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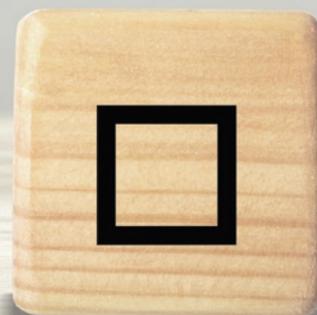
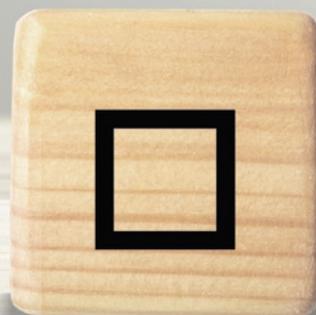
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ISO 17025 Accreditation  
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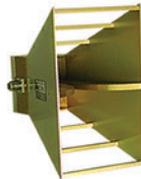
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# Expert Insights

A variety of expert perspectives on compliance design and testing, covering topics like EMC, EMI, and product safety.



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**Practical Engineering** with Don MacArthur provides actionable insights on key compliance topics like uncertainty analysis, PCB spacing, and electrical insulation systems to help engineers streamline development and excel in compliance engineering.

In **Product Insights**, Don MacArthur dives deep into practical EMI mitigation challenges, offering solutions for capacitor behavior, ferrite selection, differential probes, and more to optimize designs and advance engineering careers.

Ken Wyatt's **EMC Bench Notes** helps engineers identify and resolve EMC issues early in the design cycle using in-house pre-compliance testing tools, enhancing troubleshooting skills and reducing costly testing failures.

Patrick Andre's **Military and Aerospace EMC** shares valuable insights into EMC challenges in high-stakes environments like defense, aerospace, and military systems, offering engineers practical solutions and expertise.

Karen Burnham's **Standards Practice** explores immunity standards and advanced testing methods, helping engineers navigate compliance challenges in industries like defense, aerospace, and automotive with techniques like reverberation chamber testing.

Kimball Williams' **Signals and Solutions** connects the foundational techniques of amateur radio, such as Morse code, to modern EMC engineering, offering fresh perspectives on troubleshooting, testing, and innovation.

Full Collection of Blogs, Posts and Author Bios: <https://incompliancemag.com/expert-insights>



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**publisher/  
editor-in-chief** Lorie Nichols  
lorie.nichols@  
incompliancemag.com  
(978) 873-7777

**business  
development  
director** Sharon Smith  
sharon.smith@  
incompliancemag.com  
(978) 873-7722

**production  
director** Erin C. Feeney  
erin.feeney@  
incompliancemag.com  
(978) 873-7756

**marketing  
director** Ashleigh O'Connor  
ashleigh.oconnor@  
incompliancemag.com  
(978) 873-7788

**circulation  
director** Alexis Evangelous  
alexis.evangelous@  
incompliancemag.com  
(978) 486-4684

**features editor** William von Achen  
bill.vonachen@  
incompliancemag.com  
(978) 486-4684

**senior  
contributors** Bogdan Adamczyk  
Keith Armstrong  
Ken Javor  
Kenneth Ross  
Christopher Semanson  
Min Zhang

**columns  
contributors** Bogdan Adamczyk  
Erin Earley  
Min Zhang  
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**advertising** For information about  
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Sharon Smith at  
sharon.smith@  
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## FCC Rescinds Certain Cybersecurity Measures

In an internally contentious ruling, the U.S. Federal Communications Commission (FCC) has rescinded a previous Commission action intended to hold telecommunications carriers legally responsible for implementing and certifying cybersecurity protocols.

According to an Order on Reconsideration, the Commission called a January 2025 Declaratory Ruling by the Commission “based in part on the Declaratory Ruling’s flawed legal analysis,” thereby making it “unlawful and ineffective.”

At the same time, the Commission also withdrew a Notice of Proposed Rulemaking (NPRM) that accompanied the Declaratory Ruling.

To support its decision, the Commission cited numerous efforts this year to strengthen cybersecurity measures for communications networks, including the establishment of a Council on National Security to advise the Commission on cybersecurity issues, and the adoption of targeted but flexible rules for communications providers.

The Commission also cited its recent efforts to ban what it calls “bad labs” from the FCC’s equipment authorization program.

However, the Commission’s Order faced critical pushback from at least one Commissioner, Anna M. Gomez, who said that “By rescinding previous efforts to strengthen our networks and offering nothing in their place, the FCC leaves the country less secure at the very moment when these threats are increasing.”

## EMC Test Lab Market Expected to Nearly Double in Next Ten Years

The future of the global economy may be unclear, but there’s at least some “bright light” for those in the EMC testing business.

That’s the key takeaway in a recent report issued by consulting firm Future Market Insights (FMI), titled “EMC Electromagnetic Compatibility Test Laboratory Market Forecast and Outlook 2025 to 2035.” According to FMI’s research and data analysis, the global market for EMC testing is expected to reach \$2.9 billion by the year 2035, nearly double the \$1.6 billion projected for 2025. That’s a compound annual growth rate (CAGR) of 6.5% per year over the next 10 years.

The report says that growth in EMC testing over the next 10 years will be driven by several factors. These include the rapid technological evolution of electronic devices and a rising demand in key industries, such as aerospace, telecommunications, and consumer electronics. The authors specifically note the shift to electric and autonomous vehicles in the automotive industry, and that the need for an advanced EMC testing infrastructure to support that transition will also fuel growth.

Finally, increasing regulatory requirements around the globe for EMC compliance and EMC certification will contribute to the future growth of the EMC testing infrastructure.

## EU Commission Seeks Input on Product Safety Framework

The Commission of the European Union (EU) is taking steps to ensure that its product safety legislative framework reflects the realities of technology in the 21st Century.

According to a press release issued last month, the Commission is seeking comments on two significant initiatives related to its current

framework. The first initiative would review the Commission’s principles for market access, CE marking, and conformity assessment. According to the Commission, the end goal of the review is to simplify current rules, reduce administrative burdens, and improve alignment of regulations across multiple industry sectors.

The second initiative would assess how the Commission’s current market surveillance regulation could better help authorities and customs officials enforce current EU product rules and ensure enforcement against the marketing of unsafe or non-compliant products.

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## EU Commission Taking Steps to Simplify Access to the EU’s “Single Market”

The Commission of the European Union (EU) has introduced a package of measures that it says will help to simplify existing rules and regulations in order to further support the EU’s market size and future growth.

The Commission’s package of measures, titled “Simplifying the Single Market,” would, according to the Commission, “make it easier for businesses to operate, innovate, and grow, while maintaining high standards of protection for consumers and the environment.” The proposed initiatives in the package include:

- Supporting small mid-cap companies—The Commission would create a new category of business entities for small mid-cap companies (SMCs), and give these companies access to simplified rules and reduced compliance barriers.
- Simplifying GDPR rules—Record keeping obligations under the EU’s General Data Protection Regulations would also be simplified for small and medium-sized enterprises (SMEs) and small mid-caps (SMCs).

- Digitalizing product legislation—This initiative would allow companies to provide product information in digital format, easing administrative burdens while also making it easier for consumers to access critical product information.
- Postponement of battery due diligence requirements—The Commission will postpone the implementation of due diligence requirements under its Batteries Regulation for a period of two years, giving companies more time to comply.





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S Y S T E M S

## BEYOND THE TECHNICAL

# Engineering Fundamentals Beyond the Textbook

## Faith, Hope, and Collaboration in Compliance Work

By Kimball Williams and the In Compliance Editorial Team

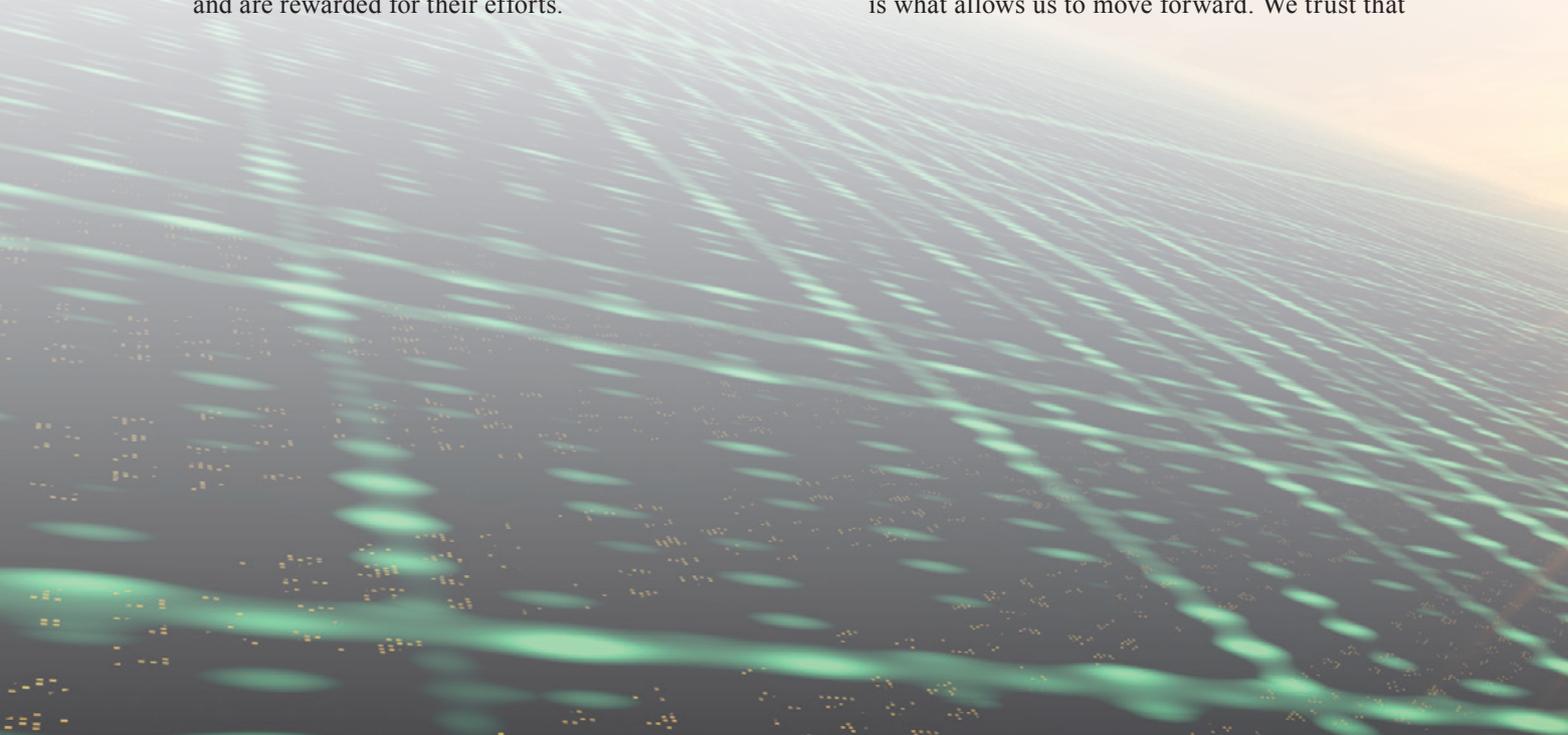
**T**raining in any of the scientific or technical disciplines is rarely linked to the faith-based philosophies that abound in our societies. Yet, upon reflection, the virtues of faith, hope, and charity—so often discussed in spiritual contexts—are deeply embedded in the daily work of engineers.

A well-known quote from the Christian Bible, 1 Corinthians 13:13, states: “And now these three remain: faith, hope, and love; but the greatest of these is love.” The Greek language offers multiple words for love, and in some translations, “charity” is used instead—emphasizing generosity and selflessness. While the Quran may not present these three virtues in a single verse, its teachings consistently highlight their importance: “Allah loves the doers of good.” Similarly, Hindu texts like the Bhagavad Gita and the Upanishads recount stories of those who extend help and are rewarded for their efforts.

*This article began as one engineer's reflection and became something more through conversation. Kimball Williams shared his thoughts, then stepped back to let us reshape his words. We're grateful for his trust in the collaborative process.*

These early philosophical and spiritual teachings—our first “schools” of human behavior—stress the same principles that quietly guide our work as engineers. In fact, these virtues are not just abstract ideals; they are practical tools in the world of compliance and technical problem-solving.

Would any of us begin a project without at least a little faith that we could carry it to completion? Faith in our training, our tools, and the standards we follow—whether it's NEC, IEEE, or UL—is what allows us to move forward. We trust that



Ohm's Law still applies, that Maxwell's equations remain true, and that the principles of Newton and Kepler continue to guide our understanding of motion and force.

Hope is equally essential. We may not see every solution at the outset, but we hope our education and experience will help us navigate the unknowns. In compliance work, hope shows up in our diligence: we hope our documentation is thorough, our designs meet evolving standards, and our teams catch errors before they become liabilities.

And then there's charity—perhaps the most overlooked virtue in technical fields. But in engineering, charity often takes the form of collaboration. When we encounter a problem that vexes us, we reach out to colleagues, mentors, and peers. Their generosity—whether it's time, insight, or encouragement—is a form of love. It's what makes engineering a human endeavor, not just a technical one.

We've learned much since our earliest philosophers gave us guidelines for social behavior, but their lessons remain valid. Just as gravity hasn't stopped working and levers still function, the principles of faith, hope, and charity continue to support our work—even in the most regulated and rigorous corners of engineering.

And sometimes, amid the calculations and compliance checklists, we're reminded of wonder. The lightning bugs have returned to the backyard again—tiny lanterns of joy blinking in the dusk.



photo by Kimball Williams

And just the other day, a visitor perched quietly on the rail outside the window. Regal, focused, and utterly still. A reminder that life is still unfolding, still offering quiet moments of grace.

So if the daily news feels heavy and the world seems uncertain, pause. Notice that life continues. The sun still rises in the East and sets in the West. And in our work, as in our lives, faith, hope, and charity remain—not just as virtues, but as engineering fundamentals. 

## PRODUCT INSIGHTS

# Challenges in Compliance Engineering Training

By Don MacArthur

Compliance engineering is a critical field that ensures products and systems meet regulatory standards, safeguarding public health and safety while promoting environmental sustainability. The training of compliance engineers, however, presents significant challenges, particularly in keeping up with constantly evolving regulations and balancing theoretical knowledge with practical application. This article explores these challenges and offers insights into effective training strategies for compliance engineers.

## KEEPING UP WITH REGULATIONS

One of the most daunting challenges in compliance engineering training is staying updated with the ever-changing landscape of regulations and standards. Regulatory bodies frequently revise guidelines to keep pace with technological advancements, emerging risks, and societal needs. For instance, changes in environmental regulations, safety standards, and electromagnetic compatibility (EMC) requirements can occur several times a year, depending on the industry and region.

**Constant Updates:** Engineers must continuously monitor updates from bodies such as the International Electrotechnical Commission (IEC), the Federal Communications Commission (FCC), and the Environmental Protection Agency (EPA). This requires a robust system for tracking regulatory changes, interpreting their implications, and incorporating them into training programs. Without a streamlined process, engineers may struggle to comply with the latest standards, risking non-compliance and potential legal repercussions.

**Global Variations:** Compliance regulations can vary significantly across different countries and regions. For multinational companies, engineers must be knowledgeable about local regulations in each market where their products are sold. This adds complexity to training programs, as they must cover a wide range of standards and ensure engineers can apply them effectively in various contexts.

**Access to Resources:** Reliable access to up-to-date resources is essential for compliance engineers.

However, staying informed through official publications, online databases, and industry associations can be time-consuming and costly. Training programs need to integrate these resources efficiently, providing engineers with the necessary tools to stay current with regulatory changes.

## BALANCING THEORY AND PRACTICE

Another significant challenge in compliance engineering training is balancing theoretical knowledge with practical application. While a strong theoretical foundation is essential, engineers must also develop hands-on skills to effectively apply their knowledge in real-world scenarios.

**Comprehensive Curriculum:** Training programs must offer a comprehensive curriculum that includes both theoretical and practical components. This means covering fundamental principles, such as risk assessment, safety analysis, and regulatory frameworks, as well as practical skills, such as conducting compliance tests, interpreting test results, and implementing corrective actions.

**Practical Training:** Incorporating practical training into the curriculum can be challenging due to limited access to testing facilities and equipment.

Hands-on experience is crucial for understanding the complexities of compliance testing and developing problem-solving skills. Training programs must find ways to provide practical experiences, such as through partnerships with testing labs, internships, or simulations.

#### **Case Studies and Real-World**

**Examples:** Using case studies and real-world examples can bridge the gap between theory and practice. Analyzing past compliance issues, successful mitigation strategies, and industry best practices helps engineers understand the practical implications of their work and learn from real-world experiences.

**Continuous Learning:** The dynamic nature of compliance engineering requires continuous learning beyond initial training. Engineers must engage in

ongoing professional development through workshops, seminars, and online courses to stay current with evolving regulations and technologies. Training programs should emphasize the importance of lifelong learning and provide resources for continued education.

#### **SUMMARY/CONCLUSION**

Training compliance engineers presents several challenges, particularly in staying updated with constantly changing regulations and balancing theoretical knowledge with practical application. Effective training programs must develop robust systems for tracking and interpreting regulatory changes, provide a comprehensive curriculum that includes practical experiences, and emphasize continuous learning. By addressing these challenges, training programs can equip compliance engineers with the skills and knowledge necessary to ensure products and systems meet regulatory standards, ultimately promoting public health, safety, and environmental sustainability.

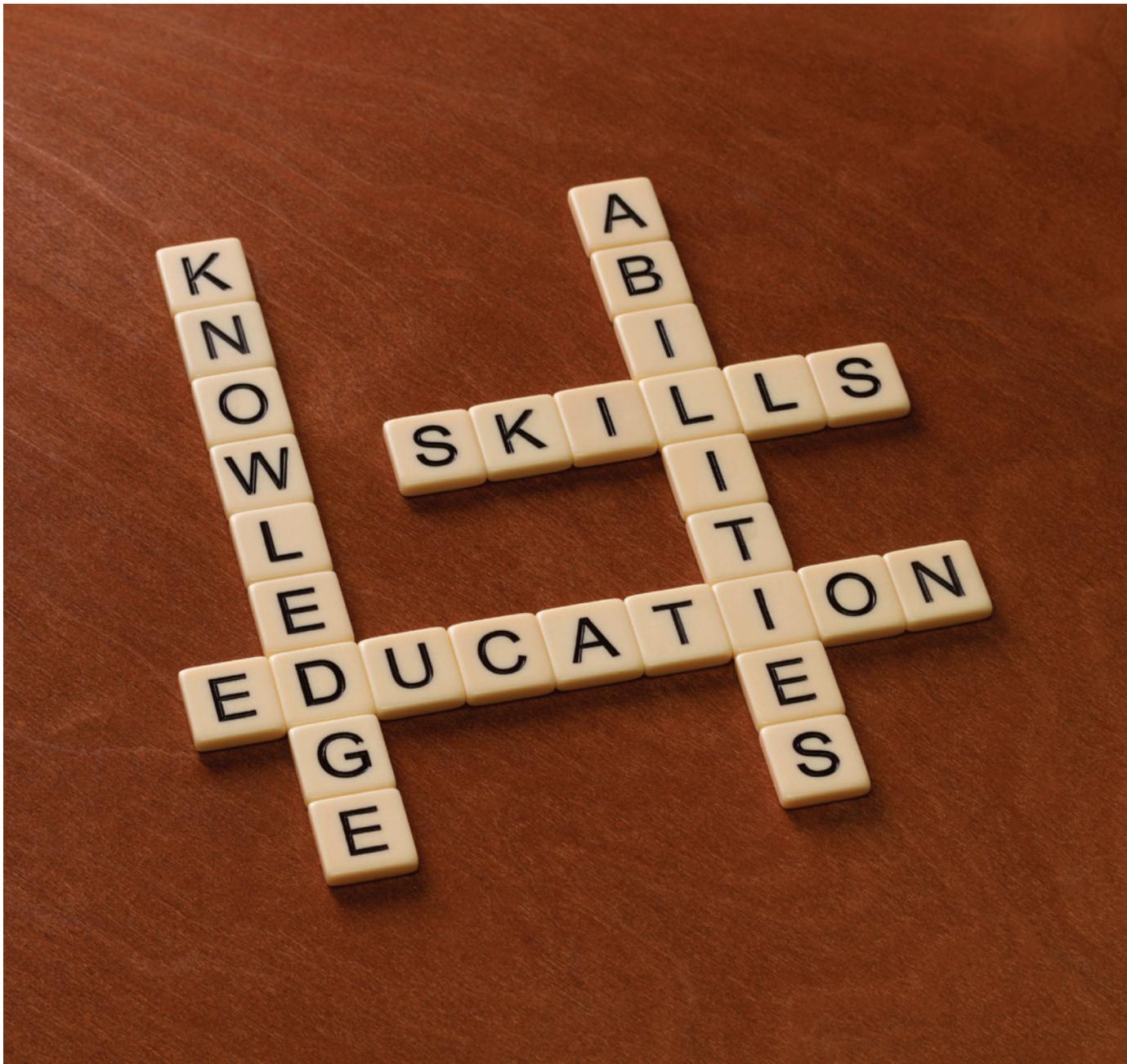
#### **REFERENCES AND FURTHER READING**

1. "ISO/IEC 17025:2017 - General requirements for the competence of testing and calibration laboratories." International Organization for Standardization (ISO).
2. "Electromagnetic Compatibility (EMC) Testing and Certification." Federal Communications Commission (FCC).
3. "Environmental Regulations and Compliance." Environmental Protection Agency (EPA).
4. "Compliance Engineering: A Handbook for Engineers and Managers" by Stephen W. Director and Richard C. Dorf.
5. "Design Techniques for EMC Compliance: A Handbook for Designers" by Mark I. Montrose.



# CONTINUING YOUR PROFESSIONAL EDUCATION IN 2026

Compiled by the *In Compliance Magazine* Editorial Team



**W**elcome to 2026! Regardless of where you are in your career, your ongoing efforts to refresh or expand your technical knowledge and skills are essential to your continued professional and personal growth and success. So, as the new year begins, we've once again queried training resources throughout our industry to provide you with an overview of free or affordable solutions to meet your training goals and to help you on your journey to becoming your best self in the new year.

In this article, you'll find sources of compliance-related seminars, workshops, and other types of training offered live, including both virtual and in-person options, as well as pre-recorded webinars and on-demand training offerings. We've also included a list of industry symposia, conferences, and exhibitions to be held in both the U.S. and around the world.

The information that follows is current as we go to press (early December 2025). But please note that dates for live in-person seminars, workshops, and symposia provided here are subject to change. So check the listed websites for the most up-to-date information on scheduling. Finally, we invite you to submit updates and corrections, as well as suggestions for additional listings for our Events section. Please send your comments to us at [editor@incompliancemag.com](mailto:editor@incompliancemag.com).

## **LIVE VIRTUAL AND IN-PERSON SEMINARS AND WORKSHOPS**

The **American Association for Laboratory Accreditation (A2LA)** WorkPlace Training portal offers both in-person and virtual classroom trainings on ISO compliance in both English and Spanish, featuring live instructor-led sessions. Individual training offerings cover areas including international standards, management systems, technical subjects, and soft skills. Course instructors are subject matter experts with many years of professional training experience. Additional details are available at <https://www.a2lawpt.org/training>. (Also see listings under "In-House/Custom Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

**EMC and Compliance International** is pleased to announce that the 2026 EMC and Compliance International Conference will be held April 29 - May 1, 2026 in Oxford, United Kingdom. The annual global gathering of EMC experts, researchers and engineers offers a dynamic platform for sharing the latest innovations and techniques in EMC, radio engineering, functional safety, electrical safety, and compliance. Featuring keynote sessions, workshops, tutorials and trainings, the Conference covers a broad range of topics, including measurement techniques, design for EMC, troubleshooting, and EMC for platforms, systems, and installations. For more information, or to register, go to <https://www.emcandci.com>.

The **Equipment Reliability Institute** offers several live, in-person public classes throughout the year, including courses on "Military Standard 810 Testing" and "Fundamentals of Random Vibration and Shock Testing." For complete information and 2026 training dates, go to <https://equipment-reliability.com> and click on "Scheduled Trainings" in the box in the middle of the home page. (Also see listing under "In-House/Custom Seminars and Workshops")

The **EOS/ESD Association, Inc.** offers access to a wide variety of online and in-person educational opportunities throughout the year. These courses and certifications provide ESD professionals with the knowledge, tools, and credentials needed to meet the challenges of ESD in their companies. The Association offers courses at different locations and also during the annual EOS/ESD Symposium. Further, the Association publishes and distributes numerous educational materials on ESD and has pathways built to navigate training and certification programs and levels. For full details, visit the Association's website at <https://www.esda.org>, and click on the links in the boxes on the home page for "Training & Education," "Certification," and "Events." (Also see listing under "Recorded Webinars and On-Demand Training" and "Industry Symposia, Conferences, and Exhibits")

**Eurofins York** offers in-person classroom compliance training throughout the year at various locations in the United Kingdom. To get more information, visit <https://www.yorkemc.com/services/training>. (Also see listings under “In-House/Custom Seminars and Workshops”)

Dr. Bogdan Adamczyk of **Grand Valley State University** (GVSU) will offer a two-day certificate course for industry “Principles of Electromagnetic Compatibility” in April and October 2026, at the GVSU EMC Center in Grand Rapids, Michigan. Numerous measurements and demonstrations reinforce the course topics. The course is intended for both practicing professionals and new engineers entering the field. For additional details go to <https://www.gvsu.edu/emccenter>.

The **IEEE EMC Society** offers access to a number of in-person and virtual presentations and webinars on a variety of EMC-related subjects. For more information, go to <https://www.emcs.org/virtual-and-webinar-events.html>. (Also see listings under “Recorded Webinars and On-Demand Training” and “Industry Symposia, Conferences, and Exhibits”)

**Intertek** offers live virtual and in-person public seminars and workshops throughout the year at various locations in the U.S. and around the world. Additional information is available at the company’s “Knowledge and Education” portal at <https://www.intertek.com/knowledge-education>. (Also see listing under “Recorded Webinars and On-Demand Training”)

Dr. Todd Hubing of **LearnEMC** offers a series of live, online courses covering EMC topics ranging from fundamentals to advanced design and modeling techniques. Courses include “Fundamentals of Electromagnetic Compatibility” and “Advanced Design for EMC Compliance.” For additional details, go to <https://learnemc.com>.

The **Rohde & Schwarz** Technology Academy offers a comprehensive selection of live virtual and in-person courses on a wide variety of technical subjects dealing with EMC and RF testing and measurement. For more information, visit [https://www.rohde-schwarz.com/us/knowledge-center/technology-academy/ta-overview\\_256215.html](https://www.rohde-schwarz.com/us/knowledge-center/technology-academy/ta-overview_256215.html). (Also see listing under “Recorded Webinars and On-Demand Training”)

Randal Vaughn and Lee Hill of **Silent Solutions LLC** and GmbH offer over twelve public and private EMC training events each year, both online and in person in the U.S. and in Europe. For 2026, planned trainings include “Applying Practical EMI Design and Troubleshooting Techniques,” “Advanced PCB Design for EMC & Si,” and “Mechanical Design for EMC.” For training locations and dates, visit <https://www.silent-solutions.com/education/courses-and-events>.

The **TCB Council** sponsors live and virtual regulatory compliance workshops on wireless technologies throughout the year. View the Council’s upcoming trainings at <https://www.tbcouncil.org/education-training-programs>. (Also see listings under “Recorded Webinars and On-Demand Training”)

**TÜV SÜD America** offers live virtual public and private training courses and webinars that are enhanced by the real-life experiences of its auditing and testing teams, offering years of experience in the worldwide international standards arena. These courses can help prepare you for the most challenging compliance issues. To see the current offerings, visit the TÜV SÜD “Events & Webinar Hub” at <https://www.tuvsud.com/en/events-and-webinar-hub>. (Also see listing under “Recorded Webinars and On-Demand Training”)

**UL Solutions** is currently offering live events and seminars, virtual webinars, and other forms of training in the U.S. and locations around the world. Companies rely on UL Solutions’ educational programs for the expertise and tools required to design and install safer products, increase efficiency, realize improved speed to market, and advance their approach to prevention and compliance. For a current listing of 2026 programs and dates, go to <https://www.ul.com/events>, and click on “Event Type” in the left margin. (Also see listing under “Recorded Webinars and On-Demand Training”)

**Washington Laboratories** offers a wide variety of informative webinars and training sessions through its Washington Laboratories Academy. Training offerings range from compliance, EMC and RF testing, and environmental testing to topics like MIL-STD 461/810, Product Safety, Wireless Certification, and other key areas of regulatory compliance. Sessions combine in-depth technical information with practical, real-world engineering

insights and solutions to meet today's engineering challenges. Visit <https://www.wll.com/schedule>.

Kenneth Wyatt of **Wyatt Technical Services, LLC** is an independent consultant specializing in EMC design, troubleshooting, and training services. Specialties include EMC troubleshooting, pre-compliance testing, and design reviews. For further information on his public seminar schedule for 2026, visit <https://benchtopemc.com> and click in "Training" at the top of the page. (Also see listing under "Recorded Webinars and On-Demand Training")

### IN-HOUSE/CUSTOM SEMINARS AND WORKSHOPS

Many experts and training organizations offer standard and/or customized workshops and seminars and workshops on an in-house basis. These training programs offer companies an opportunity to train multiple compliance personnel with a specialized approach designed for their needs. The following is a list of organizations and trainers that offer both virtual and in-person seminars and workshops for in-house presentation.

The **American Association for Laboratory Accreditation (A2LA)** offers customized laboratory staff training on a number of topics. For more information, go to <https://www.a2lawpt.org/training>, click on the pull-down tab for "Courses" and select

"Group Training." (Also see listings under "Live Virtual and In-Person Public Seminars and Workshops" and "Recorded Webinars and On-Demand Training")

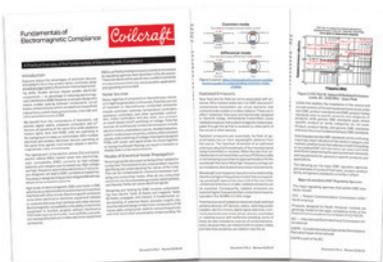
Vladimir Kraz of **BestESD Technical Services** provides customer-oriented classes and workshops on practical aspects of managing EMI, EOS, and ESD within the factory environment, using a results-based approach to provide participants with a fuller understanding of managed parameters. Classes and workshops are conducted on the customer premises and can include hands-on demonstrations and training on actual tools and processes in production. Specifics include overview and compliance with SEMI E.176 standard and current ESDA work on EOS. For additional information, go to <https://www.bestesd.com>.

**The EMC Academy** offers an array of workshops and seminars, both virtually and in-person. The Academy's extensive training portfolio covers a wide range of topics, and customized or more specialized training is also available. For more information, go to <https://www.emcstandards.co.uk>.

**Equipment Reliability Institute** also provides on-site training on a broad range of testing and design topics. Go to <https://www.equipment-reliability.com> and click on "Onsite Training" in the box in the middle of the home page. (Also see listing under "Live Virtual and In-Person Public Seminars and Workshops")

## Informative Application Note: The Fundamentals of EMC

*Coilcraft*



- Reviews sources of electromagnetic noise and modes of noise propagation
- Lists EMC compliance agencies and testing standards
- Provides design hints for passing EMC pre-compliance and compliance tests

Learn more @ [coilcraft.com/AppNotes](https://coilcraft.com/AppNotes)

**Eurofins York** offers customized, in-house training offerings in addition to their comprehensive schedule of public training programs. For additional details on their “bespoke” training options, go to <https://www.yorkemc.com/services/training/on-site-training>. (Also see listing under “Live Virtual and In-Person Public Seminars and Workshops”)

**StaticWorx** provides in-person and online custom training on electrostatic discharge and anti-static flooring. Sessions help architects and designers as well as facilities and contracting professionals learn how to specify ESD flooring and include subjects such as: differentiating between conductive and dissipative floors; meeting ANSI/ESD S20.20 when working with ESD-sensitive electronic parts and assemblies; and meeting DoD standards when handling explosives. The company’s “Architects’ Workshop” on ESD flooring is an AIA-IDEC accredited course. For additional information, go to <https://staticworx.com/anti-static-flooring-basics-idec-accredited-course>. (Also see listing under “Recorded Webinars and On-Demand Training”)

### RECORDED WEBINARS AND ON-DEMAND TRAINING

Your time is valuable, and your schedule doesn’t always allow you to participate in live virtual and in-person presentations. But there are plenty of training options that you can take advantage of, right from the comfort of your daily workspace. Many organizations and training experts provide on-demand webinars, as well as books, podcasts, and e-learning programs. Here are a few options to get you started:

The **American Council of Independent Laboratories (ACIL)** hosts an archive of previously recorded webinars that are available on-demand, covering EMC standards, key EMC committee meetings, and other EMC activities. For more information, go to <https://www.acil.org> and click on “On Demand Education” in the box at the top right corner of the page.

The **American Association for Laboratory Accreditation (A2LA)** offers a comprehensive suite of self-paced e-learning options on metrology and calibration through its WorkPlace Training portal. More than thirty different courses providing the equivalent of hundreds of hours of training are

currently available, including online training on ISO/IEC 17025 compliance. For more information, go to <https://www.a2lawpt.org/e-learning> and click on “E-Learning” in the bar at the top of the home page. (Also see listings under “Live Virtual and In-Person Public Seminars and Workshops” and “In-House/ Custom Seminars and Workshops”)

**EMC Fast Pass** provides comprehensive online training courses and short courses to assist electronic engineers, compliance specialists, and hardware manufacturers design and test products that pass EMC and RF certifications the first time. Course offerings include:

- EMC Design for Compliance: Immunity
- EMC Design for Compliance: Emissions
- Intrinsically Safe (IS) Hardware Design
- FCC Wireless (RF) Pre-Compliance
- EMC Technician Training

Additional information is available at <https://emcfastpass.com>. (Click on the link in the box “Online Training Courses.”)

The **EOS/ESD Association, Inc.**, in addition to its courses and certifications offered at events, has a wide variety of online classes, online certification programs, training videos, and complementary educational resources at <https://www.esda.org>. Click on the link in the box “Training & Education” on the home page for more information. Complementary ESD videos are available under the heading “ESD Overview” on the home page. (Also see listings under “Live Virtual and In-Person Public Seminars and Workshops” and “Industry Symposia, Conferences, and Exhibits”)

**ETS-Lindgren** offers a number of recorded webinars that are available on-demand covering topics such as EMC testing, wireless/5G testing, automotive testing (including e-motor and autonomous vehicles), ANSC C63® standards updates, and electromagnetic protection. Visit <https://www.ets-lindgren.com/services/education-training> for additional details about the company’s on-demand offerings are available at. The company’s YouTube channel at <https://www.youtube.com/@etslindgrenvideo> features many educational videos, including the popular mode filtered demonstration of the new EMC test site validation technique proposed for

ANSI C63.25.3 (available at <https://www.youtube.com/watch?v=42uLkR2uFe8>).

The **IEEE EMC Society** also provides access to several on-demand recordings of recent presentations at Society and Chapter events. Further information is available at <https://www.emcs.org/virtual-and-webinar-events.html>. (Also see listings under “Live Virtual and In-Person Public Seminars and Workshops” and “Industry Symposia, Conferences, and Exhibits”)

**Intertek’s** extensive catalog of live and on-demand webinars complements the company’s live virtual and in-person training options. Additional information is available at <https://www.intertek.com/knowledge-education/webinars>. (Also see listing under “Live Virtual and In-Person Public Seminars and Workshops”)

**Rohde & Schwarz** offers a comprehensive selection of on-demand webinars, virtual demonstrations, videos, and other virtual learning options covering a wide variety of technical subjects. Learn more by accessing the Rohde & Schwarz Technology Academy at [https://www.rohde-schwarz.com/us/knowledge-center/technology-academy/ta-overview\\_256215.html](https://www.rohde-schwarz.com/us/knowledge-center/technology-academy/ta-overview_256215.html). (Also see listing under “Live Virtual and In-Person Public Seminars and Workshops”)

**StaticWorx** also offers a vast collection of on-demand videos about static electricity. These videos answer frequently asked questions, explain complex technical terms, help you understand static-control flooring, and address problems caused by random static discharge. Visit the company’s YouTube channel at <https://www.youtube.com/@staticworx> to access their video library. (Also see listing under “In-House/ Custom Seminars and Workshops”)

The **TCB Council** also maintains an archive of its educational workshops and trainings on wireless technologies. For more information, go to <https://tcbcouncil.mclms.net/en>. (Also see listings under “Live Virtual and In-Person Public Seminars and Workshops”)

**TÜV SÜD America** also offers on-demand webinars covering various topics in the areas of product safety, EMC, management systems, and competency assessments. To learn more, go to the TÜV SÜD



### RTCA DO - 160G Airborne Equipment Environmental Adaptability Test System

- S17 Voltage Spike Test System TPS-160S17
- S19 Induced Spike / Induced Signal Susceptibility Test System ISS 160S19 / ISS 1800
- S22 Indirect Lightning Induced Transient Susceptibility Test System LSS 160SM8, ETS 160MB
- S23 Lightning Direct Effect Test System  
---LCG 464C High Current Physical Damage Test System  
---LVG 3000 High Voltage Attachment Test System

Standard in compliant with: RTCA DO-160G Section 17 / 19/22/23, MIL-STD-461G (CS117), SAE ARP5412, AECTP 250/500



### MIL - STD - 461 Military Test Systems

- CS106 Power Leads Spike Signal Conducted Susceptibility Test System TPS-CS106
- CS114 Bulk Cable Injection Conducted Susceptibility Test System CST-CS114
- CS115 Bulk Cable Injection Impulse Excitation Conducted Susceptibility Test System TPS-CS115
- CS116 Cables and Power Leads Damped Sinusoidal Transients Conducted Susceptibility DOS-CS116
- CS118 Personal Borne Electrostatic Discharge Test Equipment EDS MAX30

Standard in compliant with: MIL - STD - 461 CS106, CS114, CS115, CS116, CS118

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“Events & Webinar Hub” at <https://www.tuvsud.com/en/events-and-webinar-hub>. (Also see listing under “Live Virtual and In-Person Public Seminars and Workshops”)

**UL Solutions** also provides safety- and compliance-related training delivered via its extensive library of on-demand webinars. Topic areas include hazard-based safety engineering, global market access, global directives, code compliance, conformity assessment, sustainability, responsible sourcing, social auditing, and many more. For additional details, visit <https://www.ul.com/resources/resource-library>, and click on “Resource Type” in the left margin. (Also see listing under “Live Virtual and In-Person Public Seminars and Workshops”)

Kenneth Wyatt of **Wyatt Technical Services, LLC** offers several webinar- and video-based trainings. Topics include EMC theory, product design for compliance, PC board design for low EMI, taming wireless self-interference, and benchtop EMC troubleshooting. For more information, visit <https://benchtopemc.com> and click on “Training” at the top of the page. (Also see listing under “Live Virtual and In-Person Public Seminars and Workshops”)

## INDUSTRY SYMPOSIA, CONFERENCES, AND EXHIBITS

Annual symposia are an excellent resource for extensive technical training, as well as the exchange of new ideas and technical concepts. The benefit of attending these events is that attendees can sample a vast array of workshops quickly and efficiently while connecting with colleagues and professionals with the same interests. (The symposia listed below are planned as live in-person events unless otherwise noted. Please check the listed website for the most current information on dates and locations.)

### DesignCon 2026

February 24-26, 2026 – Santa Clara, California (U.S.)  
<https://designcon.com>

### EMV 2026

March 24-26, 2026 – Cologne, Germany  
<https://emv.mesago.com/koeln/en.html>

### A2LA Annual Conference 2026 (AnnCon26)

April 12-15, 2026 – Nashville, Tennessee (U.S.)  
[https://a2la.org/annual\\_conference](https://a2la.org/annual_conference)

### EuCAP 2026 – The 20th European Conference on Antennas and Propagation

April 19-24, 2026 – Dublin, Ireland  
<https://www.eucap2026.org>

### EMC & Compliance International Exhibition & Workshops (EMC & CI 2026)

April 29-May 1, 2026 – Oxford, United Kingdom  
<https://www.emcandci.com>

### Sensors Expo & Conference

May 5-7, 2026 – Santa Clara, California (U.S.)  
<https://www.sensorsconverge.com>

### 2026 IEEE International Symposium on Product Compliance Engineering (ISPC)

May 12-14, 2026 – Boston, Massachusetts (U.S.)  
<http://2026.psessymposium.org>

### 2026 International Applied Computational Electromagnetics Society (ACES) Symposium

May 24-27, 2026 – Thessaloniki, Greece  
[https://aces-society.org/conference/Greece\\_2026](https://aces-society.org/conference/Greece_2026)

### 2026 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)

May 25-28, 2026 – Nancy, France  
<http://i2mtc2026.ieee-ims.org>

### IMS 2026 – IEEE International Microwave Symposium

June 7-12, 2026 – Boston, Massachusetts (U.S.)  
<https://ims-ieee.org>

### The Battery Show Europe

June 9-11, 2026 – Stuttgart Germany  
<https://www.thebatteryshow.eu>

### 2026 IEEE International Symposium on Antennas and Propagation & ITNC-USNC-URSI Radio Science Meeting

July 12-17, 2026 – Detroit, Michigan (U.S.)  
<https://2026.apsursi.org>

### 2026 International ESD Workshop (IEW)—Asia

July 13-16, 2026, Singapore  
<https://www.esda.org/events/2026-international-esd-workshop-iew-asia>

### 2026 IEEE International Symposium on Electromagnetic Compatibility, Signal & Power Integrity (EMC + SIPI)

August 3-7, 2026 – Dallas, Texas (U.S.)  
<https://2026.emcsipi.org>

### EMC Europe 2026

August 31-September 4, 2026 – Prague, Czech Republic  
<https://www.emceurope2026.org>

### San Diego Test Equipment Symposium

September 15, 2026 – San Diego, CA (U.S.)  
<https://www.sdtes.org>

### 48<sup>th</sup> Annual Electrical Overstress/Electrostatic Discharge Symposium

September 26-October 1, 2026 – Frisco, Texas (U.S.)  
<https://www.esda.org/events/48th-annual-eosesd-symposium-and-exhibits>

### European Microwave Week 2026

October 4-9, 2026 – London, United Kingdom  
[https://www.eumwa.org/en/29th-eumw-2026.html?cmp\\_id=20&news\\_id=255&vID=50](https://www.eumwa.org/en/29th-eumw-2026.html?cmp_id=20&news_id=255&vID=50)

### The Battery Show 2026, North America

October 12-15, 2026 – Detroit, Michigan (U.S.)  
<https://thebatteryshow.com>

### 48<sup>th</sup> Annual Meeting and Symposium of the Antenna Measurement Techniques Association (AMTA)

November 1-6, 2026 – Austin, Texas (U.S.)  
<https://2026.amta.org>

### IEEE EMC SOCIETY 2026 REGIONAL EVENTS

#### Southeastern Michigan IEEE EMC Society, “EMC Basics + Workshop”

January 10, 2026 – Farmington Hills, Michigan (U.S.) (Proceeds will benefit the Society’s Library Fund)  
<https://www.emcsociety.org>

#### 2026 Chicago IEEE EMC Mini Symposium

May 5, 2026 – Schaumburg, Illinois (U.S.)  
<https://www.emcchicago.org/sectfiles/events.htm>

### Southeastern Michigan EMC Fest 2025

May 7, 2026 – Livonia, Michigan (U.S.)  
<https://www.emcfest.org>

### 2026 Minnesota EMC Event

September 22, 2026 – Bloomington, Minnesota (U.S.)  
<https://www.mnemevent.com>

### Milwaukee EMC Event

September 24, 2026 – Milwaukee, Wisconsin (U.S.)  
<https://r4.ieee.org>

We hope this list will help you meet your professional development goals in 2026. Many additional trainings and events will be planned throughout the year, so be sure to check our events calendar at <https://incompliancemag.com/calendar> to find the most up-to-date information. Another way to brush up on the basics and delve deep into advanced topics is by visiting our online resource center, the *In Compliance Technical Library* at <https://incompliancemag.com/technical-library>.

In the meantime, we hope that the year ahead brings only good health and happiness to you and your loved ones! 🍀

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<http://www.ets-lindgren.com/services/education-training>



## HANDS-ON EMC AT GVSU

Grand Valley State University offers unique EMC education opportunities provided by its EMC Center located in Grand Rapids, Michigan. The center houses an industrial EMC precompliance lab supported by academia and industry that brings decades of EMC & SIPI expertise, tools, and capabilities to the classroom and student experience. Practicing EMC professionals and new engineers entering the field can earn undergraduate and graduate EMC badges issued by GVSU and attend a two-day certificate course, "Principles of Electromagnetic Compatibility," offered in April and October 2026, taught by Dr. Bogdan Adamczyk, professor and EMC Center director.

<http://www.gvsu.edu/emccenter>



*"Professor Adamczyk's presentation style was excellent. I would have loved to have him as a teacher in college."*

*EMC Center Attendee*



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*“Collaborative learning among engineers in product manufacturing, testing, and design nets more efficient and effective regulatory approvals.”*

*Chris Harvey, Executive Director  
TCB Council*



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# THE EMC DEMO BOX

Making Electromagnetic Compatibility Education Accessible and Engaging



Marcel van Doorn holds an M.Sc. degree in Electrical Engineering from Eindhoven University. After working at Dutch Railways on electromagnetic modeling, he joined Philips Electronics in 1986, where he specialized in EMC testing, standardization, design, and research. Since 2018, he has been an independent EMC trainer & consultant, sharing his expertise with engineers worldwide. van Doorn can be reached at marcel.van.doorn@home.nl.



By Marcel van Doorn

**E**lectromagnetic compatibility (EMC) has always been one of the most challenging topics to teach. Although every electrical engineer recognizes its importance, the underlying physical mechanisms – coupling, radiation, resonance, and reciprocity – are often difficult to visualize. Traditional lectures and circuit models rarely succeed in making the invisible visible.

As the Chinese philosopher Confucius said more than two thousand years ago: “I hear and I forget. I see and I remember. I do and I understand” (Figure 1). This insight forms the educational philosophy behind the EMC Demo Box, which allows students to observe and interact directly with real electromagnetic phenomena.

After more than 35 years of providing EMC training to international audiences, I felt the need for a demonstration tool that would let engineers truly see and feel what happens in practice. From this idea, the EMC Demo Box was born, a concept developed and refined over many years of workshops. The current version stands out for its simplicity, yet it enables users to explore an impressive range of electromagnetic phenomena with clarity and confidence.

The EMC Demo Box is a compact, low-cost tool that makes electromagnetic compatibility (EMC) tangible and easy to explore. Designed for use in ordinary classrooms, it enables hands-on investigation of real EMC phenomena, such as slot radiation, common- and differential-mode coupling, grounding, and filtering, without expensive shielded facilities. Through live measurements and countermeasures, participants directly see how design choices affect emissions and immunity.

Combining radical simplicity with a strong pedagogical focus, the EMC Demo Box bridges theory and practice, deepening understanding and fostering the problem-solving skills essential for modern EMC design.

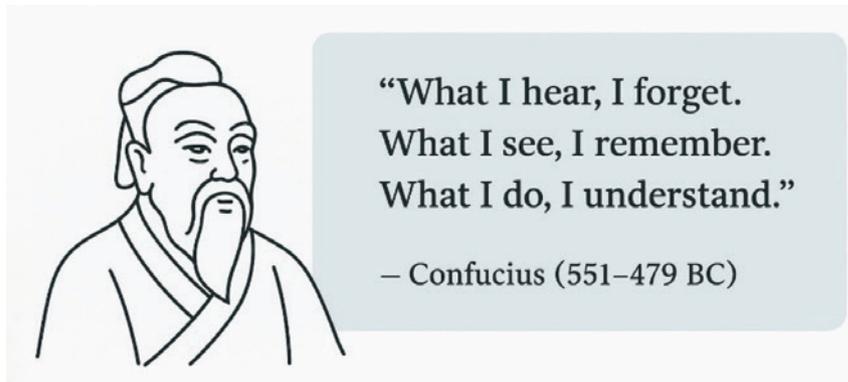


Figure 1: The educational philosophy behind the EMC Demo Box – inspired by Confucius.

## MAKING THE INVISIBLE VISIBLE

The EMC Demo Box is a compact metal enclosure equipped with several BNC connectors (both grounded and floating), slots, apertures, and an internal broadband source: a short double-braided coaxial cable with a pigtail that acts as a combined differential-mode and common-mode source (Figure 2 on page 24). This internal source is connected to the tracking generator output of a spectrum analyzer (typically 200 mV, swept from 1 MHz to 1 GHz), producing rich electromagnetic fields that couple through the slots, apertures, and connectors of the metal housing.

It is intentionally simple inside, but externally it exhibits rich electromagnetic behavior. When connected to a spectrum analyzer with tracking generator, together with a current clamp, field probe, and coaxial cables, it becomes a complete EMC demonstration system.

This setup allows students and engineers to explore how real electronic designs behave over a wide frequency range, from conducted to radiated effects. Most experiments show effects in the range of roughly 1 MHz to 1 GHz, where cable and slot resonances become clearly visible.

What makes the EMC Demo Box conceptually unique is its fundamental simplicity. Unlike conventional demonstration systems that rely on digital, analog, or RF circuitry, it contains no active electronics. A short coaxial cable with a pigtail, driven by the tracking generator of a spectrum analyzer, serves as a broadband electromagnetic source. This physically pure approach provides a scalable and realistic model of electromagnetic coupling and radiation across a wide frequency range.

The EMC Demo Box operates at low voltages (200 mV), ensuring a safe and student-friendly learning environment. Its simplicity and low cost make it ideal for exploring EMC behavior in an ordinary classroom, without the need for a shielded room or laboratory. With only a simple spectrum analyzer with tracking generator, all demonstrations can be performed almost anywhere, making the setup perfect for universities, training centers, and companies.

Table 1 lists all instruments and materials required to perform the EMC Demo Box demonstrations discussed in this article. The selected components represent standard laboratory tools that are widely available, making the experiments easy to reproduce in any educational or industrial environment.

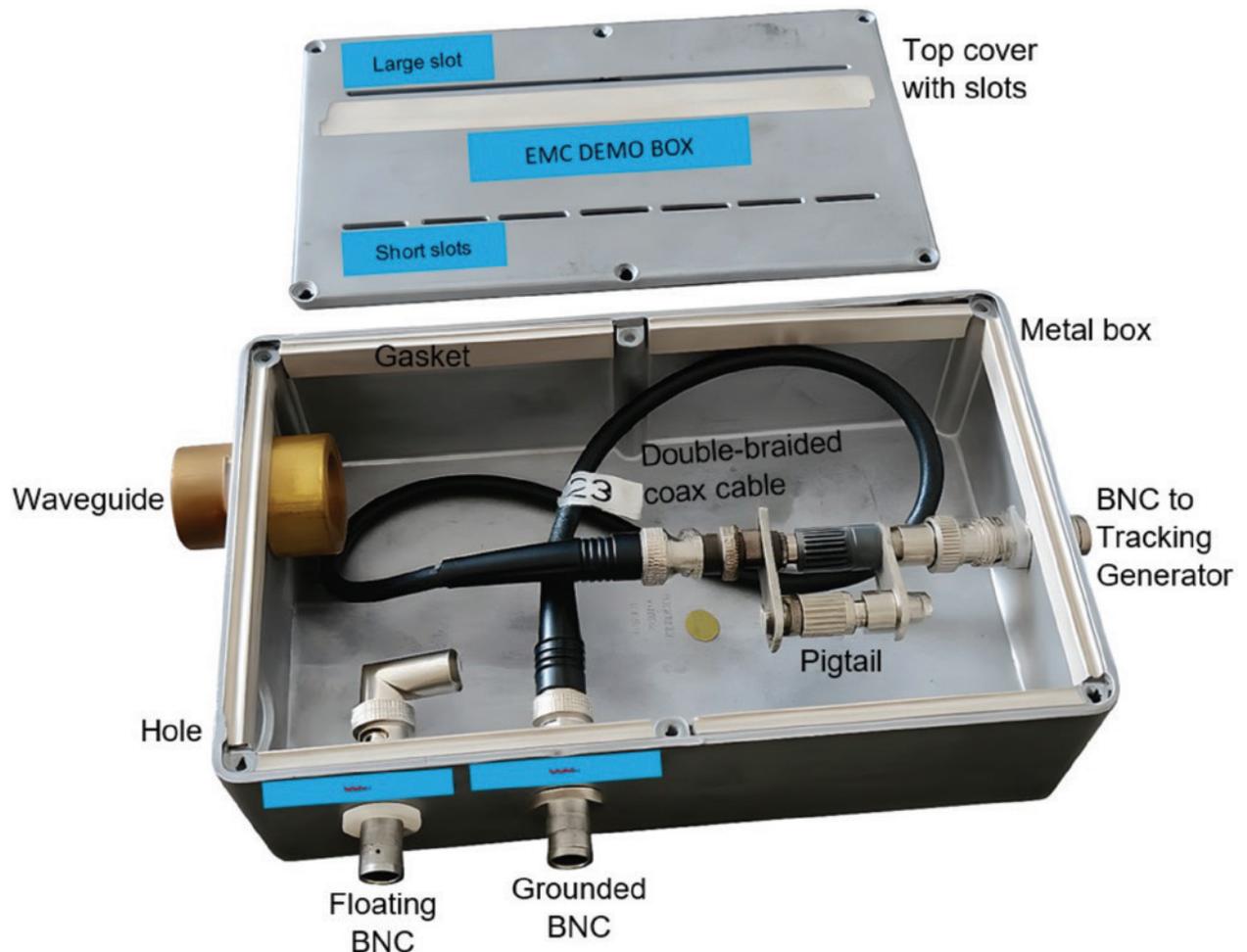


Figure 2: Opened EMC Demo Box showing internal source, slots, connectors, and apertures.

With the dimensions and component list provided in Table 1, the EMC Demo Box can easily be reproduced for educational or research purposes. The EMC Demo Box distinguishes itself through its radical simplicity, physical purity, and strong pedagogical focus. It is a timeless tool that reveals the essence of EMC.

**EMC PHENOMENA DEMONSTRATED**

Using the EMC Demo Box, a wide variety of electromagnetic mechanisms can be observed and measured:

- Slot radiation and leakage through apertures and waveguides
- Common-mode and differential-mode cable radiation
- Grounding and shielding effects

- Return-path and connector influence
- Impact of ferrites, filters, and conductive tapes
- Reciprocity: By swapping the generator and analyzer connections, the same setup demonstrates both emission behavior (by measuring fields from the box) and immunity behavior (by injecting signals into the box).

(For a complete description of the demonstrated EMC phenomena, see Appendix A.)

During workshop sessions, participants perform hands-on measurements, apply countermeasures, and immediately see the effects on the analyzer display. They can visualize cable and slot resonances, common-mode currents, and field coupling, turning abstract concepts into real, memorable experiences.

Category	Item/Description	Specifications/Notes
<b>Measurement Instrument</b>	Spectrum Analyzer with Tracking Generator (Rigol DSA815-TG)	Frequency range: 9 kHz - 1.5 GHz
<b>Demo Hardware</b>	EMC Demo Box	Eddystone die-cast aluminum enclosure (188×120×57 mm) with slotted top cover (1×160 mm, 7×20 mm), 22 mm hole, 40×22 mm waveguide, three BNCs (two grounded, one floating), top cover secured with conductive gaskets, and six screws.
<b>Current Probe</b>	FCC F-61	Frequency range: 150 kHz - 1 GHz; transducer factor applied in analyzer.
<b>Magnetic Field Probe</b>	EMCO Probe	Loop diameter: 3 cm
<b>Cables (50 Ω)</b>	Double-braided coaxial cables (RG223) with BNC connectors Single-braided coaxial cable (RG58) with BNC connectors	2 × 0.5 m, 3 × 1 m 1 × 1 m
<b>Terminations &amp; Connectors</b>	BNC Terminators Connectors / Adapters	2 × 50 Ω 2 × N-BNC
<b>Filter Component</b>	π-Type Low-Pass Filter	Cut-off frequency $f_c = 48$ kHz; characteristic impedance $Z_0 = 50\Omega$
<b>EMC Countermeasures</b>	Clip-On Ferrite Beads Conductive Tape Conductive fabric sheet	2 pieces 2 strips, each 180 × 10 mm 10 × 10 cm
<b>Grounding Accessories</b>	Copper Wires Pigtails constructed from two BNC banana plugs	Lengths: 10 cm and 3 cm Loop area: 7 cm <sup>2</sup>

Table 1: Overview of instruments and components required to perform all EMC Demo Box experiments

As part of the exercises, participants are also challenged to determine which countermeasures are required to bring the EMC Demo Box into compliance with legal EMC emission limits, reinforcing the direct link between design choices and regulatory performance.

An instructive example of what can be observed with the EMC Demo Box is shown in Figure 3. It compares the common-mode current measured on a coaxial cable (type RG223) in two configurations, one with the cable shield floating and the second with the shield connected through a proper 360-degree grounding termination to the metal box. The measurement was performed using a current probe and a spectrum analyzer in the frequency range from 30 to 300 MHz.

The results clearly demonstrate the importance of a proper cable termination. When the shield is left

floating, significant common-mode current appears, exceeding  $3 \mu\text{A}$  across a wide range of frequencies. In contrast, when the same cable is bonded with a 360-degree connection to the ground, the common-mode current drops by more than 30 dB, remaining well below the legal  $3 \mu\text{A}$  limit line (based on CISPR 32 Class B limits for multimedia equipment).

This simple experiment makes visible how an improper shield connection can drastically increase common-mode emissions, an effect that is often underestimated in practice but becomes immediately clear when demonstrated with the EMC Demo Box.

In its current form, the EMC Demo Box effectively demonstrates fundamental EMC principles from 1 MHz to 1 GHz, covering common emission and immunity challenges. Its core design, a metal enclosure with controlled apertures and coupling paths, is inherently scalable. With the simple

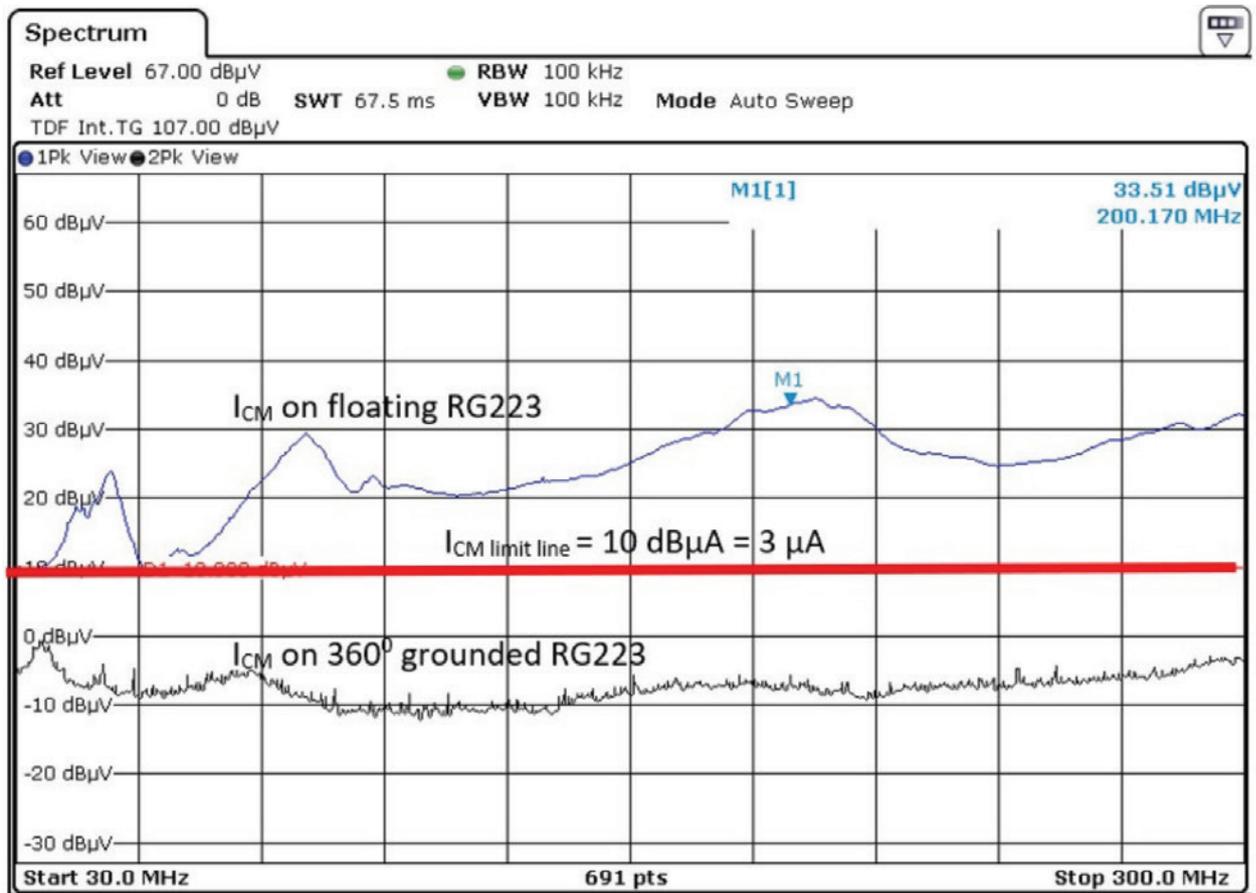


Figure 3: Measured common-mode current on a coaxial cable under two termination conditions

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Through guided experiments, participants not only see the effects, but also understand why they occur. They learn that EMC issues are rarely caused by schematic design alone, but by physical coupling paths, geometry, and current distribution.

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substitution of a spectrum analyzer featuring a tracking generator capable of operating up to 6 GHz, the demonstration platform can be seamlessly extended to higher frequencies, making the EMC Demo Box a versatile and inherently future-proof tool for both current and emerging EMC applications.

### FROM OBSERVATION TO UNDERSTANDING

The educational impact is profound. Through guided experiments, participants not only *see* the effects, but also understand why they occur. They learn that EMC issues are rarely caused by schematic design alone, but by physical coupling paths, geometry, and current distribution.

This hands-on approach bridges the gap between theory and physical reality, transforming EMC from a compliance problem into a design discipline. Through this practical, experiment-driven approach, participants not only solidify their theoretical knowledge but also develop critical thinking and analytical skills essential for diagnosing and solving complex EMC challenges in real-world design.

The same setup is also used in industry-oriented sessions, not only for engineers but also for management awareness training. By witnessing in real-time how a small mechanical detail, like a cable shield connection, can cause or suppress interference by 30 dB or more, decision-makers gain immediate and tangible insight into why EMC considerations must begin early in the design process.

Feedback from participants confirms the educational value of the EMC Demo Box. As an example, an engineer reported that “after completing the hands-on exercises, the theory suddenly made sense, we could see the real behavior of currents and fields that had previously been just formulas.”

The educational approach of the EMC Demo Box is supported by established pedagogical research and

trends in EMC education. The philosophy of “learning by doing,” succinctly captured by Confucius, is strongly advocated in modern engineering education.<sup>1</sup>

Furthermore, the value of simple, hands-on tools for teaching EMC fundamentals has been demonstrated by leading educators in the field.<sup>2,3</sup> The EMC Demo Box aligns with this consensus, providing a versatile and accessible platform to implement these proven educational strategies.

### THE HUMAN ELEMENT IN THE AGE OF AI

In an era where artificial intelligence transforms both education and engineering, the EMC Demo Box reminds us of the irreplaceable value of learning by doing. While AI can analyze data, simulate circuits, and even generate theoretical explanations, it cannot reproduce the intuition and understanding that come from performing real measurements and observing physical phenomena.

Developed from decades of EMC training and workshop experience, the EMC Demo Box offers something no algorithm can provide: the human connection between cause and effect. It shows that true EMC competence emerges not only from knowledge, but from direct interaction with the physical world.

The Demo Box also serves as a counterweight to AI-driven education. It turns learning into active exploration: students form hypotheses, make measurements, and draw conclusions. They learn to think and reason like engineers, rather than simply producing ready-made answers generated by a machine.

Ultimately, the EMC Demo Box trains skills that no AI can provide: critical thinking, judgment, and responsibility. These human qualities are essential for designing safe, reliable, and compliant technology, and for keeping humans firmly in the loop as AI continues to reshape technical practice.

The EMC Demo Box demonstrates that simplicity is the key to understanding complexity. It transforms invisible electromagnetic behavior into something visible, measurable, and repeatable.

## CONCLUSION

The EMC Demo Box demonstrates that simplicity is the key to understanding complexity. It transforms invisible electromagnetic behavior into something visible, measurable, and repeatable. And it shows that EMC is not about black-box testing, but about understanding the underlying physics of design.

As Confucius said: *“What I do, I understand.”*

That simple wisdom continues to guide how we teach and how we truly learn the art of electromagnetic compatibility. Even in an age of artificial intelligence and digital automation, it is through direct experience – through doing, observing, and understanding – that real engineering insight is born. True understanding in EMC cannot be written; it must be experienced.

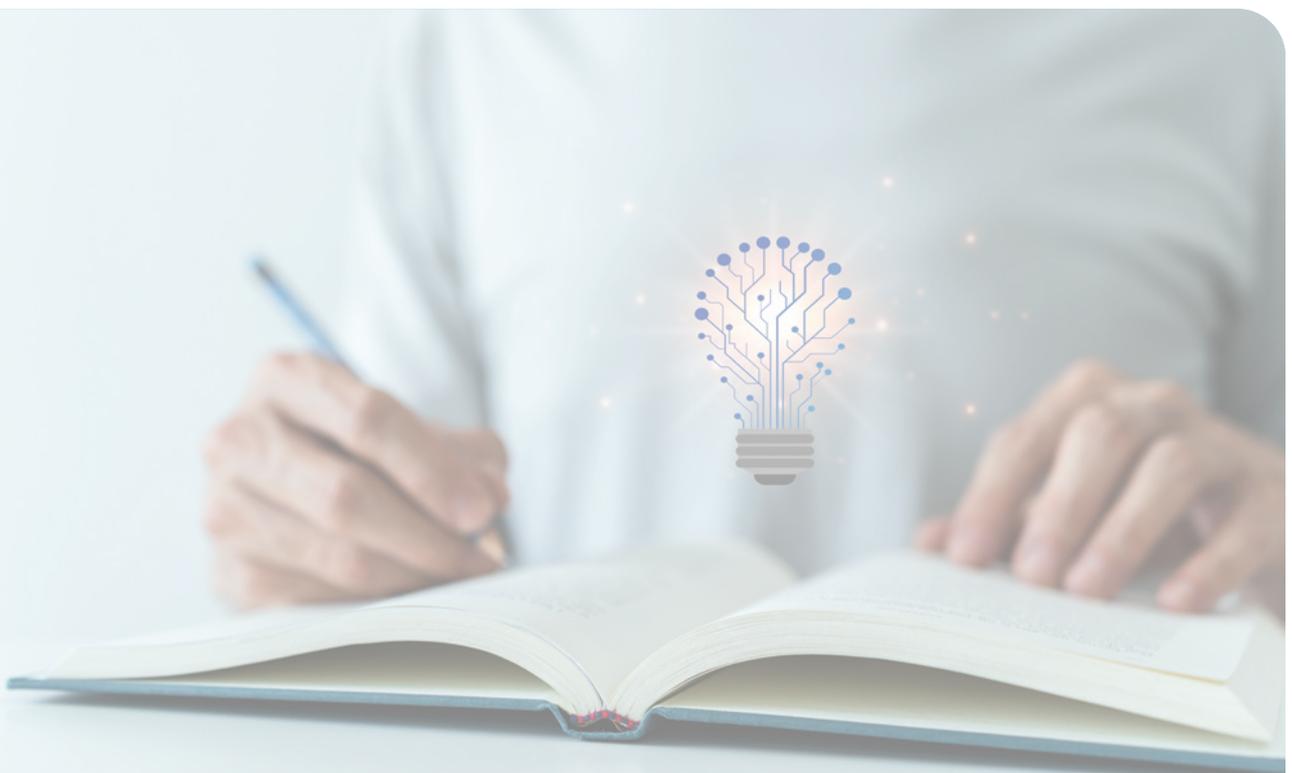
The EMC Demo Box is currently used in several university and industry training programs to bring these principles to life. Readers who wish to explore

the full set of hands-on exercises and demonstrations are invited to consider one of the following specialized EMC courses:

- High Tech Institute – Electromagnetic Compatibility Design Techniques
- High Tech Institute – EMC Course for Mechatronic Engineers
- PAO – Electromagnetic Compatibility (EMC) 

## ENDNOTES

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## Appendix A

### EMC Phenomena Demonstrated with the EMC Demo Box

#### 1. Radiation from apertures and slots

Even small apertures in a shielding enclosure act as efficient antennas when their dimensions approach half the wavelength of the interference. The demo shows how a long slot resonates and radiates strongly, and how simple countermeasures (e.g., conductive tape or shortening the slot) reduce emissions.

#### 2. Cable radiation and common-mode excitation

By attaching a single-braided coaxial cable to the box, strong common-mode (CM) currents appear on the cable shield, turning the cable into an unintended antenna (cable resonances). Students can measure how far these CM currents exceed legal emission limits, and how ferrite beads, grounding, filtering, or cable choice mitigate the problem.

#### 3. Shielding quality and transfer impedance

A comparison between RG58 (single-braided) and RG223 (double-braided) coaxial cables clearly shows how lower-quality shielding leads to substantially higher CM currents. This demonstrates the concept of transfer impedance (DM-to-CM conversion,  $Z_T = V_{CM}/I_{DM}$ ) and why cable construction, braid density, and connector quality directly affect EMC behavior.

#### 4. Connector mounting and shield termination

The demo highlights how improper termination (e.g., a floating connector or long pigtail ground) introduces parasitic inductance and leakage paths. Measurements show how even a high-quality double-braided cable can lose most of its shielding effectiveness when its shield is routed through a pigtail. Proper 360° shield termination, by contrast, keeps interference inside the enclosure and prevents CM excitation.

#### 5. Filtering

Low-pass filters effectively reduce non-functional high-frequency currents. Measurements show how both differential-mode (DM) and common-mode (CM) currents drop when appropriate filtering is applied.

#### 6. Ferrite beads

Ferrite cores provide a frequency-selective impedance, typically reducing CM currents on cables by roughly 10 dB at the resonance frequencies. The demo makes this effect measurable and repeatable.

#### 7. Waveguide below cutoff

A waveguide below cutoff (diameter  $\ll \lambda/2$ ) provides effective shielding. If a metallic cable is routed through the waveguide, it bypasses the cutoff principle and acts as a leakage path. Only non-conductive cables (e.g., optical fiber) can pass through without degrading shielding effectiveness.

#### 8. Reciprocity principle

The reciprocity principle states that the transfer function between two points is unchanged when the generator and receiver are interchanged, provided the system is linear, passive, and time-invariant. The EMC Demo Box satisfies these conditions, enabling emission-immunity reciprocity experiments with the same setup.

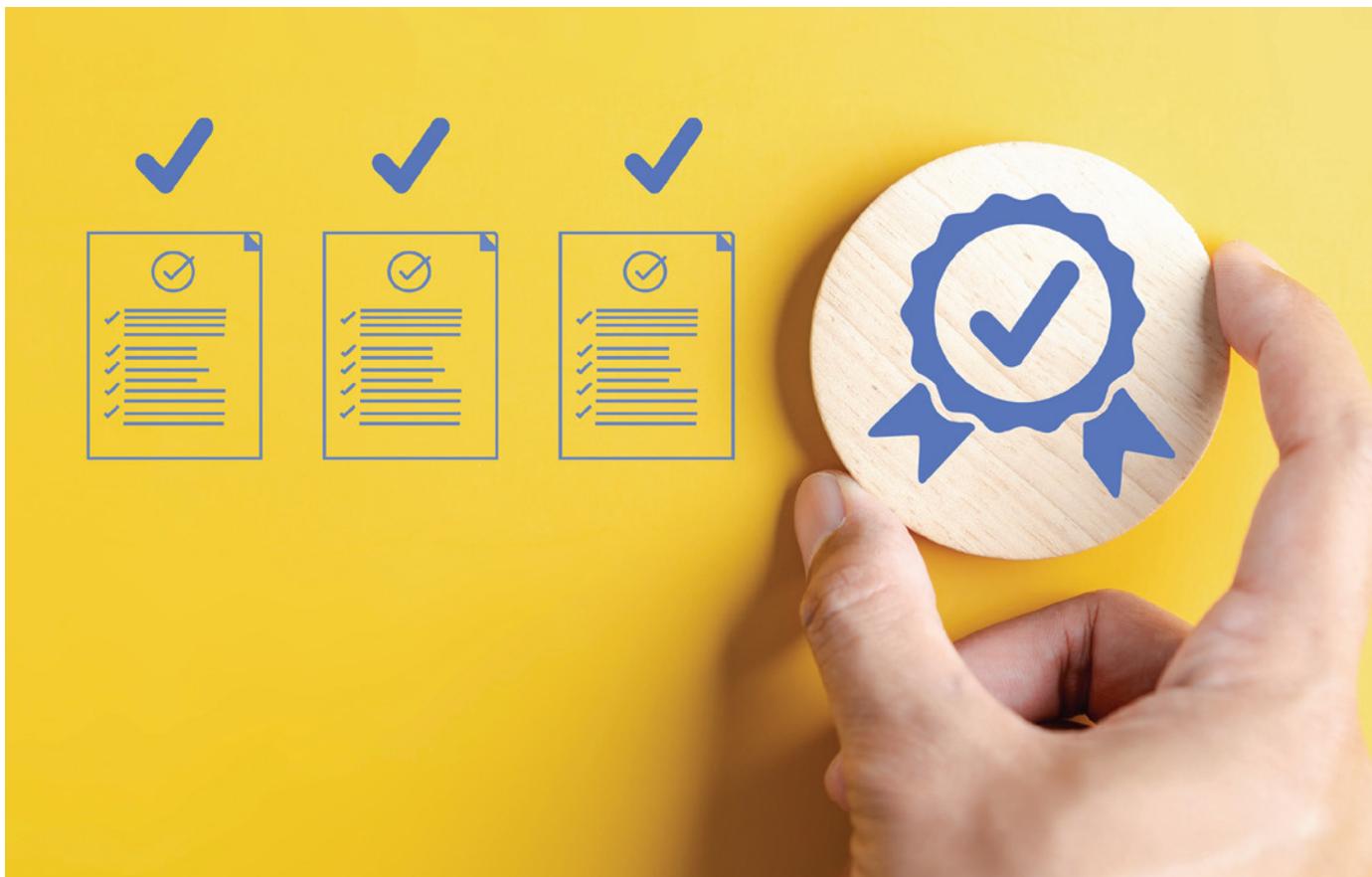
# ISO 17025 ACCREDITATION FROM A TEST LAB'S PERSPECTIVE

Did You Know Your Third-Party Accredited Test Lab Must Comply with Standards Too?

Independent testing laboratories become accredited under International Standards Organization ISO 17025, just as most manufacturers today accredit their organizations using ISO 9000-9001 or other applicable standards.

The third-party test lab accreditation program requires that a testing lab be evaluated by compliance auditors, a process that can take days, or even weeks, as auditors scrutinize every detail of every standard for which the test lab is seeking accreditation. The audit process

involves observing every step of the testing and reporting process, and includes reviewing documentation, inspecting the test equipment and its calibration, questioning the test engineers, evaluating the facility itself, checking the current version of the software, as well as reading through minutes of managers' meetings, training manuals and responses to customers inquiries. This rigorous review and inspection provide a thorough evaluation of the test lab's systems and processes and helps to ensure that the quality of its evaluations meets the requirements of the applicable standards.



## By Marilyn Sweeney, Mitch Gaudyn and Brian Mattson

The process of obtaining accreditation is complex and challenging. However, test labs that have been accredited to ISO 17025 are most likely to provide their manufacturing customers with the highest-quality testing by knowledgeable and experienced test engineers. Test lab customers can also ask to see the test lab's Certificate of Accreditation which can be thirty pages or longer as it lists each test in a standard for which the test lab has been accredited.

### WHY WOULD A TEST LAB WANT TO PUT ITS EMPLOYEES THROUGH SO MUCH PRESSURE?

First off, the test lab wants to be a high-quality, first-rate lab that does every aspect of the testing and reporting process accurately with results that are reliable and repeatable, so their customers' products work well out in the field.

Secondly, certification provides manufacturing customers with assurances that their lab will provide the highest quality testing and reporting to the latest requirements of each appropriate standard for each country in which they sell their product.

### THE ACCREDITATION PROCESS

The first step for a test lab is to check the background of the various accreditation bodies such as ANAB, NVLAP, A2LA, and others to make sure they are reputable and that they have the technical expertise to provide the accreditation the lab needs. Then they hire one of the accreditation bodies.

Next, they make sure the accrediting body understands the scope of the audit they want, so they receive accreditation for standards in all the different types of industries they test for and in all the different countries they test for, and for all the

Marilyn Sweeney is CEO and one of the founding members of D.L.S. Electronic Systems, Inc., a compliance testing laboratory located in Wheeling, IL. She can be reached at [msweeney@dlsemc.com](mailto:msweeney@dlsemc.com).



Mitch Gaudyn is the Quality Manager at D.L.S. as well as the Technical Facilities Manager and can be reached at [mgaudyn@dlsemc.com](mailto:mgaudyn@dlsemc.com).



Brian Mattson is the General Manager of D.L.S. and can be reached at [bmattson@dlsemc.com](mailto:bmattson@dlsemc.com).



different types of testing they do, such as EMC, FCC, ISED, environmental, wireless, and product safety. The number of standards that a test lab is accredited for determines how long the audit will take and how much it will cost.

Although the accreditation bodies' processes vary somewhat, they all evaluate your lab on an annual basis according to the ISO Quality Standard 17025. However, accreditation bodies may differ in the scope of what they cover each year. For example, an accreditation body may give a very comprehensive evaluation every other year, which can take two full weeks or more, and on the odd years provide a surveillance audit consisting of a shorter spot-check taking around four days to complete, depending on whether or not you have scope updates or additions.

The test lab is normally not informed as to what details will be checked, so it must make sure that every section of its quality system is in perfect condition, which includes contracts review, quoting process, testing, calibration, reports, etc.

### PREPARING FOR AN AUDIT

The best way to prepare for an upcoming audit is to always keep your facility, test equipment, test procedures, report procedures, etc., top-notch. To do this, you designate a quality control engineer whose job is to scrutinize every aspect that could possibly be evaluated by the auditors. If the engineer finds something that is not up to standard, they immediately make the necessary changes. Following are some examples:

### **Monitoring Standards**

Test labs constantly monitor standards agencies and industry publications to be informed when new standards are introduced and when they will be enforced, and also when the current version of a standard is being updated. When the lab purchases a new standard or a new version of a standard, they need to add it to their directory of standards. Before an audit, the lab must verify that its standards directory is current and that nothing has been omitted, as the auditor will be checking this information. You never want to test to an outdated standard (unless a customer has a specific reason for needing to test to that standard, which is rare).

### **Training and Teaching**

Test labs are continuously training and teaching test engineers on the intricacies of accurately setting up and testing for standards of each specific product industry. This training must be recorded in each employee's training manual, showing every type of test they are qualified to perform. If the laboratory tests for many different product industries, the engineers increasingly become more knowledgeable at testing a wider variety of products. Before an audit, we verify that the training records for each employee list all the capabilities of that employee, as auditors will look at their individual training manuals. No one wants their product tested by an engineer who has not been properly trained on how to set up and perform that specific test.

### **Set Up and Perform Testing Properly**

Each test engineer not only needs to be able to set up and perform a test properly but must also understand the details of the test standard and the basis for its particular requirements before they begin the actual testing. So, before an audit, each employee should have the knowledge required to understand and accurately answer any questions that an auditor may ask them. They need to know why they are setting up that test in that specific way and why they are testing that product in that specific way.

### **Test Equipment**

Standards generally specify what test equipment is required to fully assess their requirements. After

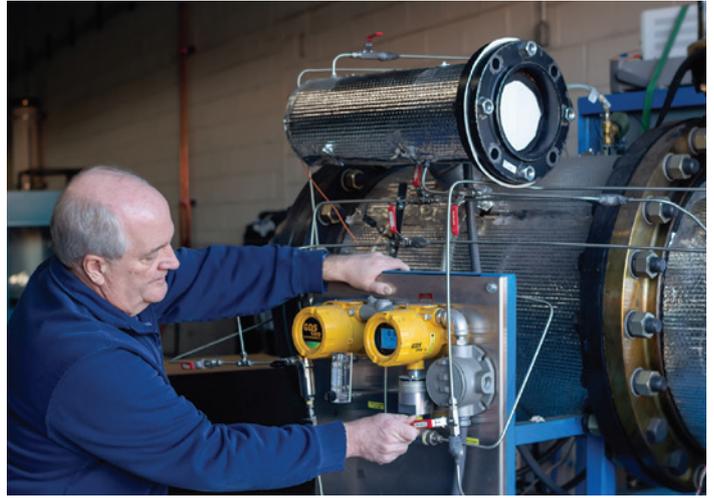


Figure 1: Example of proficiency testing in action

purchasing the specified equipment, the test lab is responsible for making sure it is working properly during testing, that the current software version number is recorded in the equipment database, and that the equipment is calibrated on a regular basis and is traceable to NIST. Test labs are able to do some calibrating themselves and some equipment gets serviced on-site by a third party, while some equipment has to be sent out to be calibrated, which can be time-consuming.

### **Facility Requirements**

Many standards detail specific facility requirements, such as the layout of the room, the type of absorbing material used, and specific requirements to meet normal site attenuation. For example, test chambers are sometimes required to be of a specific height in order to raise and lower antennas, while others may need turntables in order to rotate the product being tested. The auditors check the facilities at each of the company's locations for these issues.

### **Creating Reports**

Standards specify exactly how a report is to be constructed, with photos showing the test setup, the testing that was performed, and the results of each test to verify the validity of the test results and the accuracy of the test report. Auditors check each detail of the report system and how test results are recorded as well as the test lab's communication with customers post-testing to determine their satisfaction. If the customer

does raise concerns about the testing, the auditors verify that the issues identified were addressed to the customer's satisfaction. Finally, every detail of the test setup and the testing must be documented so it can be repeated at a later date if necessary.

### **Organization Chart**

Auditors also check the test lab's organization chart, making sure each employee knows which manager they are accountable to. Auditors also read the minutes of managers' meetings to see that everyone follows through on any changes that need to be made. They review the test lab's goals and priorities.

## **THE AUDIT**

The accrediting body appoints qualified auditors who will spend a few days to a few weeks at the test lab, depending on the number of standards for which the test lab is to be accredited. The auditors generally change from year to year. They begin by working with the lab's quality control manager to see that all records have been kept and are up-to-date, as proper documentation is a huge part of the audit. They interview lab personnel for their knowledge and performance and to verify that they have the required experience with the test procedures, the test equipment, and the standards used.

Auditors will also decide if the lab is adequately staffed for the type and volume of testing currently undertaken, and that the laboratory has the necessary competencies related to the fulfillment of ISO/IEC 17025:2017

requirements. The specific accreditation body may also have additional accreditation requirements. As you can see, no stone is left unturned. Every possible aspect of testing and reporting is scrutinized.

### **Certificate of Accreditation**

Once the auditors are satisfied that they have thoroughly checked every aspect of the lab's testing and reporting qualifications, and the lab has been found to be:

- Technically competent and well organized in their approach to testing for all the standards on their scope of accreditation; and
- Their management quality system is well-defined and is being implemented to ensure they follow ISO/IEC 17025:2017 requirements,

they present the test lab with a Certificate of Accreditation, which also includes comments on competence, comments on conformity, and opportunities for improvement.

### **Conditional Approval Pending Satisfactory Nonconformity Corrective Action Response**

If even the smallest detail is found lacking, the test lab is instead given a Conditional Approval Pending Satisfactory Nonconformity Corrective Action Response that gives the test lab 30 days to make the necessary changes. If all recommended changes have been made in the allotted time, the test lab then receives its Certificate of Accreditation.



Figure 2: An auditor checking documentation with test lab employees

## **SUMMARY**

Test labs work hard to make sure everything about their testing and reporting process is compliant at all times. Even when an auditor makes suggestions for improvement, no matter how minor, the test lab is appreciative of being notified so that it can quickly make the required improvements to maintain its compliance with the requirements of the standard. 

# SHIELDING TO PREVENT RADIATION

## Part 7: Effect of the Apertures

By Bogdan Adamczyk

This is the final article in a series [1-7] devoted to the topic of shielding to prevent electromagnetic wave radiation. All the previous articles assumed a solid shield with no apertures. This article addresses the impact of slots or apertures in the shield on radiation. It is shown that apertures can be as effective radiators as antennas of the same dimensions.

### APERTURES AND SHIELDING EFFECTIVENESS

In practice, most shields are not solid, since there must be access covers, doors, holes for cables, ventilation, and displays, like the ones shown in Figure 1.

All of these apertures reduce the effectiveness of the shield. Consider a solid shield shown in Figure 2.

The incident field induces a surface current in the shield, which may be thought of as producing the reflected field that tends to cancel the incident field [8]. In order for the shield to perform this cancellation, the induced currents must be allowed to flow unimpeded, as shown in Figure 3a.

The slot will impede the current flow. Figures 3b and 3c illustrate that the thickness of the slot is not critical, but the length of it is. An obvious solution

Dr. Bogdan Adamczyk is professor and director of the EMC Center at Grand Valley State University (<http://www.gvsu.edu/emccenter>) where he performs EMC educational research and regularly teaches EM/EMC courses and EMC certificate courses for industry. He is an iNARTE-certified EMC Master Design Engineer. He is the author of two textbooks, "Foundations of Electromagnetic Compatibility with Practical Applications" (Wiley, 2017) and "Principles of Electromagnetic Compatibility: Laboratory Exercises and Lectures" (Wiley, 2024). He has been writing "EMC Concepts Explained" monthly since January 2017. He can be reached at [adamczyb@gvsu.edu](mailto:adamczyb@gvsu.edu).



*In practice, most shields are not solid, since there must be access covers, doors, holes for cables, ventilation, and displays.*

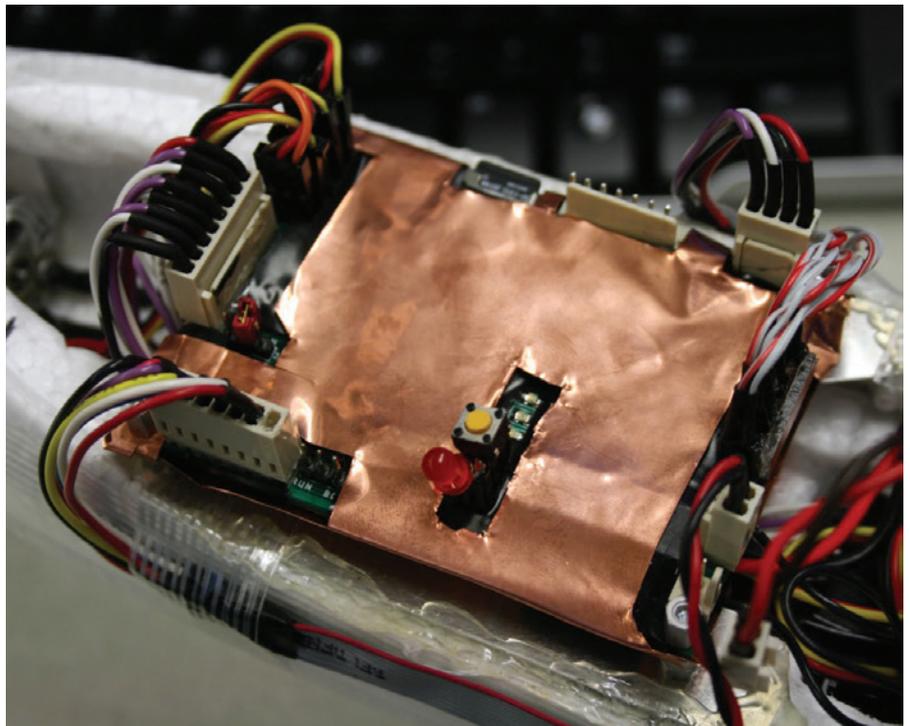


Figure 1: Metallic shield with apertures

The incident field induces a surface current in the shield, which may be thought of as producing the reflected field that tends to cancel the incident field. In order for the shield to perform this cancellation, the induced currents must be allowed to flow unimpeded.

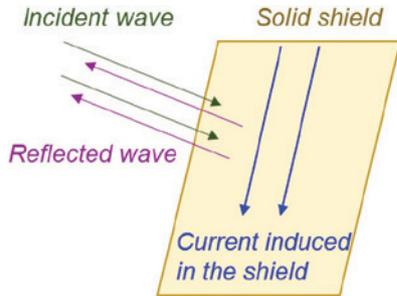


Figure 2: Incident wave induces current in the shield

might be to place the slot parallel to the current flow, as shown in Figure 4a, to minimize its adverse effect.

The problem with this solution is that it is not feasible to predict the direction of the induced current. A reasonable solution is to use a large number of small holes (Figure 4b), as these small holes disturb the induced current to a much lesser degree.

### ELECTRIC DIPOLE AND ITS FIELDS

The electric (Hertzian) dipole and its complete fields are shown in Figure 5.

The far fields of the electric dipole are

$$\hat{E}_r = 0 \quad (1)$$

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

$$\hat{H}_\phi = j\beta_0 \frac{I_0 l}{4\pi} \sin \theta \left( \frac{e^{-j\beta_0 r}}{r} \right) \quad (3)$$

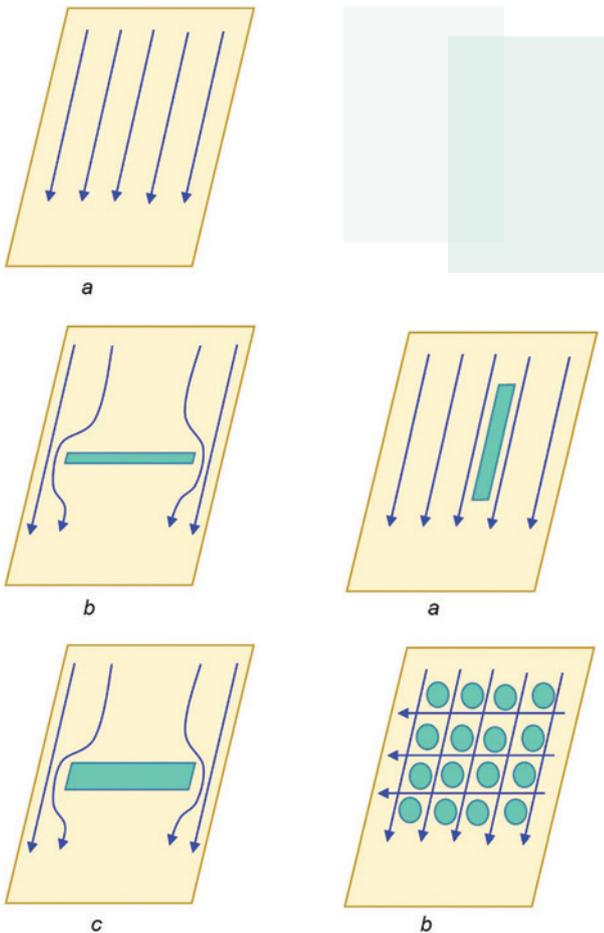


Figure 3: Effect of slots on induced currents

Figure 4: Effect of slots on induced currents

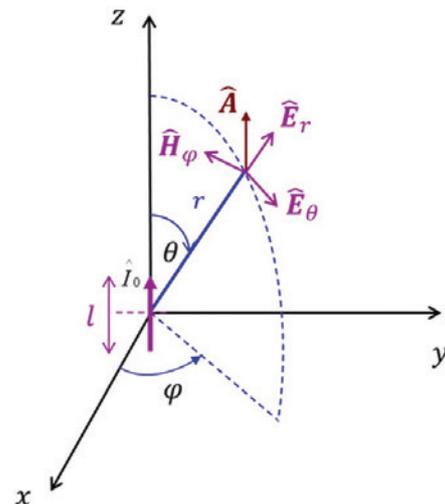


Figure 5: Hertzian dipole antenna and its fields

Babinet’s principle, modified by Brooker for antennas, provides a way to analyze the radiation from slot antennas by treating a conducting strip (of the same dimensions as the slot) like a complementary antenna to shield with a slot.

The simplified far-field model of the dipole (oriented along the  $z$  axis), and the fields at an observation point  $P$  at the location  $(\theta = 90^\circ, \phi = 90^\circ)$  are shown in Figure 6.

The fields in Figure 7 and Figure 8 are related by [9]:

$$\hat{E}_{\phi S} = \hat{H}_{\phi C} \quad (4a) \quad \hat{H}_{\theta S} = -\frac{\hat{E}_{\theta C}}{\eta_0^2} \quad (4b)$$

Electric source,  $J$ , produces the fields  $\hat{E}_\theta$  and  $\hat{H}_\phi$  at an observation point  $P$  in the far field of the antenna. The medium with intrinsic impedance  $\eta_0$  is infinite with no other objects present.

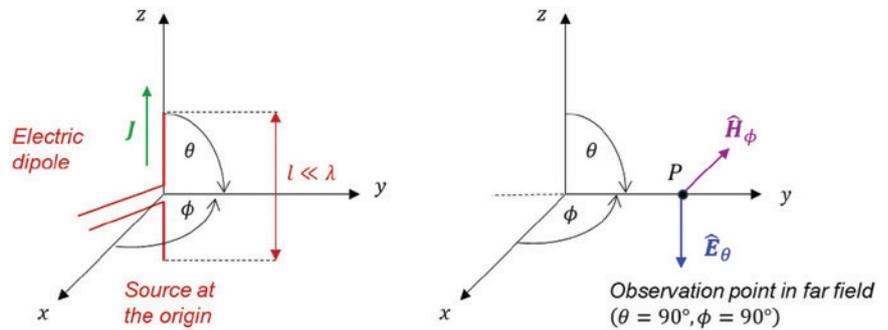


Figure 6: Far fields of the electric dipole antenna

### BABINET’S PRINCIPLE APPLIED TO A SLOT ANTENNA

Babinet’s principle, modified by Brooker for antennas [9], provides a way to analyze the radiation from slot antennas by treating a conducting strip (of the same dimensions as the slot) like a complementary antenna to shield with a slot.

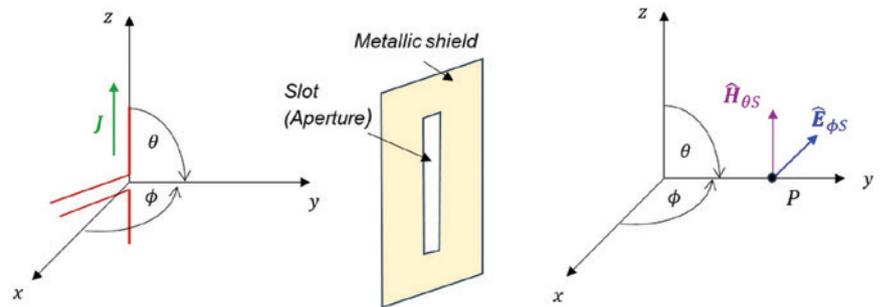


Figure 7: Far fields in presence of a shield with a slot cut out

Figure 7 shows an infinite thin flat metallic shield with a slot cut out, placed between the source and the observation point in the far field.

Now, the fields at an observation point  $P$  are  $\hat{E}_{\phi S}$  and  $\hat{H}_{\theta S}$ , as shown in Figure 7. Next, the shield is replaced by a complementary thin metallic strip of the same dimensions as the slot, as shown in Figure 8.

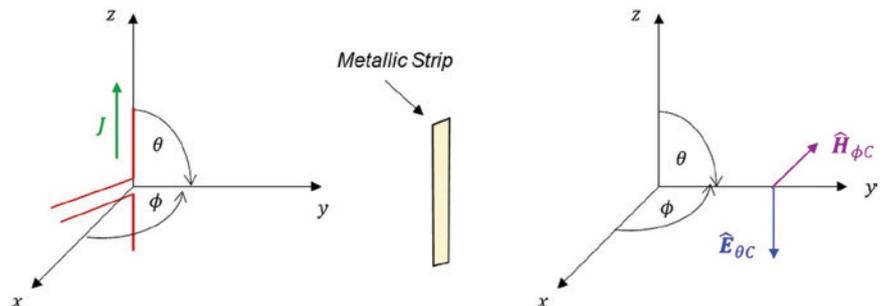


Figure 8: Far fields in presence of a metallic strip

Now, the fields at an observation point  $P$  are  $\hat{E}_{\theta C}$  and  $\hat{H}_{\phi C}$ .

Next, consider the situation shown in Figure 9a where the electric dipole is rotated and oriented along the  $x$ -axis.

Figure 9b shows the fields at the observation point in far fields with the shield containing a slot cut out, placed between the source and the observation point. Figure 9c shows the fields with a metallic strip of the same size as the slot placed between the source and the observation point.

Figure 9 leads to the two additional relations [9]:

$$\hat{E}_{\theta S} = \hat{H}_{\theta C} \quad (5a)$$

$$\hat{H}_{\phi S} = -\frac{\hat{E}_{\phi C}}{\eta_0^2} \quad (5b)$$

Equations (4) and (5) lead to the conclusion that apertures can be as effective radiators as antennas of the same dimensions. ©

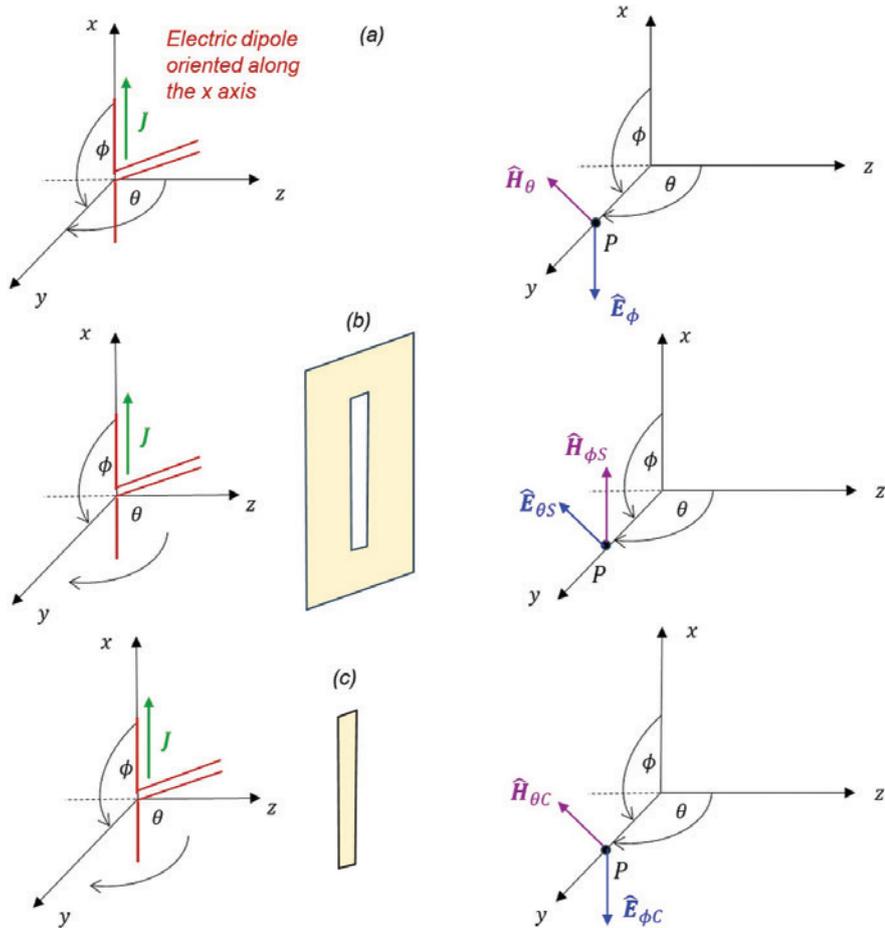


Figure 9: Far fields in the presence of a shield with a slot cut out and the metallic strip

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# SMALL FORM FACTOR CDM TESTING

## Part 1: Problems with FICDM Testing for Small Form Factor and Interface Die

By Kathleen Muhonen for EOS/ESD Association, Inc.

ANSI/ESDA/JEDEC JS-002 [1] specifies how to test and qualify a product for a factory CDM event. The document is intended for the testing of packaged devices. Thus, CDM testers in the industry have mechanical stages and contact pins that are oriented towards products in packages with pin pitches typical of today's package sizes. With shrinking footprints and increasing integration (for example, flip chip or wafer level chip scale packaging), bare die are being sold to original equipment manufacturers (OEMs). OEMs are asking the IC manufacturers to give a CDM rating for these packageless products. However, the existing CDM testers introduce issues when considering the testing of small form factor die. Additionally, there are products that have very low withstand voltages for CDM, and the traditional CDM testers do not produce reliable waveforms for voltages below 100V. This column discusses some of the issues with Field-Induced CDM (FICDM) testing, which is troublesome for small form factor and interface die.

### THE NEED FOR BARE DIE AND SMALL FORM FACTOR CDM TESTING

Several industry segments are moving to packageless products. In the mobile phone industry, many products are now packageless. ICs have more integration on one chip, and the footprint continues to shrink. Antenna tuners and filters are sold directly to the OEMs as bare die for flip chip assembly. This is more attractive as there are cost savings, space savings and performance improvements in removing wire bonds.

The flip chip products pose problems for CDM testing. One problem is that the pitch of these bumps is so

Kathleen Muhonen is a Principal Development Engineer at Qorvo, specializing in ESD protection and instrumentation. She serves on ESDA device testing standards committees and holds a Ph.D. in EE from Penn State, with prior roles at HP and Lockheed Martin.



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



small that the pogo pin of an FICDM tester cannot contact one bump at a time. In addition, these die are small, which makes it difficult to hold the device in place on a FICDM tester.

Traditionally, multi-die packages have separate ICs inside the package. Therefore, the solder ball sizes and spacings were the same size and pitch as a package substrate. With the desire for increased connections between the different die in the package, manufacturers have developed a variety of 2.5D and 3D packaging solutions. Figure 1 illustrates a 3D IC stack.

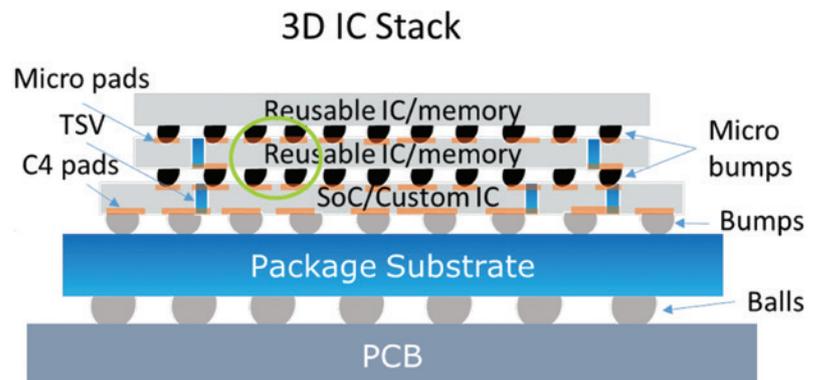


Figure 1: Die-to-die interface example, the green circle indicates a D2D interface

When a bare die product requires a CDM rating, mounting the die in a larger package and stressing the package may be an option. The purpose of the package is to allow the die to be tested on an FICDM tester without the arc terminating on the wrong pad.

3D packaging uses a functional integrated circuit die on the bottom of a stack of two or more die, as shown in Figure 1. The base IC uses through substrate vias, TSV, to make connections between the upper die and the solder bumps on its bottom to accommodate connections to other ICs, often called chiplets. One of the most common applications for stacks of chiplets is memory. The manufacturing steps in 3D assembly provide multiple opportunities for CDM events, and the small size and pitch of the micro bumps present testing challenges.

**WHY FICDM IS A PROBLEM FOR TESTING BARE DIE**

FICDM testing is an industry standard for gauging ESD susceptibility in manufacturing ICs. However, FICDM testing is frequently not suitable for testing small form factor die as listed here.

- FICDM testers may struggle to probe the small pads or bumps.
- The use of a modified pogo may change the ESD stress.
- Air discharge cannot be guaranteed at low voltages.

FICDM test results become unreliable at low voltages due to air discharge and contact impedance variability.

**Probe Too Large for Die Bumps or Pads**

Figure 2 shows a die with pads lined up near the edge. The radius of the probe is about 245 μm, but the pad size is about 50 μm x 50 μm. In this situation, contact with a single pad cannot be achieved.

**Package the Die**

When a bare die product requires a CDM rating, mounting the die in a larger package and stressing the package may be an option. The purpose of the package is to allow the die to be tested on an FICDM tester without the arc terminating on the wrong pad. Analysis of the package must be performed to de-embed the response of the die from the die-in-package response. This process is difficult and time consuming. In addition, it is possible that false failures are induced because of the large amount of charge that the package will have as opposed to the bare die.

**Testing Fine Pitch Die Bumps Using a FICDM Tester**

Factors to consider with fine pitch are:

- A pointed pogo pin tip can change the nature of the arc due to the electric field enhancement at the sharp tip.
- The positional encoder and servomotor robotics of CDM testers may not be accurate enough to optimally position the pogo pin over the bump.

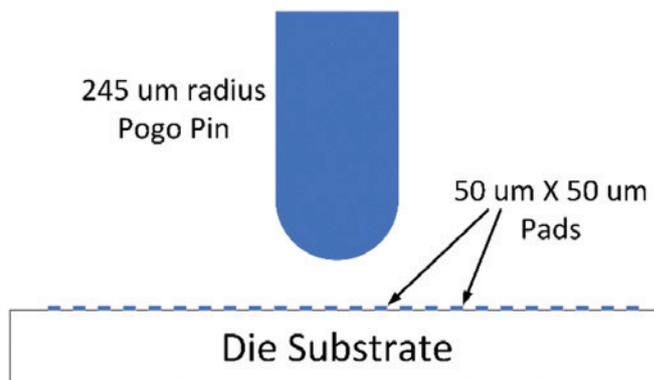


Figure 2: CDM tester probe radius and pad size photo and scale drawing

Below 250 volts, the air discharge spark becomes less repeatable as voltage drops because of the weaker electrical field and resultant weaker ionization of the air in the spark gap. The probability of getting the full discharge peak current appropriate for that voltage becomes lower.

### **Peak Current Repeatability and Spark Impedance at Low Voltages**

Below 250 volts, the air discharge spark becomes less repeatable as voltage drops because of the weaker electrical field and resultant weaker ionization of the air in the spark gap. The probability of getting the full discharge peak current appropriate for that voltage becomes lower. Also, as the voltage decreases, the variability of the spark length and the resistance of the plasma channel increase, causing the resistance of the spark to change. Die-to-die discharge can also occur without a spark gap when the voltage difference is below tens of volts. In this case, there is no additional spark channel resistance or inductance along the discharge path. This can have unpredictable effects on the peak current and rise time. Variations in rise time and pulse width can significantly affect the failure mechanisms created by an ESD event.

### **SUMMARY**

FICDM testers with a pogo pin are unsuitable for bare-die or interface die testing. First, the minimum pogo pin tip diameter is too large for testing microbumps used in small form factor products. Second, the variability of spark discharges at voltages below 250 volts is not predictable. Packaging a die for testing with the FICDM tester is also possible. This method delivers the quickest results because it uses common FICDM testers. However, the package's complex post-test de-embedding is required to deliver correct die-level results.

There exist several viable options for bare-die CDM testing. There is no consensus on which one of these options is the best. The follow-on papers to this introduction will review what has been used in the industry, along with the pros and cons of each approach.

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### **REFERENCE**

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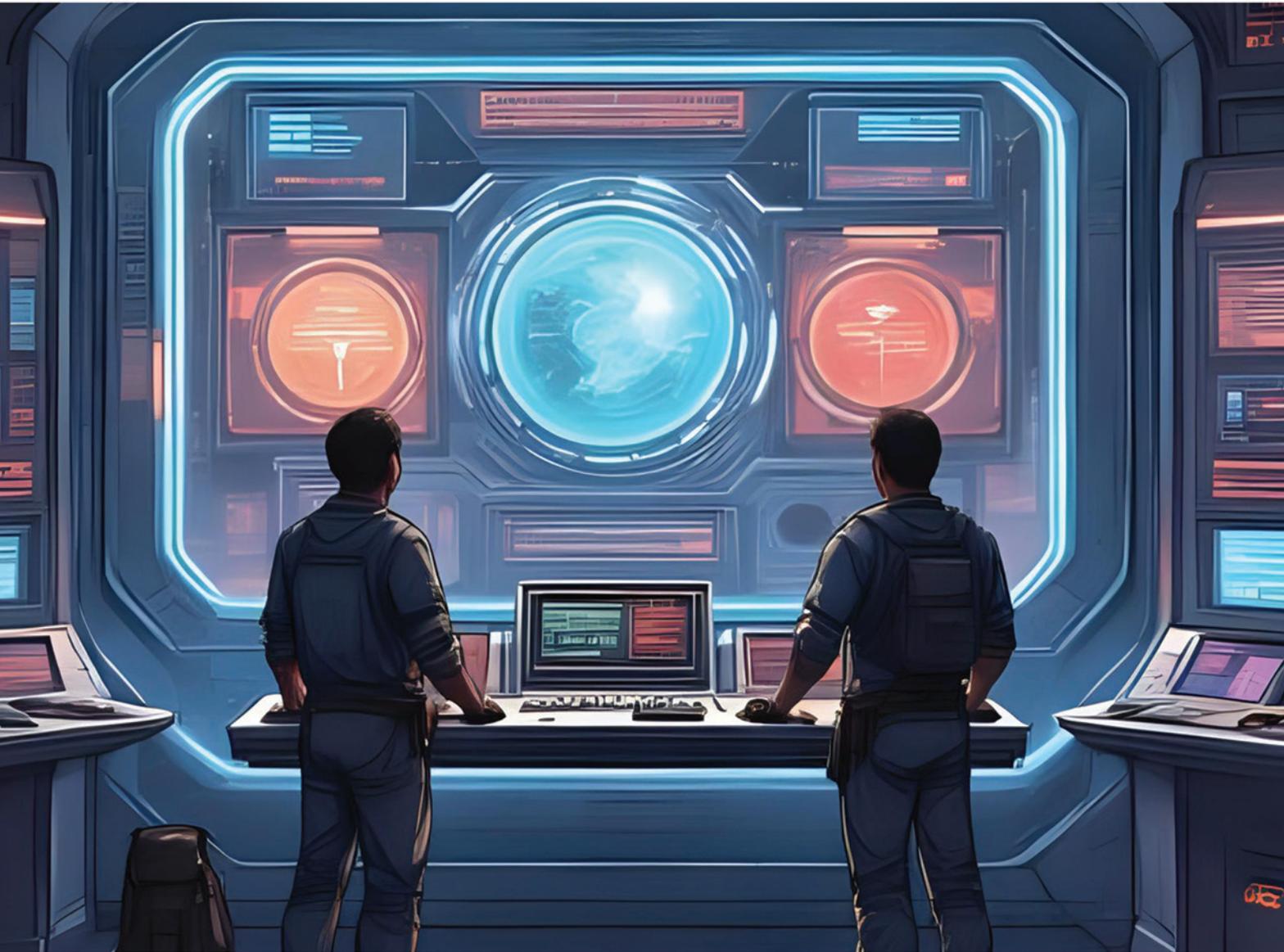
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