Given the Dalkon Shield litigation, you wonder why Monsanto wanted to buy an IUD manufacturer without doing significant research on the Copper-7 to confirm its safety.

Monsanto was also involved in another disastrous acquisition. This time, it was Bayer's acquisition of Monsanto in 2018, which included its chemical

product, Roundup. Roundup has been involved in significant litigation for many years, and Bayer has already paid \$10 billion to settle earlier cases and has had to set aside almost \$6 billion this year for pending cases. And individual liability verdicts are still occurring. In March of this year, a jury awarded \$2.1 billion to a farmer who claimed that Roundup caused his cancer.

In all of these situations, a sophisticated company bought a product line that might have already had product liability issues. Or they failed to conduct adequate pre-acquisition analysis that would have enabled them to discover the risk of future litigation before the purchase. Competent lawyers surely helped structure these deals, but in the end the acquiring company had to shoulder the sometimes-enormous financial burden.

The Importance of a Safety Audit

So, what should an acquiring company do before deciding to buy a business or product line? The most obvious step is for the buyer to be sure that the acquisition lawyers retain experienced product liability or product safety counsel and independent product safety professionals to do an in-depth audit of the company or product line to be acquired. This audit should go well beyond the actual incidents and litigation that have been disclosed.

If this audit is done, and the buyer still wants to proceed, they should plan for eventual litigation or safety issues arising in the future. So, there should be contractual provisions that will apply if there are lawsuits or recalls involving products manufactured by the seller. Most importantly, who is going to be responsible for new litigation and safety issues involving products manufactured pre-acquisition? Decisions must be made regarding who will retain the documents needed for defense, which personnel are required to handle the case and their employer affiliations, and whether the seller's employees can provide assistance while remaining in the seller's employ.

This audit should help the buyer decide whether to buy the company or product line, what kinds of improvements need to be made in the products or procedures for designing future products, and whether any recall or post-sale warning to consumers of the pre-acquisition products may be necessary.

I suspect that, in the majority of deals, the buyer will not assume liability for products sold by the seller. This is usually done by making it an asset purchase and not a complete purchase of the company. Despite doing this, there are ways for the courts to place liability on the buyer even though they did not make or sell the product involved in the purchase that injured someone. These theories place liability on the successor when there has been fraud in the sale of the business to get rid of liability or in cases in which the injured parties have no recourse against the seller since the seller is out of business and there is no one that will be responsible.

This means that the buyer should structure the deal so that the seller or its insurance company is available to compensate any deserving injured party. But even if this is done, the buyer needs to decide if it really wants to buy a company that has had lots of lawsuits and will have more lawsuits that will generate bad publicity. If the seller is responsible for defending cases involving its products, the buyer loses control over the handling of the litigation. Settlements or plaintiffs' verdicts suffered by the seller could generate new lawsuits against the buyer, which would harm its reputation and business relationships.

SELLER

Let us now turn to the perspective of the selling company.

Wouldn't it be nice if manufacturers could sell the part of their business that had the biggest product liability risk and be done with it? Unfortunately, it is not that easy. If you can convince the buyer to assume all current and future risks, and if it is still in business and can adequately cover the risk when an incident occurs, then the seller will be protected.

However, since the buyer usually does not want to assume risks on products that were sold prior to the date of their acquisition, the seller may still have to defend cases on products it sold despite no longer owning the business. This raises serious potential problems for both buyers and sellers.

When I was in-house counsel, my company tried to sell a division that had lots of lawsuits. No one would buy it and assume responsibility for products manufactured prior to the acquisition. So, we kept the liability and were responsible for defending lawsuits



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for many years. Ultimately, my company recalled all of the products it manufactured. We experienced many of the serious problems discussed here.

The buyer will usually inherit the personnel, documents, and assets of the business that it acquires. As a result, the seller, who must defend pending and future cases it is responsible for, may not be able to defend itself easily.

After an acquisition, the buyer should immediately evaluate the quality and safety of the products it has acquired and make appropriate design or safety changes for future production. As a result, it is likely that there will be improvements in various aspects of the product, including the design, warnings, and instructions.

In reality, even if the buyer is not legally responsible for products sold before acquisition, the reputation of their products is a significant asset, and the buyer wants it protected. To obtain such protection, the buyer might decide to make a safety improvement and want to offer the improvement to prior customers. Or it may want to undertake a retrofit or recall of products in the field. In either case, the buyer will need the seller's cooperation and maybe approval to make these improvements.

These kinds of activities by the buyer can create big problems for the seller as it attempts to defend pending lawsuits. One way to prove that the product was defective at the time of sale is to show that the manufacturer improved its manufacturing procedures or started to sell products with improved designs, warnings, and instructions sometime after the accident. Even though the buyer is a different company than the seller, the improvements show that they can be made, and that the successor company considered the improvements necessary.

SOME RECOMMENDATIONS FOR SELLERS

As a result, the seller needs to seriously consider the effect of the buyer's possible post-acquisition actions when entering into negotiations for the sale of the product or division. There should be an agreement as to when and how personnel and documents from the acquiring company are made available to the seller and whether the buyer will be compensated for its time and effort.

There should also be an agreement about whether the buyer needs to consult with the seller before making significant changes in manufacturing and design, so the seller can at least be aware of it before it comes up in a lawsuit. Although the seller may not be able to stop a manufacturing or design change by the buyer, it should be allowed to provide input about the appropriateness of the changes and help the buyer assess any risks that arise from making these changes.

In addition, there should be some agreement about whether the buyer needs the seller's permission before it reports a safety issue to the U.S. government or a foreign government entity and to undertake a recall. The matter of responsibility for the cost of any potential recall also needs to be discussed.

Of course, while all of these activities could seriously hamper the seller's ability to defend its cases, they could also damage the buyer's position in the marketplace and its ability to defend its future cases.

In addition to these agreements, the buyer and the seller should both agree to periodically discuss their litigation history and strategy. Adverse verdicts against one party will undermine the other's ability to defend itself in future litigation as well. Also, without this coordination, there are likely to be inconsistent positions taken on the products that are being defended by both the buyer and seller.

CONCLUSION

As a result of all of these considerations, given the significant potential problems we've identified in this article, the buyer should seriously consider assuming all liability for products sold before the sale in order to control its own fate and eliminate the risk of a seller creating future risks for the buyer. If an audit is performed, the buyer will hopefully have a reasonably good idea of future risk and can price that risk into the purchase price, as well as determine whether the transaction should also include a monetary hold-back from the seller's proceeds to pay for future liabilities that will be the financial responsibility of the buyer. 



PRODUCT Showcase



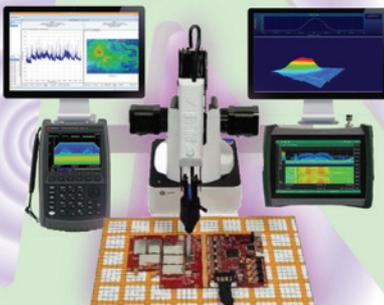
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SHIELDING TO PREVENT RADIATION

Part 2: Uniform Plane Wave Normal Incidence on a Conducting Shield

By Bogdan Adamczyk

This is the second 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. This article discusses the normal incidence of a uniform plane wave on a solid conducting shield with no apertures.

UNIFORM PLANE WAVE INCIDENT ON A SHIELD IN FAR FIELD

Consider a conducting shield of thickness t , conductivity σ , permittivity ϵ , and permeability μ , surrounded on both sides by air (free space, and thus a perfect dielectric), as shown in Figure 1 [2].

A uniform plane wave is normally incident on its left interface. Uniformity assumption, together with normal incidence, means that the shield is in the *far field* of the radiation source.

The **incident wave** upon arrival at the leftmost boundary (\vec{E}_i, \vec{H}_i) will be partially **reflected** (\vec{E}_r, \vec{H}_r) and partially **transmitted** (\vec{E}_1, \vec{H}_1) through the shield. The transmitted wave (\vec{E}_1, \vec{H}_1) upon arrival at the rightmost boundary will be partially **transmitted** (\vec{E}_t, \vec{H}_t) through the shield.

The reflected wave (\vec{E}_2, \vec{H}_2) propagates back through the shield and strikes the first interface, incident from the right.

Once again, a portion of this wave is transmitted through the left interface and adds to the total reflected field in the left medium, and a portion is reflected and proceeds to the right.

The process continues in the same fashion, but the additional reflected and transmitted fields are progressively

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attenuated. If a shield has a thickness that is much greater than the skin depth of the material [3] at the frequency of the incident field, these multiple reflections and transmissions can be disregarded, and only the initial reflection and transmission at the left and right interfaces need to be considered.

The **incident wave** is described by (since air is treated as a perfect dielectric $\alpha_0 = 0$ and $\hat{\gamma}_0 = \alpha_0 + j\beta_0 = j\beta_0$)

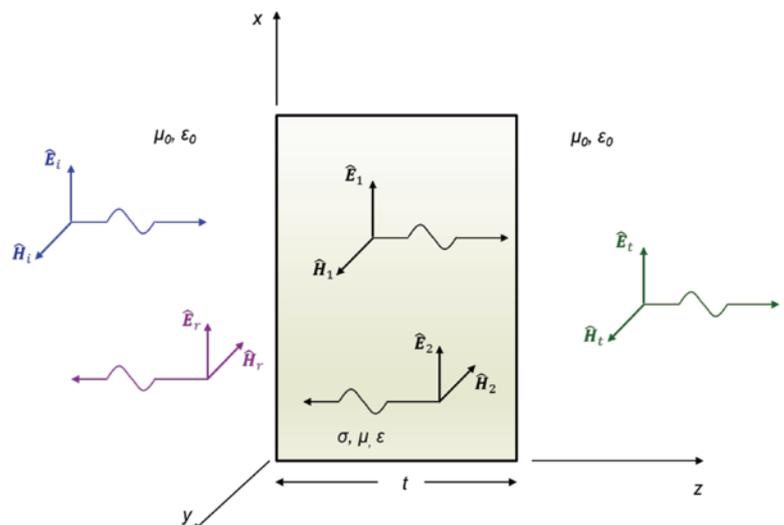


Figure 1: Uniform plane incident on a conducting shield

$$\hat{E}_i = \hat{E}_i e^{-j\beta_0 z} \mathbf{a}_x \quad (1a)$$

$$\hat{H}_i = \frac{\hat{E}_i}{\eta_0} e^{-j\beta_0 z} \mathbf{a}_y \quad (1b)$$

where

$$\beta_0 = \omega \sqrt{\mu_0 \epsilon_0} \quad (2)$$

$$\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \quad (3)$$

The reflected wave is described by

$$\hat{E}_r = \hat{E}_r e^{j\beta_0 z} \mathbf{a}_x \quad (4a)$$

$$\hat{H}_r = -\frac{\hat{E}_r}{\eta_0} e^{j\beta_0 z} \mathbf{a}_y \quad (4b)$$

The wave transmitted through the left interface is described by

$$\hat{E}_1 = \hat{E}_1 e^{-\hat{\gamma} z} \mathbf{a}_x \quad (5a)$$

$$\hat{H}_1 = \frac{\hat{E}_1}{\hat{\eta}} e^{-\hat{\gamma} z} \mathbf{a}_y \quad (5b)$$

where

$$\hat{\gamma} = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} = \alpha + j\beta \quad (6)$$

$$\hat{\eta} = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}} = \eta e^{j\theta_\eta} \quad (7)$$

The wave reflected at the right interface is described by

$$\hat{E}_2 = \hat{E}_2 e^{\hat{\gamma} z} \mathbf{a}_x \quad (8a)$$

$$\hat{H}_2 = -\frac{\hat{E}_2}{\hat{\eta}} e^{\hat{\gamma} z} \mathbf{a}_y \quad (8b)$$

Finally, the transmitted wave through the right interface is described by

$$\hat{E}_t = \hat{E}_t e^{-j\beta_0 z} \mathbf{a}_x \quad (9a)$$

$$\hat{H}_t = \frac{\hat{E}_t}{\eta_0} e^{-j\beta_0 z} \mathbf{a}_y \quad (9b)$$

SHIELDING EFFECTIVENESS OF THE SHIELD IN FAR FIELD

The effectiveness of the shield, or shielding effectiveness, SE , can be determined by evaluating the ratio of the incident field magnitude to the transmitted field magnitude.

$$(SE)_E = \frac{|\hat{E}_i|}{|\hat{E}_t|} \quad (10a)$$

$$(SE)_H = \frac{|\hat{H}_i|}{|\hat{H}_t|} \quad (10b)$$

Since the wave is a uniform wave, the two definitions are identical, since the electric and magnetic field magnitudes are related by the intrinsic impedance of the medium.

Let's demonstrate that. Recall from the previous article, [1], that the uniform plane wave was described by

$$\hat{E}_x = \hat{E}_m^+ e^{-\alpha z} e^{-j\beta z} + \hat{E}_m^- e^{\alpha z} e^{j\beta z} \quad (11a)$$

$$\hat{H}_y = \frac{\hat{E}_m^+}{\eta} e^{-\alpha z} e^{-j\beta z} e^{-j\theta_\eta} - \frac{\hat{E}_m^-}{\eta} e^{\alpha z} e^{j\beta z} e^{-j\theta_\eta} \quad (11b)$$

The wave described by Equations (11) consists of the forward and backward propagating waves.

$$\hat{E}_x = \hat{E}_m^f + \hat{E}_m^b \quad (12a)$$

$$\hat{H}_y = \hat{H}_m^f + \hat{H}_m^b \quad (12b)$$

where the forward waves are described by

$$\hat{E}_m^f = \hat{E}_m^+ e^{-\alpha z} e^{-j\beta z} \quad (13a)$$

$$\hat{H}_m^f = \frac{\hat{E}_m^+}{\eta} e^{-\alpha z} e^{-j\beta z} e^{-j\theta_\eta} \quad (13b)$$

while the backward waves are described by

$$\hat{E}_m^b = \hat{E}_m^- e^{\alpha z} e^{j\beta z} \quad (14a)$$

$$\hat{H}_m^b = -\frac{\hat{E}_m^-}{\eta} e^{\alpha z} e^{j\beta z} e^{-j\theta_\eta} \quad (14b)$$

Let us concentrate on the forward propagating waves and look at their magnitudes. But before we do that let's look at a very important and useful Euler's identity, usually expressed in a manner similar to

$$e^{j\phi} = \cos \phi + j \sin \phi \quad (15)$$

and therefore

$$|e^{j\phi}| = |\cos \phi + j \sin \phi| = \sqrt{\cos^2 \phi + \sin^2 \phi} = 1 \quad (16)$$

It might not be apparent from Eq. (15) that Euler's identity is valid for any argument, whether it has a meaning or not. Just like this one

$$e^{j(\text{school bus})} = \cos(\text{school bus}) + j \sin(\text{school bus}) \quad (17)$$

since

$$|e^{j(\text{school bus})}| = \sqrt{\cos^2(\text{school bus}) + \sin^2(\text{school bus})} = 1 \quad (18)$$

which means that

$$|e^{j(\text{whatever})}| = 1 \quad (19)$$

Now, let's return to Equations (13) and obtain the magnitudes of the forward propagating uniform plane wave.

$$|\hat{E}_m^f| = |\hat{E}_m^+ e^{-az} e^{-j\beta z}| = |\hat{E}_m^+| |e^{-az}| |e^{-j\beta z}| \quad (20a)$$

$$|\hat{H}_m^f| = \left| \frac{\hat{E}_m^+}{\eta} e^{-az} e^{-j\beta z} e^{-j\theta_\eta} \right| = \left| \frac{\hat{E}_m^+}{\eta} \right| |e^{-az}| |e^{-j\beta z}| |e^{-j\theta_\eta}| \quad (20b)$$

or

$$|\hat{E}_m^f| = |\hat{E}_m^+| e^{-az} \quad (21a)$$

$$|\hat{H}_m^f| = \frac{|\hat{E}_m^+|}{\eta} e^{-az} \quad (21b)$$

Now, let's determine the ratio of the magnitude of the forward E wave to the magnitude of the forward H wave

$$\frac{|\hat{E}_m^f|}{|\hat{H}_m^f|} = \frac{|\hat{E}_m^+|}{\frac{|\hat{E}_m^+|}{\eta}} = \eta \quad (22)$$

Let's repeat the definition of the shielding effectiveness given by Equations (10), as Equations (23)

$$(SE)_E = \frac{|\hat{E}_i|}{|\hat{E}_t|} \quad (23a)$$

$$(SE)_H = \frac{|\hat{H}_i|}{|\hat{H}_t|} \quad (23b)$$

and let's concentrate on Eqn. (23b). The magnitudes of the incident and transmitted forward H waves are related to the magnitudes of the incident and transmitted forward E waves by

$$|\hat{H}_i| = \frac{|\hat{E}_i|}{\eta} \quad (24a)$$

$$|\hat{H}_t| = \frac{|\hat{E}_t|}{\eta} \quad (24b)$$

Thus,

$$(SE)_H = \frac{|\hat{H}_i|}{|\hat{H}_t|} = \frac{\frac{|\hat{E}_i|}{\eta}}{\frac{|\hat{E}_t|}{\eta}} = \frac{|\hat{E}_i|}{|\hat{E}_t|} \quad (25)$$

Which shows that the two definitions of the shielding effectiveness given by Equations (23) are identical.

Usually, we use definition in Eq. (23a) and express the shielding effectiveness in decibels. Then, the definition in Equations (24) becomes

$$(SE)_{dB} = 20 \log_{10} \frac{|\hat{E}_i|}{|\hat{E}_t|} \quad (26)$$

The objective of the next articles will be to determine the shielding effectiveness given by Equation (26). [📄](#)

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ADDRESSING AN INDUSTRY CONCERN: THE DEMAND FOR A CDM BARE DIE TESTING METHOD

By Lena Zeitlhofer, Theresa Lutz, Friedrich zur Nieden, Kai Esmark, and Reinhold Gaertner

On behalf of EOS/ESD Association, Inc.

BACKGROUND

The definition and verification of Charged Device Model (CDM) targets for single dies in 2.5D or 3D devices concerns the industry. Even if bare dies offer a low capacitance, recent studies have shown that significant discharge current levels can be reached during a CDM-like discharge, e.g., at a very low charging voltage of 5 V, 500 mA can be reached [1]. The question of whether existing CDM targets should be scaled down for bare dies to accommodate lower charging voltages is raised [2].

Testing of single bare dies using the field-induced CDM (FICDM) setup according to JS002 [3] standard is not possible. One issue is the difficulty of touching bare die pads with the pogo-pin, whose diameter can exceed the pad size. Moreover, FICDM testing at voltages below 20 V leads to unstable waveforms. The standardized testing setup does not reflect the real capacitance and peak current relationship due to the small dimensions and thickness of the dies, which affect CDM peak currents, rise times, and pulse widths. There are arguments for using alternative testing methods, such as CCTLP, to enable the testing of bare dies [4].

These challenges are addressed by an alternative approach that transforms CDM charging voltage into current using the parameter device volume and effective capacitance C_{eff} . This transformation [5] facilitates alternative testing methods like Capacitively Coupled Transmission Line Pulsing (CCTLP). The capacitance is proportional to the

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product dimensions. Besides the area, the thickness of a die influences the peak current.

CAPACITANCE AND VOLUME

CDM voltage can be translated into a CCTLP current level based on the capacitance and volume of the product [5]. 3D simulations with idealized metallic cuboids of various dimensions demonstrate that C_{eff} is directly proportional to the area, showing saturation as cuboids increase in size.

Figure 1 on page 48 shows the relation between device dimensions in volume versus the C_{eff} in a CDM tester. The solid lines represent the upper limit for a device dimension coming from the static capacitance simulation with fully metallic cuboids. The products always lay below the solid line, and the respective height is color-coded. The simulation shows that height itself has only an influence if the height itself surpasses the side length of the fully metallic body. For packaged devices, the experiments show a contrary effect in a way that the capacitance decreases with height. This is because the slimmer the packages, the more percentage of conductive material they include that contributes to the device capacitance.

PEAK CURRENT AND VOLUME

Figure 2 shows the maximum measured peak current at 500 V respective to its volume. It compares actual measurement results from products and simulation data from cuboids with varying square base dimensions from 0.3 mm to 60 mm x/y length and varied heights. The peak currents for real products always stay below their theoretical limit defined by the cuboids, making this a valuable worst-case estimation. The gap between the limit and real data is much smaller for slim packages than for packages with increased height. In some cases, the gap almost vanishes. The reason is that the “conductive” share of the package volume of slim packages (especially chip-scale packages) comes very close to the volume of metallic cuboids.

Bare dies are not incorporated in any package, and, therefore, deliver the largest C_{eff} values according to their body dimensions. The maximum peak current relative to their dimensions can be achieved for bare dies without packaging, highlighting the importance of a current-based target level. This can be deduced from Figure 3 for different packaged devices.

CONCLUSION

Waveforms for bare dies at low charging voltage of, e.g., 20 V, are very fast and can hardly be measured. The importance of such pulse parameters for device failure has been shown in [7] and [8]. In Figure 4, CCTLP waveforms of a bare die (2x2 mm²) referring to a CDM voltage of 20 V are shown. The measured CDM curves vary between 10 mA and 30 mA. The waveforms are presented for a 30 ps rise time.

The increasing prevalence of products with stacked dies necessitates defining and verifying design targets at low charging

voltage levels. Current CDM testing methods, specifically the FICDM tester, are inadequate for bare dies due to issues with contact and reproducibility. CCTLP, however, offers a method with reliable and stable testing even for low charging voltages, leading to currents in the mA range.

The dielectric layer in the FICDM setup significantly affects effective device capacitance and peak current, often doubling these values with a thinner layer. Stacking processes in production environments lack this dielectric layer, with sparks occurring at minimal distances. Bare dies can achieve higher peak currents

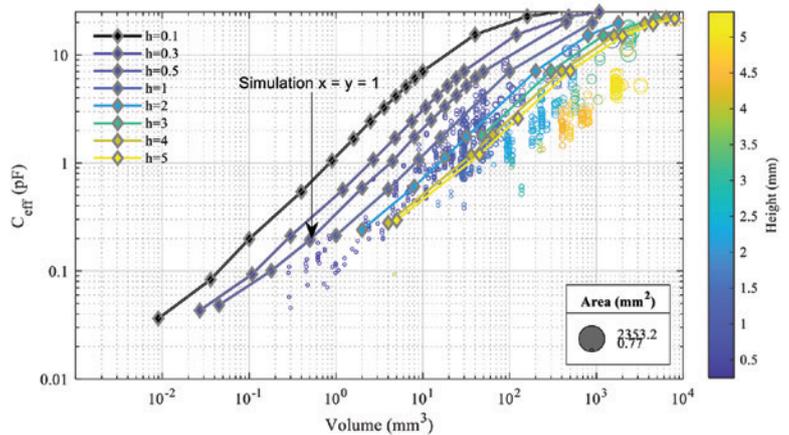


Figure 1: Simulated cuboid values with varying square base dimensions and heights (solid line) in comparison to calculated effective capacitance from the product’s current waveform integral extracted from the database. The red and green markers refer to the dimensions of the test devices in the standard CDM setup and a CDM setup with a tenfold reduced dielectric thickness.

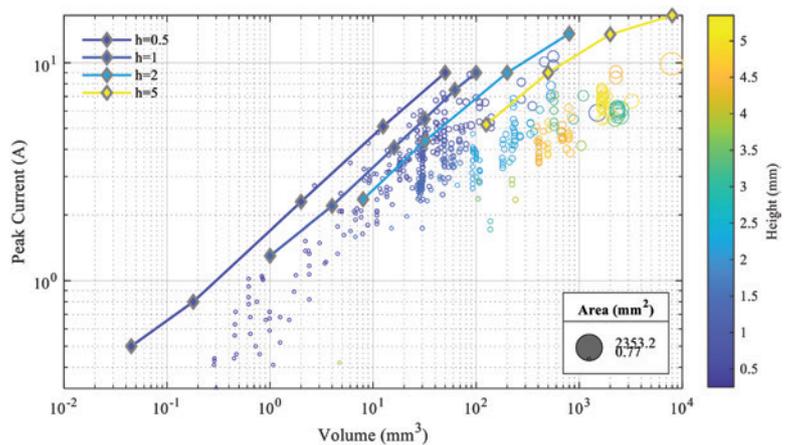


Figure 2: Comparison of upper limit for peak current of fully metallic cuboids in comparison to measured data for real products. Datasets focus on different values for the height of the package/cuboid from 0.5 mm and 5 mm.

The increasing prevalence of products with stacked dies necessitates defining and verifying design targets at low charging voltage levels.

relative to their dimensions, comparable to fully metallic cuboids in simulations. Time constants of waveforms for bare dies at low charging voltages differ markedly from those of packaged products, with fast events potentially exceeding 12 GHz. 

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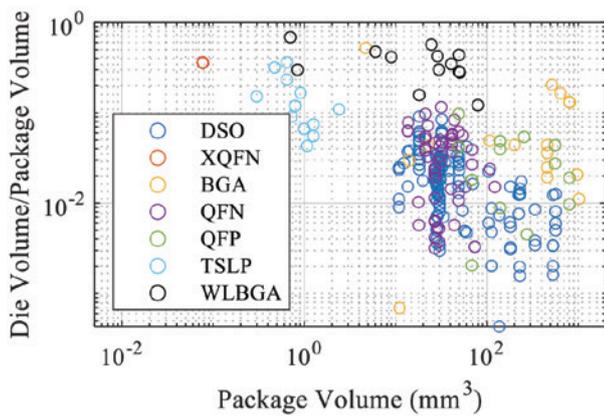


Figure 3: Volume of the die relative to the package volume for certain package types

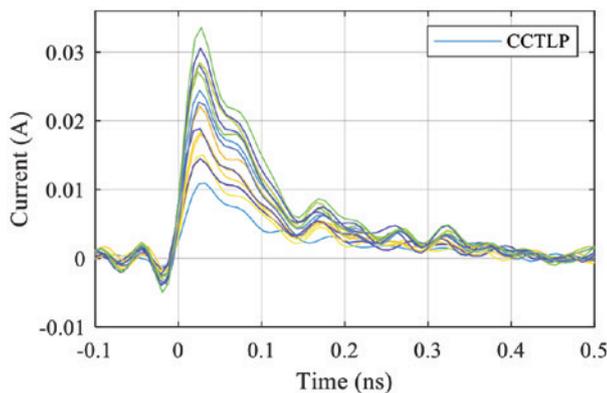


Figure 4: CCTLP waveforms of a bare die with size 2x2 mm. The current refers to a 20 V CDM charging voltage.

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