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TECHNICAL PROGRAM DETAILS



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CHAIR'S MESSAGE

WELCOME FROM MARK STEFFKA, THE 2023 EMC+SIPI GENERAL CHAIR

WELCOME!

The IEEE EMC Society is pleased that you have joined us for this year's symposium in Grand Rapids, Michigan. Members of the 2023 Symposium committee have worked hard and dedicated themselves to being able to provide a high-quality event, both from a technical standpoint and with regards to social activities that we know you are sure to enjoy.

The content of this year's program carries on the long tradition of these symposia in offering high quality technical program content and opportunities for attendees to interact with exhibitors from around the world. This is demonstrated in the fact that we have over 150 technical paper presentations scheduled (in addition to the papers shown during the poster session), five (5) "Ask the Experts" sessions on a wide variety of topics over several days, 20 "Experiments and Demonstrations" that will be available for all to see in the exhibits area, and 30 "Workshop & Tutorial" sessions. In addition to all that, the registrations for the SIPI "Short Course" and the *Clayton R. Paul Global University* demonstrate that these educational opportunities are valued and relevant.



EMC+SIPI

Back again for this year are the numerous opportunities to attend, and participate in the "Standards Week" sessions and Technical Committee meetings (that are open to all).

To recognize our exhibitors that have joined us this year, we will have an exhibits area opening celebration on Tuesday morning and look forward to seeing all of you there!

Of special note this year, is that we our recognizing our esteemed colleague, Mr. Henry Ott, for his decades of unparalleled technical contributions to the science of EMC, his pursuit of high quality EMC education, and his outstanding leadership in the EMC Society. As a result, our annual tutorial session that has been designed to help those new to EMC (or those who wanted to "brush up" on their knowledge), will now be dedicated to his legacy and known as the "Henry W. Ott Fundamentals of EMC", which will be a full-day tutorial on Monday. All those that benefited from Mr. Ott's dedication to helping us become better in EMC are invited to join us at the conclusion of the Fundamentals sessions on Monday afternoon to recognize what he meant to us.

In conclusion, it has been an honor for me to work with the members of the EMC+SIPI 2023 Symposium planning committee to create what we know will be a valuable (and sometimes amazing) experience!

Mark Steffka

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



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EMC+SIPI

Install and **open** the eventScribe app. Find your event icon in the Upcoming Events (bottom row) or **search** for **EMC+SIPI 2023. Tap** the event icon to launch your event's app.

2. Login to the App:

Tap **Create Account** and enter the event code seen on the signs at the Symposium.

3. App Tips:

Download the app before you go! Wi-Fi connection onsite can affect the functionality of the app. **Browse** the event information and create a personal schedule by tapping on the star next to presentation titles.





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DOWNTOWN GRAND RAPIDS MAP



Attractions 1 Gerald R. Ford Presidential Museum D2 Grand Rapids African American Museum & Archives E4 Grand Rapids Art Museum E4 Grand Rapids Children's Museum F5 5 Grand Rapids Downtown Market 14 6 Grand Rapids Public Museum E2 **Hotels/Meeting Spaces** AC Hotel by Marriott E4 Amway Grand Plaza, Curio Collection by Hilton E3 Canopy by Hilton G4 CityFlatsHotel E5 1 Courtyard by Marriott F3 DeVos Place Convention Center D3 Embassy Suites B4 The Finnley Hotel F5 GVSU Eberhard Center F2 Hampton Inn & Suites C6 Holiday Inn Downtown E2 18 Homewood Suites by Hilton E4 19 Hyatt Place E5 JW Marriott Grand Rapids E3 21 Residence Inn by Marriott F5 Entertainment 22 Ah-Nab-Awen Park D2 23 The B.O.B. F4 Bridge Street Nightlife C1 DeVos Performance Hall D4 Downtown Skate Park B4 GLC Live at 20 Monroe F4 Grand Rapids Ballet H3 Grand Rapids Civic Theatre F5 The Intersection G3 Ionia Ave Nightlife F4 Pyramid Scheme G5 Rosa Parks Circle E4 Spectrum Theater E6 St. Cecilia Music Center F6 Studio Park G4

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GRAND RAPIDS TRANSPORTATION

COMPLIMENTARY SHUTTLE SERVICE FROM THE AIRPORT!

Experience Grand Rapids will be providing EMC SIPI Symposium attendees complimentary (one way) airport transportation from the Gerald R. Ford International Airport to the Amway Grand Plaza Hotel on the dates and times below.

Sunday, July 30th: 10:00AM - 8:00PM Monday, July 31st: 10:00AM - 8:00PM

Transportation will be by full-size motorcoach departing from the airport every hour. To take the shuttle please exit through door #2 (across from the Delta Ticket Counter).

If you are traveling outside of the dates and times noted above please review alternate options noted below.





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If you'd like to book online, please visit the **METRO CABS** website.



RIDE SHARE

In Grand Rapids and at GFIA, both Uber and Lyft provide rideshare services. To access these services download their apps to your mobile device via the Google Play Store or the Apple App Store.

To catch your rideshare at GFIA, exit the terminal through door #2 (across from the Delta ticket counter), and go to the Rideshare Shelter on the boulevard. This is the designated pick-up/drop-off point for all rideshare vehicles.

PUBLIC TRANSPORTATION

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The Rapid bus system, Route 27, serves the Gerald R. Ford International Airport Monday through Friday. You can catch the bus at the climate-controlled shelter on the boulevard across from door #4. When paying with cash, we recommend paying with the exact amount, as each bus ride costs \$1.75 and the fare box cannot provide change. There are no transfers with cash payments. When paying with a Wave card, rides are \$1.75 with free transfers within 1 hour and 45 minutes of the payment. When using the Wave card, you'll never pay more than \$3.50 per day and no more than \$47 per month for unlimited rides.

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DEVOS CONVENTION CENTER MAPS



STREET LEVEL



DEVOS CONVENTION CENTER MAPS



OVERLOOK LEVEL



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AREA INFORMATION

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SPEAKERS BREAKFAST

Grand Gallery DEF • 7:00am-8:00am (Breakfast Only on the Day of Presentation)

REGISTRATION/INFO DESK HOURS

- Sunday- 2:00 pm to 6:00 pm
- Monday 7:00 am to 6:00 pm
- Tuesday 7:30 am to 6:00 pm
- Wednesday & Thursday 8:00 am to 5:00 pm
- Friday 8:00 am to 11:00 am

COMPANION SUITE

Gerald Ford Ballroom – Amway Grand Monday – Thursday: 7:00 am – 10:00 am (Registered Companions Only)

ABOUT GRAND RAPIDS

Get ready to be wowed - Grand Rapids never fails to surprise visitors with the huge variety of things to see and do here: World-renowned art, museums and historic sites for cultural vacationers. World-class golf, recreation and beaches for nature lovers. Incredible farm-to-table restaurants for foodies and wholesome "playcation" fun for families.

It's all topped off by the most vibrant downtown between Chicago and Cleveland - all the benefits of a big city with none of the hassle.

THE DEVOS CONVENTION CENTER

DeVos Place is a premier convention center located in downtown Grand Rapids. Nestled beside the Grand River, the picturesque riverfront setting is the perfect backdrop IEEE EMC+SIPI 2023. Downtown Grand Rapids is located 15 minutes from Gerald R. Ford International Airport and easily accessible from all major interstates.

THE AMWAY GRAND PLAZA

Discover historic charm and modern comforts at our host hotel in Grand Rapids. Set along the Grand River, the hotel has skywalk access to Van Andel Arena and downtown hot spots. There are nine on-site restaurants and bars, in addition to the indoor pool, fitness center, and on-site spa.

WELCOME TO BEER CITY, USA

In 1844, the first pub was born in Grand Rapids by Christoph Kusterer, a German immigrant and trained Braumeister. The rest was history. Beer became very popular in the 1880's when refrigerated train cars were invented. In 1893, Kusterer Brewing Co. consolidated to become part of Grand Rapids Brewing Company, a group of six local breweries. They brewed nearly 250,000 barrels a year until prohibition struck in 1919. Today, Grand Rapids is a community and culture shaped around the artistry and craftsmanship of beer. They got their title of Beer City, USA in 2012, but continue to win awards such as Best Beer Town in 2014, Best Beer Scene in 2017, and Best Beer City in 2021.



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GENERAL INFORMATION

EMC+SIPI



BRINGING COMPATIBILITY TO ENGINEERING INNOVATIONS SINCE 1957

The IEEE EMC Society has been at the pivot point of engineering technology for over a half-century. With a long history of developments in Electromagnetic Compatibility and Electromagnetic Environmental Effects, the Society brings sharp focus to methods and practices for proper performance of energy, electrical, communications, information technology and wireless systems. The Society promotes

information sharing through regional chapters and international symposia. Collaboration across the research, design, test, regulatory and media industries has helped shape the world as we know it.



LEADING EDGE INFO

- EMC Measurements
- Signal & Power Integrity
- EMI Control
- EMC Management
- Low Frequency EMC
- Computational Electromagnetics
- High Power
 Electromagnetics
- Electromagnetic
 Environments
- Smart Grid EMC
- Regulatory Requirements for EMC, ESD, EMI, and SIPI

... AND MORE!

CALL FOR VOLUNTEERS

We are in need of volunteers to help make EMC+SIPI 2023 run as smoothly as possible. Previous year's volunteers have made the event a success.

We welcome new and past volunteers to help with the following positions:

- Help with Registration
- Collect tickets and direct traffic at the Welcome Reception, and Gala Events
- Host Poster Papers

- Monitor Exhibit Hall Demonstrations
- Monitor Technical Papers, Workshops, and Tutorials
- Man the Speaker Ready Room
- Stuff Tote Bags

Participating as a volunteer has some great perks! Registered attendees contributing as a volunteer will receive:

- An opportunity to connect with other peers and industry professionals
- Food and beverages during your hours of service
- Free Symposium shirt

Local residents, who are not registered for the Symposium, will also receive these great benefits:

- Free one-day registration for every day you volunteer
- See what's happening in the EMC and SIPI fields
- Free parking pass for the day you volunteer

TO VOLUNTEER, PLEASE VISIT OUR WEBSITE AT: www.emc2023.org/ volunteer-info.html

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TECHNICAL CHAIR'S MESSAGE

WELCOME FROM GENE SALTZBERG, THE 2023 TECHNICAL PROGRAM COMMITTEE CHAIR

WELCOME!

On behalf of the Technical Program Committee, welcome to the 2023 IEEE International Symposium on Electromagnetic Compatibility, Signal & Power Integrity (EMC+SIPI). I hope to meet everyone during this exciting week full of discussions, where we can share insights, ask questions, learn from the experts and innovators, as well as see new products.

The 2023 IEEE International Symposium on EMC and Signal & Power Integrity (EMC+SIPI) will be held in Grand Rapids, Michigan for the first time, and the second time in Michigan.

I encourage you to attend one of the many special sessions or traditional paper sessions. In case you would like to have an extensive discussion about a topic, I suggest attending a workshop or tutorial. What is the difference? A tutorial is more one-directional, towards the audience, while a workshop is more interactive with extensive discussion. This year we have a record number. The popular experiments and demonstrations program provide hands-on learning opportunities to complement the technical presentations. See live and discuss with the presenters and colleagues, and reproduce the experiment or demonstrations to show your colleagues when you



WEMC+SIPI

get back home. The "Ask the Expert" panel sessions will give another flavor to the conference. See the program for the details.

The "Standards Week" (held for the first time in 2019) is a combination of talks, tutorials, workshops, panel sessions, and demonstrations to update the engineering community about new developments in International EMC and Signal Integrity/Power Integrity (SIPI) standards. Standards Week will include a collection of what is going on in standards bodies, such as in the IEC, CISPR, ANSI C63, etc. and what will affect us in the coming years. You can also attend one of the many standards committee meetings and/or working group meetings during the symposium week to learn more about the standards process, and how you can get involved. These meetings are open to all interested in EMC and SIPI standards.

Our Clayton R. Paul Global EMC University (CRPGU) features an overview of fundamental topics presented by expert instructors from universities and industries from around the globe. The Global University is larger and more extensive than ever before, and will provide an excellent knowledge boost for everyone who has already a basic knowledge in the field of EMC and SIPI.

The DeVos Place Convention Center is an excellent venue for our symposium. It sits on the banks of the Grand River, which is located in the heart of downtown, and attached to the conference hotel. We will use the Exhibit Hall for the exhibits, poster papers, the experiments and demonstrations, TC Showcases, as well as, "Ask the Experts" panels. The Grand Gallery Overlook Meeting Rooms, which are adjacent to the Exhibit Halls, will host six parallel sessions. Switching between sessions during a break is an easy and short walk.

This extensive program will provide something for everyone. I hope you use this opportunity to catch up with old friends and make new ones.

Gene Saltzberg Technical Program Committee Chair, EMC+SIPI 2023



MONDAY, JULY 31 • SCHEDULE AT A GLANCE



SPEAKERS BREAKFAST

Grand Gallery DEF • 7:00am-8:00am • (Breakfast Only on the Day of Presentation)

REGISTRATION/INFO DESK Monday – 7:00 am to 6:00 pm

COMPANION SUITE (Registered Companions Only) Gerald Ford Ballroom - Amway Grand Monday - Thursday: 7:00 am - 10:00 am

STANDARDS WEEK SESSIONS

Join us for this special track on current and emerging International EMC and SIPI Standards! Attend open Working Group meetings with opportunities to contribute and ask questions.



MONDAY, JULY 31



INTRODUCTION TO EMI MODELING TECHNIQUES 8:00 AM - 12:30 PM Gallery Overlook B

Sponsored by TC-9

Co-Chairs:

Giulio Antonini, *Universita degli Studi* dell'Aquila, L'Aquila, Italy

Bruce Archambeault, International Business Machines Corp, Four Oaks, NC, USA

Experts:

Karen Burnham, Electro Magnetic Applications, Inc., Lakewood, CO, USA

James Drewniak, *Missouri S&T EMC* Laboratory, *Missouri University of Science and Technology, Rolla, MO, USA*

This tutorial will provide an introduction to commonly used numerical EMC modeling techniques without the need for detailed math. Practicing modelers will also benefit from learning the fundamentals of modeling techniques they are currently not using. Each technique will be presented along with its strengths and weaknesses, so engineers can decide which techniques are appropriate for their types of problems.

PLANNED SPEAKERS & TOPICS

Introduction to the Finite Element Method Chuck Bunting *Oklahoma State University, USA*

Modeling with the Method of Moments Jim Drewniak, Daryl Beetner *Missouri University of Science and Technology, USA*

Introduction to FDTD

Bruce Archambeault International Business Machines Corp, USA

Hybrid Modeling Approaches

Karen Burnham Electro Magnetic Applications, Inc., USA

Introduction to the Partial Element Equivalent Circuit (PEEC) Approach Applied to EMC+SI/PI Problems Giulio Antonini¹, Daniele Romano¹, Albert E. Ruehli² ¹Universita degli Studi dell'Aquila, Italy; ²Missouri University of Science and Technology, USA

SOCIAL MEDIA TOOLKIT Share that you're attending EMC+SIPI 2023!

We've created this content for your convenience to promote the 2023 EMC+SIPI Symposium via social media. Use our sample text below to promote visitors to your booth, attendance at your presentation, or simply your brilliance in attending the world's premier gathering of EMC and SIPI professionals!



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MONDAY, JULY 31

HENRY W. OTT FUNDAMENTALS OF EMC 8:00 AM - 6:00 PM

Gallery Overlook C/D

Sponsored by EdCom

Chair:

John C. McCloskey, NASA, College Park, MD, USA

Co-Chair:

MO-ALL-CD

TUTORIAL

Jen Dimov, NASA, Greenbelt, MD, USA

This annual tutorial is an overview of many of the major topics that need to be considered when designing an electronic product or system to meet signal and power integrity (SIPI) and electromagnetic compatibility (EMC) requirements. The tutorial will present the foundational ideas from physics and mathematics and will demonstrate the engineering approaches to help the attendees to successfully design, evaluate, diagnose, and/ or solve EMI problems. The main objective of this tutorial is to provide a learning opportunity for those that are new to EMC as well as provide a review of the basics to those who already have some experience in this area.

For decades, the "Fundamentals of EMC" tutorial event has been a key part of each symposium to help those new to EMC learn the basic physics, mathematics, and techniques in order to be successful in their work and career. For much of that time, our esteemed colleague, mentor, and leader in the EMC Society, Mr. Henry Ott, made that day the high quality, critically important event that is has become. Therefore, it is with great appreciation for all the work Mr. Ott did and the dedication he had to help us all in "lighting our candle of EMC knowledge" that the leadership of the EMC Society is pleased to announce that this session be known as the "Henry W. Ott Fundamentals of EMC Tutorial", to honor and celebrate his legacy.

PLANNED SPEAKERS & TOPICS

Inductance and Capacitance Bruce Archambeault

International Business Machines Corp, USA

Cross Talk

Eric Bogatin University of Colorado Boulder, USA

Transmission Lines and Basic Signal Integrity Xiaoning Ye

Intel Corporation, USA

PCB Decoupling on Multi Layer PCBs for Power Integrity Design

Jim Drewniak, Chulsoon Hwang Missouri University of Science and Technology, USA

Grounding

Todd Hubing LearnEMC, USA

Filters

Frank Leferink University of Twente, Netherlands

Radiated Electric and Magnetic Field Emissions Shielding Mitigations

Pablo Narvaez Jet Propulsion Laboratory, USA

Radiated Emissions Cheung-Wei Lam

Apple Inc., USA

Conducted Emissions

Lee Hill SILENT Solutions LLC and GmbH, USA

The Yin/Yang Relationship Between Conducted and Radiated Coupling

John McCloskey NASA Goddard Space Flight Center, USA



MONDAY, JULY 31



MACHINE LEARNING AND AI FOR EMC AND SIPI 8:00 AM - 12:30 PM Gallery Overlook E

Chairs:

Alistair Duffy, *De Montfort University, Loughborough, United Kingdom*

We are currently seeing a growth in the use of machine learning and artificial intelligence applied to EMC and Signal Integrity and Power Integrity applications. More than this, many engineers are considering whether the techniques associated with ML/AI can help provide insight into design and analysis or, in fact, answer research and development questions that are currently elusive.

The EMC Society is responding to this by both bringing together a Special Committee on Machine Learning and Artificial Intelligence (SC3 - ML/AI), which will bring together expertise and interest in this subject as well as identify and promote good practice. In addition, it is looking at how to provide education and training for the widest spectrum of interest within the Society's field of interest. This workshop proposal is one of those contributions.

It contains presentations that will provide

- An overview of techniques, which will help those new to the topic to gain an appreciation of what is involved
- More technically advanced analysis of techniques that will have applications to EMC and SIPI
- Case-study reviews

PLANNED SPEAKERS & TOPICS

Introduction to the ML/AI 'Landscape' Alistair Duffy De Montfort University, United Kingdom

From Machine Learning to Data Driven, a Path from Blackbox to Physics Recovery in EMC Studies Lijun Jiang The Chinese University of Hong Kong, China

Efficient Optimization Algorithms for High Dimensional Electromagnetic Problems Using Optimality Moein Nazari Cadence Design Systems Inc., USA

Application of AI and ML In Robotic Antenna Measurements Dennis Lewis The Boeing Company, USA

A Review of Previous Applications of Machine Learning to Signal Integrity and EMC Challenges in IT Equipment Design Samuel Connor IBM, USA

Panel Discussion: Solved Problems, Open Questions and Applications for ML/AI in EMC and SI/PI Alistair Duffy De Montfort University, United Kingdom

Closing Remarks: Introducing Special Committee SC3 on ML/AI in EMC and SIPI



MONDAY, JULY 31

MO-AM-F Tutorial

AUTOMOTIVE EMC STANDARDS UPDATE 8:00 AM - 12:30 PM Gallery Overlook F

Sponsored by TC-2



Chairs:

Craig Fanning, *Elite Electronic Engineering, Inc., Downers Grove, IL, USA*

Garth D'Abreu, *ETS-Lindgren, Cedar Park, TX, USA*

This tutorial will provide key updates to the global Automotive EMC Standards as well as review proposed changes to address the rapidly developing automotive industry. Experts actively involved and leading the global automotive standards committees will share the trends affecting changes to the standards and reasoning behind these changes. Attendees will guickly learn what is new in these standards, what to expect in the new revisions, what to anticipate in future standards based on automotive technology trends, and how this may influence their current EMC test and measurement activity. Attendees will also have a chance to contribute directly to the new standards revisions.

PLANNED SPEAKERS & TOPICS

Automotive Standards Development by CISPR/D: Review of CISPR 12, CISPR 36, and CISPR 25 Craig Fanning Elite Electronic Engineering, Inc., USA

Automotive Standards Development by ISO/TC22/ SC32/WG3 Craig Fanning Elite Electronic Engineering, Inc., USA

Automotive Ethernet Link Overview and Aspects of Implementation of the Link Segment Rich Boyer Aptiv - Signal and Power Solutions, USA

Why Device Under Test Behavior Acceptance and Monitoring Criteria is Needed in an EMC Test Plan James Muccioli *Continental Automotive Systems, USA*

Evaluating Measurement Repeatability Challenges in Reverberation Chambers Garth D'Abreu, Jack McFadden

ETS-Lindgren, USA

EMC for Integrated Circuits – Test Methods for Vehicular Applications Bob Mitchell TUV Rheinland, USA





MONDAY, JULY 31



AMERICAN NATIONAL STANDARDS COMMITTEE (ANSC) C63 -ELECTROMAGNETIC COMPATIBILITY 8:00 AM - 12:30 PM Gallery Overlook G



Sponsored by TC-1

Chairs:

Daniel D. Hoolihan, *Hoolihan EMC Consulting, Lindstrom, MN, USA*

Experts:

Zhong Chen, ETS-Lindgren, Cedar Park, TX, USA

Nicholas Abbondante, Intertek USA Inc, Houston, TX, USA

Ernesto Mendoza, Signify NV, Rosemont, IL, USA

Andrew Griffin, Cisco Systems Inc, San Jose, CA, USA

This tutorial will introduce the ANSC C63-EMC ("C63 Committee") to conference attendees and highlight the latest status of key C63 Standards. Many C63 standards are Incorporated by Reference (IBR) by the United States Federal Communications Commission (FCC) and are mandatory for measuring electronic products for compliance with FCC Rules. A number of C63 standards are also used by Canada for showing compliance to their Regulations.

PLANNED SPEAKERS & TOPICS

American National Standards Committee (ANSC) C63 Electromagnetic Compatibility Daniel D. Hoolihan Hoolihan EMC Consulting, USA

Insights to the C63.25 Series Standards: Site Validation Measurements Zhong Chen *ETS-Lindgren, USA*

Draft Standard ANSI C63.25.3 Nicholas Abbondante

Intertek, USA

Standard for Methods of Measurement of Radio-Frequency Emissions from Lighting Devices Ernesto Mendoza

Signify North America Corporation, USA

Draft ANSI C63.4:202? A Review Andy Griffin Cisco Systems, Inc., USA



MONDAY, JULY 31

MO-AM-H TUTORIAL

BASIC EMC MEASUREMENTS 8:00 AM - 12:30 PM Gallery Overlook H Sponsored by TC-2

Chairs:

Ghery Pettit, Pettit EMC Consulting LLC, USA

There continues to be those entering the EMC field who are performing measurement activity for both emissions and immunity. In addition, there are practitioners who want to get a second opinion to support what they are doing. They are all at least familiar with basic EMC immunity measurements methods that cover a wide range of electromagnetic phenomena. This tutorial will cover both emissions and immunity by highlighting the latest amendment to a major multimedia emissions standard and a selection of immunity testing standards for transients that are more difficult to implement. The transient discussion will also delve into signals that are high power in a very short time. Also included: a description of emission and immunity test sites, the sites that are becoming popular and their validation requirements, as well as an overview of test setups in these facilities. Where appropriate and if time permits, attendees will be asked questions as to what they have learned and will be given an opportunity to question the speakers at a panel discussion at the end of the session.

PLANNED SPEAKERS & TOPICS

Use of Basic Measurement Facilities, Methods and Associated Errors Ghery S. Pettit *Pettit EMC Consulting LLC, USA*

CISPR 32

Ghery S. Pettit Pettit EMC Consulting LLC, USA

Performing Immunity Testing to Transient Signals Thomas E. Braxton *Elite Electronic Engineering, USA*

Continuous Wave Immunity Testing Ross Carlton *Gibbs and Cox, USA*

High Power Electromagnetics Test Facilities and Measurement Methods William A. Radasky *Metatech Corporation, USA*

MEYER MAY HOUSE

Designed by Frank Lloyd Wright in 1908 for a prominent Grand Rapids Clothier, the Meyer May House has been meticulously restored to its original grandeur, complete with original furnishings and faithfully executed reproductions. The twoyear restoration has made the Meyer May House a rare example of a Prairie house the way Frank Lloyd Wright intended.

There is no charge to tour the house and view the film, "The Renewing of a Vision," but online reservations are required for admission. Please allow at least 90 minutes to enjoy the complete experience.

VISIT THE MEYER MAY HOUSE WEBSITE





MONDAY, JULY 31

MO-PM-B TUTORIAL EMC TESTING BASICS 1:30 PM - 6:00 PM Gallery Overlook B Sponsored by TC-2

Chair:

Jack McFadden, *ETS-Lindgren, Cedar Park, TX, USA*

Co-Chair:

Bob Mitchell, TUV, Littleton, MA, USA

Experts:

Todd Hubing, *LearnEMC, Stoughton, WI, USA* Alistair Duffy, *De Montfort University, Loughborough, United Kingdom*

Ross Carlton, *Gibbs and Cox Inc, Corvallis, OR, USA*

Due to the popularity of this tutorial when it was presented in the IEEE EMC+SIPI Symposia held virtually in 2020 and 2021 as well as in person in 2022, we have brought it back with many of the original topics and speakers! This tutorial will cover basic topics in EMC testing - from bench top analysis to designing a new laboratory/test capability. Presentations will provide practical information and real-world knowledge that can be implemented immediately. While the topics may be basic to EMC testing, we will also discuss nuances that can challenge even the most experienced EMC test practitioner. Speakers include experts who are actively involved in designing, managing, or supporting EMC test facilities. Attendees will quickly learn the best practices in each topic area.

PLANNED SPEAKERS & TOPICS

What are EMC Tests Actually Measuring? Todd Hubing LearnEMC, USA

EMC Basics - Test Plan Jack McFadden *ETS-Lindgren, USA*

Antennas for EMC Alistair Duffy

De Montfort University, United Kingdom

Calibration of EMC Test Equipment Ross Carlton *Gibbs and Cox Inc., USA*

EMC Lab Design: Overview of the Process, Possibilities and Issues Bob Mitchell *TUV Rheinland, USA*



MONDAY, JULY 31

MO-PM-E Tutorial

HALF-BRIDGE MOSFET SWITCHING AND ITS IMPACT ON EMC 1:30 PM - 6:00 PM

Gallery Overlook E

Sponsored by SC-5

Chair:

Dr. Nandor Bodo, *Nexperia BV, Manchester, UK* **Co-Chair:**

Dwayne Mott, Nexperia BV, Nashville, TN, USA

Modern switching converters for low voltages (< 100 V) predominantly use power MOSFETs as the switching devices.

Switching converter applications includes inverters to synthesise AC waveforms, or for use in DC-to-DC converters. The switching devices are often arranged in a simple halfbridge configuration. At some point in time one of the MOSFETs will be actively switching (sometimes called the control FET in DC-to-DC applications) and the other one will be switched off and acting as a diode during the commutation event – this will be switched on once the switching event has finished and acts as a synchronous rectifier, (in DC-to-DC converters this MOSFET is referred to as a syncFET).

The behaviour of the MOSFETs during the switching event strongly influences efficiency and electromagnetic interference (emissions) goals.

In switch mode (PWM) designs, the switching behaviour of the MOSFET (or more generally the switching power devices) can influence the efficiency and the electromagnetic emissions from the system. This tutorial describes methods to measure the switching efficacy and various techniques that can be applied to improve the switching behaviour, thus meeting efficiency, EMC requirements and reliability goals.

PLANNED SPEAKERS & TOPICS

Introduction to MOSFET Switching Process Nandor Bodo¹, Dwayne Mott² ¹Nexperia BV, Netherlands; ²Nexperia BV, USA

Reducing Resonances in Half Bridge Circuits: Snubber Design

Nandor Bodo¹, Dwayne Mott² ¹Nexperia BV, Netherlands; ²Nexperia BV, USA

Using Simulation to Predict Conducted Emissions Nandor Bodo¹, Dwayne Mott²

¹Nexperia BV, Netherlands; ²Nexperia BV, USA





MONDAY, JULY 31



AUTOMOTIVE EMC, ESD, AND SI DESIGN CONSIDERATIONS AND TEST METHODOLOGIES 1:30 PM - 6:00 PM

Gallery Overlook F

Sponsored by TC-2

Co-Chairs:

Garth D'Abreu, *ETS-Lindgren, Cedar Park, TX, USA* Robert Kado, *Stellantis US, Auburn Hills, MI, USA*

Organizer:

Janet O'Neil, *ETS-Lindgren, Cedar Park, TX, USA*

The introduction of new international test standards for EMC and SI is a slow and laborious process that generally lags the introduction of new automotive technology. The trend toward higher levels of autonomy almost in step with the increasing percentage of electric vehicles is driving the need for different and more sophisticated automotive EMC design and test scenarios. Vehicle platforms continue to become increasingly more complex with different versions of electric propulsion, entertainment, and driver related automation all having to function reliably without affecting safety or the legacy communications infrastructure. While the industry remains sensitive to test time and cost, and manufacturers continue to address 'design for EMC' earlier in the development process, more cost effective and efficient methods of verifying performance are also a priority. Environment simulations, and scenario optimizations, are becoming increasingly attractive particularly for signal integrity related evaluation. New automotive safety standards are helping to redefine automotive design management; but fundamental changes will also be required to the way designs are engineered and tested. In this tutorial, experts from industry will share the latest developments in automotive EMC and SI related design and test activities to address these emerging automotive challenges.

PLANNED SPEAKERS & TOPICS

Importance of SI in Automotive Data Communication Link Segments in Maintaining EMC Rich Boyer *Aptiv - Signal and Power Solutions, USA*

Current and Future Challenges with Respect to Vehicle System/Subsystem Design, Validation and Simulation Keith Frazier Ford Motor Company, USA

Multi Purpose Test Environments for Modern Vehicles Garth D'Abreu *ETS-Lindgren, USA*

Comprehending the Variables and Nuances in the Automotive Indirect ESD Testing Method (Using Field Coupling Plane) through 3D EM Simulations Patrick DeRoy *Analog Devices Inc., USA*

Utilizing Dynamic Road Condition Scenarios to Automate Battery-Electric Vehicle Testing Jeremy Cline *Rohde & Schwarz, USA*



MONDAY, JULY 31

SMART GRID AND EMC ISSUES 1:30 PM - 6:00 PM Gallery Overlook G

Sponsored by SC-1

Chair:

Mike McInerney, Mac and Ernie, Champaign, IL, USA

Co-Chair:

MO-PM-G TUTORIAL

William A. Radasky, *Metatech Corporation, Goleta, CA, USA*

Experts:

Jerry Ramie, *ARC Technical Resources, Inc., San Jose, CA, USA* Tom Hartman, *Universiteit Twente, Enschede, Netherlands*

Smart Grid (as used in electric power systems) is an important topic worldwide. Smart Grid (SG) applications continue to increase, as do EMC issues with components, equipment, and standards. The tutorial will begin with a review of the activities of the IEEE EMC Special Committee 1 (SC 1) which coordinates Smart Grid EMC activity within the IEEE EMC Society. The tutorial will focus on the status at the end of 2022.

The tutorial will continue with a review of the activities of the of the key Smart Grid EMC working group in the United States (Smart Electric Power Alliance – SEPA). These activities focus on SG devices that are exposed to the electromagnetic environment where the grid traverses and terminates. The tutorial will also place in perspective the EMC work still needed to make EMC an integral part of the Smart Grid activity/operation. Specific examples of the EMC immunity testing needed for smart devices with communications functions will be provided. Problems with current standards (e.g., NEMA-ANSI-C12.1) will be highlighted.

The tutorial will conclude with a presentation on electromagnetic interference issues with Smart Meters which have resulted in overestimations of the energy bill, as well as underestimations, even resulting in a perceived energy generation. Causes of these issues are identified and solutions proposed.

PLANNED SPEAKERS & TOPICS

Introduction to the IEEE EMC Society Special Committee 1 (SC 1) and an Introduction to this Tutorial Mike McInerney IEEE, USA

SEPA (Smart Electric Power Alliance) Electromagnetic Interoperability Issues Sub-Group (EMIISG) - Its History, Accomplishments and Status William Radasky Metatech Corporation, USA

Standardized Testing Requirements for Devices with Communications Functions Jerry Ramie ARC Technical Resources, USA

From Susceptible Static Energy Meters to Electromagnetic Compatible Energy Measurements Tom Hartman University of Twente, Netherlands

28 | FINAL PROGRAM | WWW.EMC2023.ORG



MONDAY, JULY 31



SHIELDING: EMERGING CHALLENGES AND STANDARDS 1:30 PM - 6:00 PM

Gallery Overlook H

Sponsored by TC-4

Chair:

Anne Roc'h, *Technische Universiteit Eindhoven, Eindhoven, Netherlands*

Co-Chairs:

Davy Pissoort, *Katholieke Universiteit Leuven, Bruges, Belgium* Pavithrakrishnan Radhakrishnan, *Katholieke Universiteit Leuven, Bruges, Belgium*

Shielding is particularly important in critical systems and environments, such as aerospace, defense, medical equipment, autonomous systems, and transportation. In these applications, even small disruptions caused by EMI can have significant consequences, including equipment failure, data loss, or safety hazards. Shielding helps to ensure the reliable operation of these systems and protects their operators and users from the harmful effects of EMI.

In this two-part tutorial, we will provide a comprehensive overview of the principles of shielding and its various applications. We will also delve into the different techniques used for controlling EMI, including gasketing, planar materials, and other techniques, as well as their characterization methods, with illustrations and guidelines for best practice. Additionally, the tutorial will address the IEEE Shielding Standards Continuity Working Group related to these characterization and mitigation techniques, providing a detailed understanding of the current state of the art in shielding and its applications.

PLANNED SPEAKERS & TOPICS

Introduction to IEEE Standards Related to Shielding Davy Pissoort

Katholieke Universiteit Leuven, Belgium

Contemporary and Emerging Challenges in EM Shielding

Frank Leferink ¹University of Twente, Netherlands; ²Thales Nederland BV, Netherlands

Introduction on EU Doctoral Network PARASOL and SSbD Framework

Anne Roc'h Technische Universiteit Eindhoven, Netherlands

Perspective on Various Test Methods to Characterize the Shielding Effectiveness of Conductive Gaskets Pavithrakrishnan Radhakrishnan Katholieke Universiteit Leuven, Belgium

Exact Closed-Form Shielding Effectiveness of Planar Screens with Small Parallel Loops

Rodolfo Araneo Sapienza University of Rome, Italy

DID YOU KNOW?

Grand Rapids was voted #8 in the Top 20 America's Friendliest Cities by Travel+Leisure Magazine



TUESDAY, AUGUST 1 • SCHEDULE AT A GLANCE



EXHIBIT HALL HOURS

Grand Opening Ribbon Cutting at 9:20 AM! EXHIBITS OPEN: 9:30 AM - 4:00 PM WELCOME RECEPTION IN THE EXHIBIT HALL: 6:00 PM - 8:00 PM

SPEAKERS BREAKFAST

Grand Gallery DEF • 7:00am-8:00am • (Breakfast Only on the Day of Presentation)

REGISTRATION/INFO DESK HOURS

Tuesday - 7:30 am to 6:00 pm

COMPANION SUITE (Registered Companions Only) Gerald Ford Ballroom - Amway Grand Monday - Thursday: 7:00 am - 10:00 am



TUESDAY, AUGUST 1



EMI ISSUES AND SOLUTIONS OF MODERN POWER ELECTRONICS SYSTEMS WITH WIDE BANDGAP SEMICONDUCTOR DEVICES 10:30 AM - 12:00 PM

Exhibit Hall

Chair:

Shuo Wang, University of Florida, Gainesville, FL, USA

Bring your questions or simply listen and learn!

PLANNED PANELISTS INCLUDE

Dehong Liu, Mitsubishi Electric Research Labs Cong Li, GE Global Research Center Fang Luo, Stony Brook University

Abstract: Modern power electronics systems employ wide bandgap semiconductor (WBG) devices to achieve high power density and high power efficiency because of their high switching speed. The WBG devices have been widely used in power electronics systems for the electrification of transportation, renewable energy conversion, airspace, consumer electronics, industrial applications, etc. However, WBG devices lead to significant EMI issues compared with conventional Si devices. A panel consisting of experts from both academies and industry companies will discuss the EMI/EMC issues, solutions, and future trends of WBG-based power electronics systems with the audience. Both panel discussion and Q&A will be conducted at the event.





TUESDAY, AUGUST 1

STUDENT EMC HARDWARE DESIGN COMPETITION TOP 3 FINALISTS HARDWARE DEMONSTRATION 10:30 AM - 12:00 PM

Gallery Overlook B

Chair:

Pavithrakrishnan Radhakrishnan, Katholieke Universiteit Leuven, Bruges Campus, Bruges, Belgium

Co-Chairs:

Mohammad Kameli and Zhao Chen, Katholieke Universiteit Leuven, Bruges Campus, Bruges, Belgium

1. Mission: EMI Reduction

Jaewon Rhee, Seunghun Ryu, Hyunwoong Kim, Seonghi Lee, Changmin Lee Korea Advanced Institute of *Science and Technology (KAIST), South Korea*

The demonstrations describes a method to reduce EMI components at odd harmonic frequencies of a wireless power transfer (WPT) system. In a WPT system, a leakage magnetic field is generated, which may adversely affect the human body or other electronic devices. The previous reactive shielding method could reduce the magnetic field, but it had the disadvantage of reducing the power transfer efficiency (PTE). By using frequency split phenomena, the reactive shielding method can reduce the EMI components with increasing PTE. In this video, a reactive shielding method that can reduce the magnetic field while increasing PTE is proposed. Specifically, the method for designing resonant system of transmitting, receiving, and shielding for the WPT system is proposed. In addition, a method for obtaining a coupling coefficient between a shielding coil and a transmitting coil for designing structure in which magnetic field reduction can be maximized is also proposed. The theoretical analysis based on the impedance of each part is strongly correlated with the simulation and measurement result.

2. Exploiting EMC Flaws in Audio Devices Through RE by Special Design

Giorgi Tsintsadze Missouri University of Science & Technology, Rolla, US

A device utilizing two digitally controlled fractional divider PLLs has been utilized with a mixer and microcontroller. The MCU sets frequency of each oscillator accurately (~0.1 Hz) to produce modulated signal (high frequency carrier, low frequency envelope) that can couple to victim device through radiated emissions. Idea is that, even though the victim device could be operating at significantly lower frequency than the carrier frequency, if it has a EMC design flaws that make some part of the signal path good antenna at frequencies around the carrier, then it is possible to couple low-frequency signal though radiated emissions. To maximize likelihood of exploiting "bad" design frequency, the device sweeps carrier signal. In the demo, the victim is an audio device that gets injected with 1Khz tone though 200MHz - 600MHz carrier. The coupled energy can be played though speakers. This device has been put together specifically for the hardware competition and is not part of the research or thesis. The schematics and layout along with the majority of microcontroller code has been developed from scratch.

3. Crosstalk Demonstration Through Cable Bundle Model

Iqra Aitbar, Angel Pena Quintal, Arun Khilnani University of Nottingham, UK

This hardware demonstration tries to address the adverse effect on nearby communication system's interference when DC-DC power converters interact with it. It can also demonstrate the effects of mitigation techniques such as Spread Spectrum Modulation to highlight an important drawback of this well-know technique. The set-up is based on a cable bundle model generating crosstalk between a communication link (victim) and a switched mode power supply (source) as similar used in DC microgrids. The communication channel is based on a stream of transmitted/received bits while the DC converter is analysed the frequency domain, hence a double assessment is carried out. The Bit-Error-Rate tester is employed to measure the communication channel quality. These systems are coupled together with a cable bundle to observe the conducted effect of the noise generated from the converter. The final aim of this test is to demonstrate an interesting framework to further analyse conducted emissions in the low frequency band.



TUESDAY, AUGUST 1



CROSSTALK REDUCTION BETWEEN PCB TRACES BY VARYING THE PCB BOARD GEOMETRY AND UTILIZING A GUARD TRACE 10:30 AM - 12:30 PM Exhibit Hall Exp Demo 1

Sponsored by TC-10

This demonstration addresses the crosstalk reduction between PCB traces by varying the PCB board geometry (distance between the traces and distance from the traces to the ground plane), as well as utilizing a guard trace as a shield. The shield is either floating, grounded at one end (to reduce capacitive coupling), or grounded at both ends (to reduce both the capacitive and inductive coupling).

PRESENTER

Ryan Aldridge Grand Valley State University, USA





TUESDAY, AUGUST 1

TU-AM-ED2 EXPERIMENTS & DEMONSTRATIONS

DEVICES POWERED FROM ENERGY HARVESTING 10:30 AM - 12:30 PM

Exhibit Hall Exp Demo 2

Sponsored by SC-1

Problem Statement: Our environment is in change and everything will be "electronified". Our glasses, our hand gloves, shirts, shoes etc. can be connected already today with our smartphones and can send commands to the machinery surrounding us. We want this comfort and we are looking forward to having Smart Homes. The point is that we did build our house and we did not implement LAN CA Tx cables to our coffee machine or refrigerator and even all our lights are not using PoE. If you build a new house and want to implement this data cables additionally, you will think about it twice because it will raise the price. The alternative solution is to use wireless communication. But we do not want to live in electrosmog, where all this devices are continuously emitting and those devices should transmit only on request. Furthermore the efficiency should be not negatively influenced and we should all look for Energy Star certified devices.

State of Technology: We could use WiFi in all those devices and that could be the simplest and easiest way. The cost of implementation would be quite high and additional technical knowhow for maintenance from the user s side is requested. To solve this situation the design engineer will decide to use a proprietary system SRD where the ISM band is used to be cost effective.

Solution: Chip manufacturers [1], have introduced to market a new generation of processors which have already the RF module in the chip himself. Built is an ARM Cortex M4 CPU platform which can be used until 48MHz clock and the RF stage form 145MHZ to 1050MHz for transmission. This solution is amazing, low current hungry and can operate w ith 40nA@3V in Sleep Mode. In case of transmission, the current is 18mA@ +IOdBm. At this point, we can start to har vest the energy surrounding this application and power our device. For such solution, a power converter manufacture r [2] developed a new chip, which is able to harvest multiple sources. It can be used a piezo or inductive ha rvester if we have movements, or in case of temperature differences we can harvest from a TEG, or we can use the solar input i and ha rvest the l ght from the ambient. All that, w th just one single chip. If we did harvest enough energy to power but the harvested energy is still present, we can store it with the same chip into a capacity bank, then into a Supercap (balancer in chip) or even charge a Li -lon battery. Additional input, for a backup battery is also available in the same chip.

With only 2 IC's we can realize many nice projects and most ingenious self- sustaining devices with no maintenance. In our presentation we will show how easy is to start designing energy harvesting powered products and how to evaluate different harvesters. After the theoretical part, there will be a short demonstration about energy harvesting, using standard components available from different IC manufacturer.

PRESENTER

Lorandt Foelkel Würth Elektronik GmbH & Co. KG eiSos, Germany



TUESDAY, AUGUST 1



SIMULATION OF CONDUCTED AND RADIATED EMISSIONS FROM POWER ELECTRONICS AND CONNECTED CABLES 10:30 AM - 12:30 PM Exhibit Hall Exp Demo 3

Sponsored by TC-9

Modeling EMI/EMC of power electronics is necessary but challenging, the repetitive on/ off transitions of the switches is an inherent source of high frequency noise to couple through heatsink or radiate from cables. It is the derivates in the voltage and currents from these transitions that cause issues for typical SPICE based simulation tools, these solve engines are simply not optimized to deal with the switching introduced from modern power electronics. This leads to a typical workflow that includes no simulation, with all discovery occurring "in the chamber" with a physical prototype. Additionally, the presence of a distributed cable model with very small inductance and capacitance values can lead to very challenging time constants for the solver to compute. What is required is a purpose-built power electronics simulation tool with a simplified device model that can accurately model turn on/off dv/dt and di/dt without being overly complex to solve. With a reliable solve of the device transition we are able to introduce the common mode and differential mode parasitic paths required to understand conducted EMI. Additionally, if the power converter includes cable connections, we can introduce a per unit cable model based

on the Multi Transmission Line, MTL, method from a 3D solver environment. The MTL method allows us to include cable type, shielding, and routing configuration into the model. With the cable now included in the simulation of the power converter we now have a more complete understanding of the conducted EMI; furthermore, we can also link back to a high frequency electromagnetic (EM) solver to simulate the radiated emissions from the cable. This workflow of studying radiated emissions from a cable connected to power electronics is novel and significant development to include simulation into existing workflows that are based solely on hardware testing. During this software demo we will go over the details of simulation of power electronics for conducted EMI as well as the use of 3D EM simulation tool for radiated emissions from cables connected to power electronics.

PRESENTER

Albert Dunford, C.J. Reddy *Altair, USA*

DID YOU KNOW?

Grand Rapids was voted #8 in the 10 Best Affordable Places to Retire in the U.S. in 2022-2023 according to U.S. News and World Report



TUESDAY, AUGUST 1

TU-AM-ED4 EXPERIMENTS & DEMONSTRATIONS

ANOTHER CONDUCTED EMISSIONS DEMO? 10:30 AM - 12:30 PM Exhibit Hall Exp Demo 4 Sponsored by TC-7

This presentation will focus on the fundamentals of what causes emissions problems and how to reduce the levels without focusing on any particular standard. We have a low voltage (<60V) test setup to demonstrate filter design for conducted emissions. In this demo we will power up a specially designed power supply (flyback, buck or boost) and test if the board passes conducted emissions. Then we will discuss how to reduce the emissions by designing a filter. What core material to choose? What inductance? Do you need to worry about safety? What about EFT? Ultimately, we will test everything live to prove the filter design works. We will also discuss how common mode currents can cause problems in the radiated emissions spectrum.

PRESENTER

Jared Quenzer Würth Elektronik GmbH & Co. KG eiSos, Germany




TUESDAY, AUGUST 1



EMC ASSESSMENT AND EMI MODELLING FOR ELECTRICAL AND ELECTRONIC DEVICES IN THE LOW-FREQUENCY RANGE 10:30 AM - 12:00 PM Gallery Overlook D

Co-Chairs:

Erjon Ballukja, University of Nottingham, United Kingdom Karol Niewiadomski, University of Nottingham, United Kingdom

10:30AM

A Flexible Black-Box Model for Conducted Emission Predictions with Different Switching Frequencies Lu Wan, Xinglong Wu, Xiaokang Liu, Flavia Grassi, Giordano Spadacini, Sergio A. Pignari Politecnico di Milano, Italy

Abstract: Black-box modeling technique is an efficient approach to represent the electromagnetic interference behavior of power converters, whose presence may cause malfunctioning in adjacent electronic devices. Although developing a black-box model is simpler and less demanding than extracting an explicit circuit model, model effectiveness is limited to certain operating conditions, such as a fixed modulation strategy. In this work, a flexible black-box model is proposed, which can be effectively used for prediction also in case of different modulation conditions without requiring a new estimation of model parameters if modulation parameter (such as the switching frequency) changes. Flexibility is achieved by modeling time-domain noise waveforms using an analytical curvefitting model or an autoregressive model, whose accuracy is compared in time and frequency domain. The proposed model is experimentally verified on a boost converter operated with different switching frequencies.

11:00AM

A Statistical Approach to Predict the Low Frequency Common Mode Current in Multi-Converter Setups

E. Ballukja¹, K. Niewiadomski¹, D.W.P. Thomas¹, S. Sumsurooah¹, M. Sumner¹, J. Bojarski² ¹University of Nottingham, United Kingdom; ²Uniwersytet Zielonogórski, Poland **BEST EMC PAPER FINALIST**

Abstract: The aim of this paper is to explore a statistical approach to predict the distribution of the harmonics of common mode current in a setup consisting of N converters, knowing the common mode current for a single converter. To this end, we utilize Pearson's random walk approach in comparison with a simulation setup consisting of 4 DC/DC converters with their own DC sources. The two methods, compared with respect to a selected harmonic of the common mode current, show good agreement up to 10MHz - 501st harmonic of the 20kHz switching frequency. The arising mismatch could be due to limitations of our model as well as to computational errors.

11:30AM

Design of Proportional-Resonant Control for Current Harmonic Compliance in Electric Railway Power Systems

Iurie Nuca¹, Lu Wan², Petre-Marian Nicolae¹, Alexandru Netoiu³, Augustin Popescu³, Dusan Kostic¹, Flavia Grassi² ¹University of Craiova, Romania; ²Politecnico di Milano, Italy; ³SC Softronic SA, Romania

Abstract: This paper presents the process of designing proportional-resonant controller for a four-guadrant rectifier in electric railway traction system. In the context of ever-stricter power quality and electromagnetic compatibility standards in electric railway power systems, developers of electric locomotives need to adapt with new ways to comply. This paper develops on the process of designing a four-guadrant rectifier proportional-resonant control for mitigation of low frequency current harmonic distortion, a novel method in the field of railway EMC. The control parameters are determined through analytical modeling of the rectifier through transfer functions. For the purpose of studying the harmonic distortion mitigation effects, only the current control loop was modeled and designed. The modeling starts with simplification of the model via large-signal modeling of the power converter. The parameters of the circuit then were used to develop the transfer functions, and select the appropriate parameter values of the current loop plant. The control loop and parameters were evaluated on test locomotive to validate the control, with results confirming the improved impact on the electromagnetic compatibility and conformity to regulation.



TUESDAY, AUGUST 1



COMPUTATIONAL ELECTROMAGNETICS, MODELING AND SIMULATION, MULTI-PHYSICS TECHNIQUES, TOOLS, AND APPLICATIONS 10:30 AM - 5:30 PM

Gallery Overlook E

Sponsored by TC-9

Co-Chairs:

Yansheng Wang, *Rivos Inc., Santa Clara, CA, USA* Giulio Antonini, *Universita degli Studi dell'Aquila, L'Aquila, Italy* Shubhankar Marathe, *Amazon Lab126, Santa Clara, CA, USA* Jianmin Zhang, *Google Inc, Mountain View, CA, USA*

10:30AM

Finite-Difference Time-Domain Study on the Influence of the Conductor Catenary in the Simulation of Lightning Surges

Erika Stracqualursi, Rodolfo Araneo, Salvatore Celozzi Universita degli Studi di Roma La Sapienza, Italy

When accounting for the catenary shape, overhead power lines are non-uniform structures. Usually, the impact caused by the catenary on the transmission properties of the line is neglected. Hence, the line is simulated as uniform considering a constant equivalent height. In this paper, we investigate the impact of the catenary on induced overvoltages caused by direct and indirect lightning strokes. Employing a recently proposed implicit finite-difference time-domain code, we assess that the catenary may have a severe impact on the correct computation of the overvoltages. Finally, we outline the accuracy limits of the EMTP-RV software in conjunction with the LIOV module through an indepth comparison.

11:00AM

Roughness Losses Computation through the Partial Elements Equivalent Circuit Method

Fabrizio Loreto¹, Daniele Romano¹, Giulio Antonini¹, Albert Ruehli², Mauro Lai³ ¹Universita degli Studi dell'Aquila, Italy; ²Missouri

University of Science and Technology, USA; ³Microsoft Azure Perimeter Park, USA

Conductor loss caused by conductor surface roughness is a critical aspect in the design of high-speed electronic systems since it significantly affects their performances. Well-established roughness models have been proposed over the years but they have been applied only to the transmission line models of interconnects. Typically the roughness models are used to modify the per-unit-length impedance of the transmission line which is extracted by 2D model methods. The aim of this work is to overcome this limitation thus making it possible to model roughness conductors in the framework of 3D full-wave methods. More precisely, it is presented how to incorporate roughness models in partial element equivalent circuits (PEEC) models. The concept of surface impedance allows a straightforward inclusion of roughness models in 3D full-wave PEEC models. Numerical results are presented for a microstrip line confirming the accuracy of the proposed approach compared to those obtained using standard TL models and a commercial tool.



TUESDAY, AUGUST 1



11:30AM

3-D Modeling and Characterization of Ferrite and Nanocrystalline Magnetic Cores for EMI Applications

Rafael Suárez^{1,2}, María Tijero¹, Roberto Moreno¹, Aitor Arriola¹, Jose Manuel González² ¹Ikerlan Technological Research Centre, Spain; ²Universidad del Pais Vasco, Spain

BEST EMC PAPER FINALIST

Toroidal ferrites and magnetic cores are a key part of electromagnetic compatibility (EMC). They are used in several applications as in power converters, lowpower supplies, cables, etc. Therefore, it is crucial to properly characterize them for running 3-D simulations. Typically, complex magnetic permeability (CMP) is taken as the main property of the magnetic cores. In this paper the effect of CMP in simulation up to 100 MHz is investigated. The simulation spectrum has been separated into two regions, split by the resonance frequency, and simulations of several 3-D models with different CMP values are compared with their measurements in each of the regions. Three different magnetic cores are studied: two of them are used for common-mode chokes, while the other is used for interference suppression in wires. With regard to the material, two of them are ferrite cores while the other one is a nanocristalline core. Results show the major importance of CMP in 3-D simulation. However, above the resonance frequency, modeling with only CMP is not valid and other core-related effects as electric permittivity or conductivity must be considered.

1:30PM

Modeling of Imperfectly Shielded Coaxial Cables by Surface Conductivity Boundary Condition

Mazin M. Mustafa¹, James C. West², Charles F. Bunting¹, Weitao Dai², Paul G. Bremner²

¹Oklahoma State University, USA; ²RobustPhysics, USA

In this paper, we briefly discuss the validity of modeling imperfectly shielded transmission lines such as coaxial cables by a surface conductivity boundary condition. This approach is attractive for numerical simulations since it replaces the complex shielding structures by a homogenized surface boundary condition. We also present and validate a modified Coupled Transmission Lines model in order to introduce the surface conductivity representation, and show the equivalency with the surface transfer impedance. Numerical examples are provided to illustrate the effect of representing the cable's shield by a surface conductivity boundary condition on crosstalk in practical EMC scenarios.

2:00pm

Modelling the IEC 61000-4-4 Capacitive Coupling Clamp

Mohit Gopalraj Analog Devices Inc., USA

This paper talks about modelling the Capacitive Coupling Clamp (CCC) using CST and EMCoS (EM simulation softwares), conforming to the requirements based on IEC 61000-4-4 (industrial). The CCC is used during EMC transient tests to capacitively couple the transient noise onto the harness connected to the Device Under Test (DUT). A good model once achieved, can be used to charctarize different cables and the coupling with respect to these cables could be understood better.

2:30PM

Coupled EMC-Thermal Modeling of Electrical Wiring Interconnection System within Electric Aircraft

Houssem Chebbi, Michael Ridel, Philippe Reulet ONERA, France

This paper proposes a novel approach for modeling the electromagnetic compatibility (EMC) and thermal coupling effects in cable network installations for future electric aircrafts. In highvoltage cables, where resistance is strongly influenced by temperature rise, it is necessary to simultaneously compute both the R matrix per unit length, as well as other primary electrical parameters, and the temperature distribution of the cable bundle. Our approach is based on a topological description of the electrical network and aims to unify the electromagnetic and thermal models. We exploit the mathematical similarity between the two physics to develop a single model that can determine the LGC matrices of a transmission line and calculate the resistance matrix R that depends on the heat distribution in a cable bundle due to the Joule effect. In this paper, we present an initial analysis of the temperature rise and electromagnetic coupling between conductors.

CONTINUED ON NEXT PAGE...



TUESDAY, AUGUST 1

3:30PM

Metal-Coated Building Blocks as a Tool for Creating Electromagnetic Shielding

Stanislav Kovar, Tomas Kadavy, Iva Kavankova, Jan Valouch, Jan Nemec

Univerzita Tomase Bati ve Zline Fakulta Aplikovane Informatiky, Czechia

Electromagnetic compatibility has become an integral part of the development process of any electronic or electrical product; however, maintaining a balance between radiation and susceptibility is not a simple task. When solving problems with EMC, financial and time costs arise, i.e., undesirable phenomena that EMC Risk-based management tries to prevent. This article focuses on a specific type of 3D shielding that can protect and envelop a product. Creating a shielding enclosure can be complex, especially considering atypical user requirements, such as material transparency and roundness. These requirements lead to unique shapes of electromagnetic enclosures, for which no specific procedures exist. Therefore, an idea was born based on simple cubes that could be assembled into arbitrary shapes with the help of metaheuristic algorithms and thereby help developers in their efforts. The principle is based on simply joining cubes of predefined form into the desired structure. To make the process more efficient, the application of artificial intelligence is expected, which will be able to propose a solution for a user-defined design based on experience and habits.

4:00PM

The Random Coupling Model – Introduction and Applications Overview

Steven M. Anlage, Thomas Antonsen University of Maryland at College Park College, USA

The Random Coupling Model (RCM) is a method for making statistical predictions of induced voltages and currents for objects and components contained in complicated (ray-chaotic) over-moded enclosures and subjected to RF fields. It uses minimal information about the enclosures, allowing one to make fast and efficient probabilistic predictions for the relevant EMC-related quantities. It is based on simple universal predictions of wave chaos theory and is quantitatively supported by random matrix theory. The systemspecific (non-universal) aspects of the problem are quantified by means of the radiation impedance of the "ports" involved in the problem, as well as prominent short orbits. A dimensionless loss parameter, given by the ratio of a typical mode 3-dB bandwidth to the mean spacing between modes, characterizes the fluctuations of the enclosure impedance. The outcome is a prediction for the statistics of scattering properties, impedance, S-matrix, and induced voltages on ports inside the enclosure. The RCM has been tested in many contexts in one-, two-, and three-dimensional enclosures, in both the frequency and time domains, and for both linear and nonlinear ports. We present an overview of the model and illustrate it use through a series of experimental results that have been used to verify the model and take it into new directions.

4:30PM

Patient-Specific RF-Induced Heating Prediction for Deep Brain Stimulator System under Parallel Transmit at 3T with Machine Learning Method

Ran Guo¹, Jianfeng Zheng¹, Wolfgang Kainz², Ji Chen¹ ¹University of Houston, USA; ²High Performance Computing for MRI, USA

The magnetic resonance imaging (MRI) radiofrequency (RF)-induced heating of the deep brain stimulators (DBSs) is dependent on the patient's characteristics and device implantation. The rule is further varied under parallel transmission. The traditional RF-induced heating evaluation method is comprehensive but time-consuming. Hence, an artificial neural network (ANN) model is developed in this study to predict the RF-induced heating for DBS systems under the parallel transmit condition at 3T. The hyperparameters of the ANN model, including the learning rate and the number of hidden layers and neurons, are optimized to handle the dataset of 66,290,400 samples. The original data is generated with the traditional transfer function method. The performance of the ANN model is validated with four different transfer functions. Using the optimized ANN regression model, the RF heating of the DBS system can be quickly and accurately predicted. The performance of the ANN regression model has a mean absolute error (MAE) of less than 0.84 °C and a coefficient of determination (R2) value of 0.996.

5:00PM

Interval Analysis Method for the Uncertainty and Sensitivity Characterization in Transmission Line Systems

Ping Yuan¹, Lijun Jiang² ¹The University of Hong Kong, China; ²The Chinese University of Hong Kong, China

Uncertainty in electronic fabrication process could cause serious yield issues and stability concerns. Hence, identifying the resultant range caused by the uncertainty in the system is a critical topic in modern EDA design process. Monte Carlo method is considered as a golden standard but with many drawbacks. In the paper, we propose to use the interval analysis (IA) to analyze the signal integrity and power integrity problems in transmission line (TL) systems. Using the interval representing the uncertainty range of parameters in the system, the uncertainty range of the system can be derived by the derived analytical expression. It is very helpful to the early design stages when design margin is being predicted.



TUESDAY, AUGUST 1



EMC WIRELESS TECHNOLOGIES, EMC PLANNING/TESTING/SPECIFICATIONS, WIRELESS COEXISTENCE 10:30 AM - 5:30 PM

Gallery Overlook F

Sponsored by TC-12

Chair:

Harry Skinner, Intel Corporation, Hillsboro, OR, USA

Co-Chairs:

Gang Feng, Christie Digital Systems Canada Inc, Waterloo, ON, Canada Yihong Qi, DBJ Technologies (Zhuhai) Co., Ltd., Waterloo, ON, Canada DongHyun Kim, Missouri University of Science and Technology College of Engineering and Computing, Rolla, MO, USA Francesco de Paulis, University of L'Aquila, L'Aquila, Italy

10:30AM

RF Desense Risk Prediction Using EM Simulations Gokul Ramsubbaraj¹, Leo Cheng², Krishna Rao¹

¹Google LLC, USA; ²Google LLC, Taiwan BEST EMC PAPER FINALIST

RF desense can significantly affect wireless connectivity performance in consumer electronic devices. In this paper, a workflow is presented to predict RF desense risk before the hardware prototyping stage using a combination of 3D EM simulation and board level RF system test through a consumer electronic prototype application example. First, a noise floor test is performed on the radio receiver modules to quantify the noise power level which could desensitize the radio receiver modules in the application prototype. Next, a full wave 3D EM simulation is utilized to compute the simulated noise power level coupled from a highspeed digital system to the radio receiver modules through the antennas in the application prototype. The noise power levels quantified through the noise floor test are used as a guideline to compare against the simulated noise coupled to the radio receiver system to analytically predict RF desense levels. The predicted RF desense levels are compared with direct desense validation results measured on hardware prototype samples to validate the accuracy of the simulation outcome. This technique can be used to predict RF desense risk during the early hardware prototype phase to help inform hardware design engineers to make better design decisions to mitigate RF desense risk.

11:00AM

Decomposition Measurement for Antenna Gain and Radio Sensitivity of Wireless Receiving System Chaoqiang Zang¹, Lidong Chi², Fuhai Li¹, James L.

Drewniak³, Gang Feng², Yihong Qi² ¹Hunan University, China; ²LinkE Technologies Co., Ltd., China; ³Missouri University of Science and Technology, USA

A general procedure for decomposition measurements for receiver antenna gain and radio sensitivity based on received signal strength indicator (RSSI) reporting is proposed in this paper. This procedure standardizes the measurement steps for eliminating nonlinear error in RSSI reporting. After path loss calibration and RSSI uncertainty calibration, the real performance of the antenna and the radio working in the actual environment of wireless receiving system can be measured. The antenna gain is obtained from the difference between RSSI reporting and transmit power, and the radio sensitivity is obtained from the transmit power. This method helps to improve the development efficiency of radio devices and shorten the development cycle. The general procedure is suitable for single-input singleoutput (SISO) wireless receiving system having RSSI reporting such as GSM, and Bluetooth systems.

11:30AM

Ground Contact of Bendable FPC EMI Film Impact on Desense Noise for Smart Glasses

Chien-Ming Nieh¹, Deepak Pai¹, Jay Park¹, Shiro Yamauchi², Nobuyuki Ito² ¹Meta Platforms Inc., USA; ²Tatsuta Electric Wire & Cable Co., Ltd, Japan

AR/VR products face significant challenges in terms of weight and size limitation, particularly as wearable devices. Electrical Magnetic Interference (EMI) shielding film design is becoming increasingly popular due to its cost and weight advantage. The grounding design of EMI film is essential in determining its shielding effectiveness (SE). This work focuses on studying the impact of EMI film grounding design and ground contact performance in DC resistance after bending. The study presents both simulation results and manufacturing capabilities.

CONTINUED ON NEXT PAGE...



TUESDAY, AUGUST 1

1:30PM

Reconfigurable Intelligent Surface (RIS) Design for 5G n260 Frequency Band

Reza Yazdani, Manish Kizhakkeveettil Mathew, Zhekun Peng, DongHyun Kim

Missouri University of Science and Technology, USA

In this paper, a new low profile reconfigurable intelligent surface design with high resolution steering reflector and wide frequency band width is proposed at n260 frequency band, used for 5G new radio applications. The dynamic reflection phase and tunability is realized by integrating of varactor diode with each unit cell. This study presents design procedures, reflection simulation verifications, and the effects of important parameters on the performance of the proposed novel resonant unit cell. The proposed unit cell offers a dynamic reflection phase range of more than 270° at a wide frequency bandwidth. Simulation results of beam steering capability in horizontal plane at 38 GHz is presented to verify the design performance of the RIS.

2:00PM

Electrically Controlled Smart Surfaces for Reverberation Chambers

Yifan Guo¹, Zibin Weng¹, Yongchang Jiao¹, Lie Liu², Yihong Qi², Huibin Zhang²

¹Xidian University, China; ²General Test Systems Inc., China

Reverberation chambers (RC) have been utilized for more than half century. Initially, they have been employed in measuring the EM properties of material before using in EMC performance of equipment, like immunity properties or interference. Recently, reverberation chamber has been introduced into the evaluation of over-the-air (OTA) performance of wireless devices, which include TRP, TIS and gain or efficiency of antenna. As compared with anechoic or other methods, RC method can reduce the cost of measurement devices, also increase the test efficiency of TRP. In order to further improve the testing efficiency of the reverberation chamber, this paper proposes an electrically controlled smart surfaces (ESS) which could switch on or off to improve the uniformity of electromagnetic field inside chamber.

2:30PM

Static I-V based PIM Evaluation for Spring and Fabric-over-Foam Contacts

Kalkidan W. Anjajo¹, Yang Xu¹, Shengxuan Xia¹, Yuchu He², Haicheng Zhou², Hanfeng Wang², Jonghyun Park¹, Chulsoon Hwang¹ ¹Missouri University of Science and Technology, USA;

¹Missouri University of Science and Technology, USA; ²Google LLC, USA

BEST EMC PAPER FINALIST

Spring clips and fabric-over-foams (FOFs) are widely used in mobile devices for electrical connection purposes. However, the imperfect metallic connections tend to induce passive intermodulation (PIM), resulting in a receiver sensitivity degradation, known as RF desensitization. Due to the complexity of the PIM characterization, there is not yet a way to evaluate PIM performance using a simple setup for environments like factories. In this paper, a current-voltage (I-V) behaviorbased PIM evaluation method is proposed and validated with various metallic contacts and contact forces. The test results demonstrated the feasibility of the PIM performance evaluation based on the measured static I-V curve.

3:00PM

Oxidation Layer Formation on Aluminum Substrates with Surface Defects Using Molecular Dynamics Simulation

Emmanuel Olugbade¹, Hiep Pham¹, Yuchu He², Haicheng Zhou², Chulsoon Hwang¹, Jonghyun Park¹ ¹Missouri University of Science and Technology, USA; ²Google LLC, USA

BEST EMC STUDENT PAPER FINALIST

Aluminum oxide layer affects the integrity of electrical contact and can contribute adversely to passive intermodulation (PIM) behavior in radio frequency (RF) devices, necessitating a need for understanding its formation mechanism and realistic estimation of its thickness. Using ReaxFF molecular dynamics simulation technique, this study investigated the impact of surface defects on aluminum oxide layer formation. Results reveal that crystallographic orientation did not affect the kinetics of oxidation process of aluminum. However, the reaction kinetics increased significantly with surface inhomogeneities such as cracks, scratches, and grain boundaries. A non-uniform oxide layer with thickness variation in the range of 72-77% was observed due to surface imperfections. Concurrent crack healing and oxidation was observed, where the crack tips acted as sites for oxygen diffusion, thus increasing oxidation kinetics. The observations from this simulation agree with experimental reports and have important implications for optimizing the contact integrity in RF devices and for PIM control.



TUESDAY, AUGUST 1

4:00PM

Passive Testing of Electrically Small Antennas in Electronic Systems

Bin Xiao¹, Lidong Chi², Fuhai Li¹, James L. Drewniak³, Gang Feng², Yihong Qi²

¹Hunan University, China; ²LinkE Technologies Co., Ltd., China; ³Missouri University of Science and Technology, USA

In this paper, a measurement scheme, which eliminates the interference of the common mode current, for electrically small antennas is proposed. Firstly, the causes and effects of common mode currents appearing in passive testing are analyzed. Then, the influence of different outlet points of coaxial cable on the passive testing of antenna is studied experimentally and numerically. According to the distribution of the common mode currents on the ground plane when the coaxial cable feeds the antenna, the minimum current point is selected as the outlet point of the coaxial cable to reduce the influence of common mode current. Additionally, the influence of the coaxial cable's arrangement and the soldering area between coaxial cable and ground plane on the antenna under test is studied. Finally, considering the output point, arrangement and soldering area of the coaxial cable, a measurement scheme to improve the passive measurement accuracy of the electrically small antenna is proposed.

4:30PM

Challenges and Prospects of Vehicle OTA Spherical Near-Field Measurement Probes

Dao Lin¹, Zhanghua Cai², Lidong Chi², Fuhai Li¹, James L. Drewniak³, Gang Feng³, Yihong Qi² ¹Hunan University, China; ²LinkE Technologies Co., Ltd., China; ³Missouri University of Science and Technology, USA **BEST EMC STUDENT PAPER FINALIST**

This paper discusses the issue of measuring probe indicators for large-scale equipment, such as automobiles, under conditions of offset configuration. A simulation of spherical near-field measurement based on an offset configuration is presented in this paper. The measurement error is defined according to the reference data calculated by spherical wave expansion theory. Through comparative analysis of the simulation results, the main reason for the measurement error is the insufficient coverage of the probe's beamwidth. By adjusting the probe's radiation pattern using simulation software, an optimized probe that satisfies near-field measurement requirements under meter-level offset conditions is obtained. Finally, based on the simulation results, a set of recommended values for the main performance of the optimized probe is provided.

5:00PM

Challenges and Solutions for Automotive OTA Testing Jiyu Wu¹, Yihong Qi², Penghui Shen², Wei Yu², Lie Liu²,

James Drewniak³ ¹Hunan University, China; ²General Test Systems Inc., China; ³Missouri University of Science and Technology, USA

OTA (over-the-air) testing is essential for developing assisted and autonomous driving systems in vehicles, as it plays a crucial role in the localization, perception, and intelligent driving capabilities of ICVs (intelligent connected vehicles). Automotive antennas, typically much smaller in size than the vehicle itself and can be located in various positions, require spherical nearfield measurement for OTA testing. While there are established standards for OTA testing methods and uncertainties for mobile devices, base stations, and satellite components, there are still many challenges in the OTA testing of automotive systems. These challenges, specifically in SISO (single input single output) and MIMO (multiple input multiple output) configurations, are discussed along with potential solutions in this article.

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TUESDAY, AUGUST 1

TU-AM- G TECHNICAL PAPERS

EXEMPLARY PAPER SESSION 10:30 AM - 12:00 PM Gallery Overlook G

Chair:

Frank Gronwald, University of Siegen, Siegen, Germany

For this newly established symposium session, authors of already published exemplary papers have been invited to present their work to the IEEE EMC & SPI community. All of the selected exemplary papers are either award-winning, heavily cited, frequently downloaded, or of great practical value. Attendees of this session have the possibility to directly interact with high quality authors and to experience an interesting mix of different EMC & SPI topics. Presenting authors and the audience are encouraged to interact with each other and to initiate discussions and new ideas for future work.

PRESENTING AUTHORS

Susceptibility of Static Energy Meters due to Amplifier Clipping Caused by a Rogowski Coil

Presenting Author: Tom Hartman Hartman, T., ten Have, B., Dijkstra, J., Grootjans, R., Moonen, N., & Leferink, F. (2022) **Citation:** T. Hartman, B. t. Have, J. Dijkstra, R. Grootjans, N. Moonen and F. Leferink, "Susceptibility of Static Energy Meters due to Amplifier Clipping Caused by a Rogowski Coil," in IEEE Transactions on Electromagnetic Compatibility, vol. 64, no. 6, pp. 2024-2032, Dec. 2022, doi: 10.1109/TEMC.2022.3204391.

Signal Integrity Assessment of Interconnects Routed Within Bandgap Metallic Cavities

Presenting Author: Francesco de Paulis de Paulis, F., & Nisanci, M. H. (2022) **Citation:** F. de Paulis and M. H. Nisanci, "Signal Integrity Assessment of Interconnects Routed Within Bandgap Metallic Cavities," in IEEE Transactions on Signal and Power Integrity, vol. 1, pp. 83-92, 2022, doi: 10.1109/TSIPI.2022.3199331.

Transient Analysis of ESD Protection Circuits for High-Speed ICs

Presenting Author: Javad Meiguni Meiguni, J. S., Zhou, J., Maghlakelidze, G., Xu, Y., Izadi, O. H., Marathe, S., Shen, L., Bub, S., Beetner, D.G., & Pommerenke, D. (2021) **Citation:** J. S. Meiguni et al., "Transient Analysis of ESD Protection Circuits for High-Speed ICs," in IEEE Transactions

on Electromagnetic Compatibility, vol. 63, no. 5, pp. 1312-1321, Oct. 2021, doi: 10.1109/TEMC.2021.3071644.

Efficient DC and AC Impedance Calculation for Arbitrary-Shape and Multilayer PDN Using Boundary Integration.

Presenting Author: Ling Zhang

Zhang, L., Juang, J., Kiguradze, Z., Pu, B., Jin, S., Wu, S., Yang, Z., Li, E.-P., Fan, J., & Hwang, C. (2022). **Citation:** L. Zhang et al., "Efficient DC and AC Impedance Calculation for Arbitrary-Shape and Multilayer PDN Using Boundary Integration," in IEEE Transactions on Signal and Power Integrity, vol. 1, pp. 1-11, 2022, doi: 10.1109/ TSIPI.2022.3164037.



TUESDAY, AUGUST 1



SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE 10:30 AM - 5:30 PM

Gallery Overlook H

Sponsored by TC-10

Chair:

Hanfeng Wang, *Google Inc., Mountain View,* CA, USA

Co-Chairs:

Songping Wu, *Rivos Inc., Mountain View, CA, USA* Yansheng Wang, *Rivos Inc., Santa Clara, CA, USA* Ling Zhang, *Zhejiang University, Hangzhou, China*

Kaisheng Hu, Ciena, Ottawa, ON, Canada

10:30AM

Enhanced Eye Diagram Estimation Method for Nonlinear Systems with Input Jitter

Hanqing Zhang, Feijun Zheng Zhejiang University, China

An enhanced multiple-edge response (MER) based eye diagram estimation method is proposed to evaluate the performance of nonlinear systems with input jitter. Compared with existing MER-based methods which only took into account the bit effect, the proposed method first determines both orders of bit effect and jitter effect. These decided orders can affirm the necessary MERs. Subsequently, the proposed method figures out the minimal number of sampling points so that the necessary MERs can be recovered quickly based on the Nyquist theory and can be used to create eye diagrams. Lastly, the eye diagrams and their parameters are compared with those generated by traditional transient simulation and an existing MERbased method which introduces input jitter through a convolution process. The result indicates that this enhanced method is more accurate than the existing MER-based method.

11:00AM

Extraction for Multilayer Ceramic Capacitor Vibration Induced Force

Yifan Ding¹, Jianmin Zhang², Mingfeng Xue², Xin Hua², Benjamin Leung², Eric A. MacIntosh², Chulsoon Hwang¹ ¹Missouri University of Science and Technology, USA; ²Google LLC, USA

Due to the piezoelectric characteristic of the MLCC dielectric BaTiO3, the multilayer ceramic capacitor (MLCC) can vibrate when the supply voltage has AC components. The vibration of the MLCC will generate a force on the printed circuit board (PCB) it is connected to, causing the PCB to vibrate as well. The MLCC vibration-generated force is extracted using a measurement-simulation-based methodology in this paper. The force of an MLCC is first extracted at the PCB resonance frequencies. Then, a broadband force profile is obtained by using the interpolating method. The extraction methodology can be used in different boundary conditions, on different PCBs, and for different MLCCs with a good generalization.

11:30AM

On Finding an Equivalent Force to Mimic the Multilayer Ceramic Capacitor Vibration

Yifan Ding¹, Jianmin Zhang², Mingfeng Xue², Shenyin Ding², Benjamin Leung², Eric A. MacIntosh², Chulsoon Hwang¹

¹Missouri University of Science and Technology, USA; ²Google LLC, USA

BEST SIPI STUDENT PAPER FINALIST

The multilayer ceramic capacitor (MLCC) can vibrate due to the piezoelectric effect when there is AC noise on the power rail. The vibration of the capacitor will generate a force on the PCB and thus cause the PCB vibration and audible problems may occur. The work in this paper finds an equivalent force with similar behavior to the MLCC-generated force. The force is controllable and knowable and thus can mimic the capacitor vibration on the PCB.

CONTINUED ON NEXT PAGE...



TUESDAY, AUGUST 1

1:30PM

Power Supply Induced Jitter (PSIJ) Modeling, Analysis, and Optimization of High Bandwidth Memory (HBM) I/O Interface

Hyunwook Park¹, Taein Shin¹, Seongguk Kim¹, Keeyoung Son¹, Keunwoo Kim¹, Boogyo Sim¹, Hyungmin Kang¹, Seonguk Choi¹, Jiwon Yoon¹, Hyunwoo Kim¹, Chulsoon Hwang², Joungho Kim¹

¹Korea Advanced Institute of Science and Technology, Korea; ²Missouri University of Science and Technology, USA **BEST SIPI PAPER FINALIST**

Power supply induced jitter (PSIJ) in high bandwidth memory (HBM) I/O interface is modeled, analyzed, and optimized for different HBM generations. Precise models for VDDQ power distribution networks (PDNs), simultaneous switching current (SSC), and jitter sensitivities of the clock and I/O buffers are implemented for PSIJ estimation. Compared to the SPICE, the average error rate of the estimated PSIJ is 4.26 %. The critical frequency bands in the jitter spectrum where large jitters occur are derived by comparing the relative impact of the modeled interface factors in the frequency domain. For the optimization, on-chip and on-interposer decoupling capacitor (decap) placement strategies using machine learning (ML) are applied. The decap effects in the critical ranges are analyzed. Finally, based on the integrated analysis of the limitation of the decap solution and all the I/O interface factors, the major challenges of highfrequency PSIJ are characterized.

2:00PM

Signal Integrity Analysis of Notch-Routing to Reduce Near-End Crosstalk for Tightly Coupled and Short Microstrip Channel

Seunghun Ryu, Hyunwoong Kim, Seonghi Lee, Dongryul Park, Sanguk Lee, Seungyoung Ahn

Korea Advanced Institute of Science and Technology, Korea

In this paper, the notch-routing is introduced as the novel methodology to reduce the near-end crosstalk (NEXT) in tightly coupled and short microstrip channel. According to the high-integration of diverse components in a package, the space between traces gets arrower, that results in increasing NEXT due to increased capacitive coupling. We propose the modified structure of the transmission line with the uniformly placed notch so as to decrease the capacitive coupling. The proposed structure reduces NEXT by about 15% at 20 Gbps, and secures an additional height of 2.2% on the eye diagram compared to a conventional transmission line without a notch structure.

2:30PM

An Improved Test Method of Additive Jitter Quantification for Clock Buffer

Yang Wu, Rui Mao, Shengzhen Zhang, Lei Wang, Tao Xu Intel Corporation, China

Additive jitter is a critical parameter of the clock buffer in the system clock design. This paper introduced the problem in the additive jitter quantification, discussed causes of the problem, and proposed an improved method for the additive jitter quantification. The proposed method can effectively solve the problem in the additive jitter quantification and is verified by test results.

3:30PM

Signal Integrity Analysis of Wire Bonding Finger Capacitance to Reduce the Reflection of Multi-Drop Topology for Low-Power Double Data Rate (LPDDR) Hyunwoong Kim¹, Gagyeong Park¹, Seunghun Ryu¹, Jongwook Kim², Jaehoon Lee², Seungyoung Ahn1 ¹Korea Advanced Institute of Science and Technology, Korea; ²SK hynix Inc., Korea BEST SIPI PAPER FINALIST

DEST SIPI PAPER FINALIST

In this paper, in order to minimize the reflection generated in the multi-drop topology, the proposed structure to insert capacitance into the wire bonding finger using a high-K material is presented. The proposed structure can reduce the significant reflected signal due to multi-drop topology at a high-frequency range. Return loss is improved by about 2.26 dB and 0.24 dB, respectively, at 20 GHz for two loadings and four loadings systems, and the insertion loss is also improved due to this effect. Based on the eye diagram, the proposed structure, an additional height, and a width margin is obtained at 3.4 % and 2.0 % at 20 Gbps for four loadings system, respectively.



TUESDAY, AUGUST 1

4:00PM

Design and Analysis of Double-Side Characteristic Impedance Compensation Structure in 2.5D / 3D Package for High-Speed Serial Link

Seonghi Lee¹, Hyunwoong Kim¹, Jiyoung Park², Yongho Lee², Sungwook Moon², Seungyoung Ahn¹ ¹Korea Advanced Institute of Science and Technology, Korea; ²Samsung Electronics Co., Ltd., Korea **BEST SIPI PAPER FINALIST**

A double-side characteristic impedance compensation structure for a 2.5D/3D package is proposed and designed to mitigate the impedance discontinuity caused by the controlled collapse chip connection (C4)-bump. The compensation structures applicable to the interposer and package (PKG) were designed. The insertion loss according to the variables of the structure is analyzed. The insertion loss and eye-height are improved through reflection reduction of the proposed double-side compensation structure. The insertion loss is improved by 5.6 % and 9.8 % at 32 GHz and 64 GHz, respectively. The eye-height is improved by 2.5 % and 12.5 % at 128 Gbps and 256 Gbps, respectively.

4:30PM

Thermally Induced Losses on High Speed Interconnects

Gerardo Romo Luevano, Chris Ferguson, Ennai Ochoa, Harpreet Randhawa *Qualcomm Technologies, Inc., USA*

This paper presents a systematic approach for broadband characterization of thermally induced losses on high-speed interconnects. The characterization relies on S-parameter measurements of striplines fabricated on a commercial board with 20 GHz bandwidth. The measurements cover a temperature range from 0 to 100 degrees Celsius (°C), taken at 20-degree steps. For each temperature the high-speed interconnects are characterized from two-line measurements, which yields the complex-valued propagation constant at every temperature. As it is well-known, the real part of the propagation constant contains the loss information about the interconnects. By using the losses associated with the propagation constant at T= 0 °C as a reference, the thermally induced losses for all other temperatures are extracted. The thermally induced losses are then analyzed to determine the contribution from both the metal and the dielectric. Our results show that both the metal and the dielectric contribute to the thermally induced losses, but that the main contribution is primarily associated with the dielectric. From that, accurate temperature dependent models for the loss tangent $Tan\delta(T)$ and for the metal's resistivity can be defined from the measured data. It follows that the thermally induced losses due to the dielectric and the metal can be easily modelled in commercial EDA software by simply correcting the loss tangent and resistivity values for the desired temperature.

5:00PM

Simulation and Measurement Correlation Study for 112 Gbps PAM4 High-Speed Links

Tao Wang, Marvin Yin, Karthik Muniappan, Brian Brecht *Teradyne Inc., USA*

Base band signal delivery is demanding over 100 Gbps data rate. Hence, simulation and measurement correlation is necessary to ensure the quality of the design. In this work, we focus on 112 Gbps and even higher signal delivery board designs to discuss critical issues affecting simulation accuracy, measurement reliability, and correlation result analysis. Port setups, boundary definitions, probe selections, and result expectations are included in this study. Multiple channels' correlation results in both spectrum and TDR domains will be presented. This paper serves as a ground truth reference to the correlation status for 112 Gbps channel designs.



TUESDAY, AUGUST 1



SHIELDING EFFECTIVENESS DESIGN TO 10GHZ AND BEYOND, USING FAST STOCHASTIC SIMULATION 12:30 PM - 2:00 PM Exhibit Hall Exp Demo 2

Designing cables, connectors and enclosures for EMC compliance at system-level and at high frequencies is difficult, due to coupled conduction and radiation paths, shield/joint/seam leakage, connector and cable penetration uncertainties, excitation field complexity, etc. For most EMC engineers, numerically-meshed, full wave models are too large, expensive and slow to be an interactive design tool - particularly at high frequencies 1GHz and above. New, statisticallyreduced order models by comparison, are a more natural solution for his class of problem, applicable up to 10 Ghz and beyond.

STOCHASTICA software from RobustPhysics will be used to demonstrate how the new stochastic simulation facilitates fast, interactive EMC environment predictions - both currents on cables and coupled electric fields in reverberant enclosures - in minutes rather than days.

Combined Tutorial and Software demonstrations for three (3) different EMC design applications will be presented:

- Shielding Effectiveness Design to 10 GHz and beyond, using Fast Stochastic Simulation (TU-PM1-ED2)
- Conducted and Radiated Crosstalk between Shielded Cables, using Fast Stochastic Simulation (WE-PM1-ED1)
- Predicting Integrated System EMC Levels for Test Level Tailoring, using Fast Stochastic Simulation (WE-PM-ED4)

PRESENTERS

Paul Bremner, Weitao Dai, Reza Afra, Arielle Frank *RobustPhysics, USA*

TU-PM1-ATE TECHNICAL COMMITTEE SHOWCASE TC3

EMC ENVIRONMENT, SIGNAL ENVIRONMENT, ATMOSPHERIC & MANMADE NOISE, CHARACTERIZATION 12:00 PM - 12:30 PM

Exhibit Hall AtE

Chair: Karen Burnham, *Electro Magnetic Applications, Inc.*

Co-Chair: Frederick Heather



EMC MANAGEMENT, PERSONAL & LABORATORY ACCREDITATION, EMC EDUCATION & AWARENESS, LEGAL ISSUES

12:30 PM - 1:00 PM

Exhibit Hall AtE

Chair: Tom Braxton, *Elite Electronic Engineering Inc.* **Co-Chair:** Balaji Biswanadh Gollapalli

TU-PM3-ATE TECHNICAL COMMITTEE SHOWCASE TC10

SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING & CHARACTERIZATION, CROSSTALK, JITTER, NOISE 1:00 PM - 1:30 PM

Exhibit Hall AtE

Chair: Hanfeng Wang, *Google Inc.* **Co-Chair:** DongHyun Kim, *Missouri University*



TUESDAY, AUGUST 1



EMC CHALLENGES OF AUTOMOTIVE ELECTRIFICATION 1:30 PM - 3:00 PM Exhibit Hall

Chair:

Craig Fanning, Elite Electronic Engineering, Downers Grove, IL, USA

Bring your questions or simply listen and learn!

PLANNED PANELISTS INCLUDE

Garth D'Abreu, *ETS-Lindgren* Cheyne Scoby, *Rivian* Robert Mitchell, *TUV* Keith Frazier, *Ford* Ron Missier, *Ford* Rob Kado, *Stellantis*

Abstract: Electrified vehicles (EV, HEV and PHEV) have been successfully used on our roadways for over 20 years. Electric vehicles continue to gain market share with some Countries and vehicle OEMs committing to full electrification. Like all electronic products, new electromagnetic compatibility (EMC) challenges are experienced during the design phases as the technology evolves. Electromagnetic noise sources, such as high-power switching operations and high-speed communication bus architectures, can cause issues for both regulatory compliance and self-compatibility. Understanding these potential issues early in the product design cycle can assist OEMs and their suppliers to make EMC-friendly design choices. Proper power electronics design, cable routing, cable shielding, simulation and modeling, and other disciplines all have a part to play in continuing the success in this area. Join experts in this free-form panel discussion to discuss the regulatory environment, associated standards, the main challenges in both design and testing of EVs, and the best strategies for overall EMC success in the EV space.





TUESDAY, AUGUST 1



SIPI SHORT COURSE 1:30 PM - 6:00 PM Gallery Overlook D

We are pleased to be able to offer this short course on Tuesday afternoon which will enhance the participants' knowledge about SIPI as they plan their schedule for the rest of the week to attend technical presentations on these topics.

Presenter: John Golding, Siemens EDA

Bio:

John worked as a hardware engineer doing high speed design and analysis for a telecommunications equipment provider for 18 years before joining Mentor Graphics as an application engineer in 2014, specializing in signal integrity, power integrity, and EMC analysis tools. He is now an application engineer with Siemens EDA working with engineers in several industries to solve their SI/PI/EMC analysis challenges. He holds a BSEE degree from the University of Michigan and a MSEE degree from Illinois Tech.

Syllabus:

This Signal Integrity (SI) and Power Integrity (PI) short course is intended for beginner and intermediate level learners. We will cover SI and PI basic concepts and illustrate them with examples.



Duration: 4 hours
Cost: \$100 per person

OUR TOPICS WILL INCLUDE:

Signal Integrity • Basic Concepts

- Basic Concepts
 - What is Signal Integrity
 - Transmission Lines
 - Crosstalk
 - Differential Pairs
 - Vias and Impairments
 - Termination
 - Timing
- Application Examples
 - DDR Memory Interface
 - High-Speed Serial Interface

Power Integrity

Basic Concepts

- What is Power Integrity
- DC Current and Voltage
- Decoupling
- Transient Performance
- Application Examples
 - DC (IR) Voltage Drop
 - Decoupling and noise



TUESDAY, AUGUST 1

TU-PM-B TUTORIAL

ENGINEER SOFT SKILLS 1:30 PM - 6:00 PM Gallery Overlook B

Sponsored by TC-1

Chair:

Kimball Williams, IEEE, Dearborn, MI, USA

A common concern among engineers and engineering managers is the effective training of all of our associates in the 'nontechnical' aspects of EMC engineering. These are usually referred to as the 'soft skills' as opposed to the technical tools we all strive to acquire during our time in Colleges or Universities. Some of these may be touched upon briefly in school curricula. However, the effective application is usually left to 'on the job' training, which usually means no training at all, with a 'sink or swim' approach to learning these skills. This Special Session will introduce the tools, with the 'twist' of the EMC engineer's point of view. (Note: Many members acquire the necessary 'practice' through active participation in professional society (IEEE) activities.)

Our objective is to provide sufficient introductory material and guidance to allow each student to continue to develop the core skills in each area while 'on the job'. Mastery of these subjects is only gained through practice in 'real' situations over sufficient time to allow the student to perceive and understand how to 'adjust' each tool to fit the task at hand. All we can hope to do is introduce and reinforce the fundamentals and encourage each student to continue to explore the nuances within each topic on his or her own time.

PLANNED SPEAKERS & TOPICS

Engineering Ethics Tom E. Braxton *Elite Electronic Engineering Inc., USA*

EMC Leadership – Networking Skills

Daniel D. Hoolihan Hoolihan EMC Consulting, USA

Effective Presentations

Bruce Archambeault International Business Machines Corp, USA

Designing a Career Path

Kimball Williams *IEEE, USA*



TUESDAY, AUGUST 1

TU-PM1- G SPECIAL SESSION

STOCHASTIC SIMULATION FOR EMC AND SIGNAL INTEGRITY 1:30 PM - 5:00 PM

Gallery Overlook G

Jointly Sponsored by TC-8 and TC-9

Co-Chairs:

Paul Bremner, *Robust Physics, San Diego, CA, USA*

Zhen Peng, University of Illinois at Urbana-Champaign, Champaign, IL, USA

1:30PM

The Random Coupling Model – Introduction and Applications Overview

Steven M. Anlage, Thomas Antonsen University of Maryland at College Park College, USA

The Random Coupling Model (RCM) is a method for making statistical predictions of induced voltages and currents for objects and components contained in complicated (ray-chaotic) over-moded enclosures and subjected to RF fields. It uses minimal information about the enclosures, allowing one to make fast and efficient probabilistic predictions for the relevant EMC-related quantities. It is based on simple universal predictions of wave chaos theory and is quantitatively supported by random matrix theory. The systemspecific (non-universal) aspects of the problem are quantified by means of the radiation impedance of the "ports" involved in the problem, as well as prominent short orbits. A dimensionless loss parameter, given by the ratio of a typical mode 3-dB bandwidth to the mean spacing between modes, characterizes the fluctuations of the enclosure impedance. The outcome is a prediction for the statistics of scattering properties, impedance, S-matrix, and induced voltages on ports inside the enclosure. The RCM has been tested in many contexts in one-, two-, and three-dimensional enclosures, in both the frequency and time domains, and for both linear and nonlinear ports. We present an overview of the model and illustrate it use through a series of experimental results that have been used to verify the model and take it into new directions.

2:00PM

Recent Developments in Stochastic Power Flow Enable a New Solution for System-Level EMC Modelling P.G. Bremner RobustPhysics, USA BEST EMC PAPER FINALIST

Statistical power balance modeling originally applied to reverberation chamber design has the potential to benefit a much wider range of EMC and signal integrity applications. This paper will review the physics and statistical foundations of Hill's model for reverberation chambers, the extension to multiply connected cavities and the coupling to multi-conductor cable currents inside the cavity field. The paper will then introduce a new unconditional probability density function formulation, further expanding the model to handle the statistics of electrically small cavities and the incorporation of uncertainty in the cavity Q factor.



TUESDAY, AUGUST 1



2:30PM

Maximum Expected Electric Field in Multiple Connected Cavities – Experimental Validation of Stochastic Power Flow Model

P.G. Bremner¹, J.C. West², R. Afra¹, C.F. Bunting², G. Vazquez³, Dawn Trout³ ¹RobustPhysics, USA; ²Oklahoma State University, USA;

³NASA Kennedy Space Center, USA

In the space community, there is increasing interest in augmentation of launch fairing thermal-acoustic blankets, to also control electromagnetic environment threats. This second paper by the authors reports on the development of simulation methods to predict the maximum expected electric field levels when RF absorbing materials are used to reduce the mean field. To account for frequency variance in a "frequencystirred" ensemble, the paper reports the experimental validation of a new unconditional probability density function model – an enhancement to Rayleigh statistics -- for the reverberant electric field magnitude at any location and any frequency.

3:30PM

Combined Reactive and Radiation Coupling of Conductors in an Enclosure – Numerical Validation of Stochastic Wavefield Model

W. Dai¹, P.G. Bremner¹, M.M. Mustafa², J.C. West², C.F. Bunting²

¹RobustPhysics, USA; ²Oklahoma State University, USA

A low-fidelity hybrid transmission line methodstochastic power flow (TLM-SPF) model has been developed to study the coupling of electromagnetic fields to conductors in an enclosure. Model setup time is approximately 10 minutes and computational time less than one minute. The resulting stochastic predictions agree with a high-fidelity full-wave simulation over a broad frequency range that requires days of computation on a high-performance computing system. This low-fidelity hybrid TLM – SPF approach is easily extendable to multi-segment cable harnesses in multicavity compartments. It is a computationally compact approach for a full system model of an aircraft, etc.

4:00PM

On Applying the Electromagnetic Probability-of-Effect Assessment Tool to Hazards of Electromagnetic Radiation to Ordinance Carl E. Hager IV

Naval Surface Warfare Center, USA

Traditional hazards of electromagnetic radiation to ordnance testing has leveraged deterministic plane wave illumination of ordnance enclosures to full tactical electromagnetic environments at open air test sites. Previously, an electromagnetic probabilityof-effect assessment tool which statistically assesses the magnitude of a system/sub-system's hardness or safety margin to upset/failure under any level of threat was developed. The purpose of this study is to directly compare the results of the electromagnetic probabilityof-effect assessment tool to traditional hazards of electromagnetic radiation to ordnance testing on a representative ordnance enclosure. Predicted and measured currents on an electrically initiated device are compared and very good agreement between the methods is demonstrated.

4:30PM

Statistical Characterization of Cavity Quality Factor via the Stochastic Green's Function Approach

Shen Lin¹, Yang Shao¹, Zhen Peng¹, Bisrat D. Addissie², Zachary B. Drikas² ¹University of Illinois at Urbana-Champaign, USA; ²US

Naval Research Laboratory, USA BEST EMC PAPER FINALIST

There has been a strong interest in statistically characterizing the cavity quality factor (Q-factor) for large, complex enclosures. While there are existing methods for analyzing the Q-factor statistics due to distributed losses, there is currently little discussion about the statistical cavity Q-factor caused by localized losses, such as aperture leakage and absorptive loading. This paper presents a physics-oriented, hybrid deterministic-stochastic model that calculates the probability distribution of cavity Q-factor. The research work is evaluated and validated through representative experiments.



TUESDAY, AUGUST 1



MULTIPLYING COMPETENCY: REMOTE AND AUTONOMOUS CHAMBER VALIDATION 2:00 PM - 4:00 PM Exhibit Hall Exp Demo 2

Sponsored by TC-2

The proposed activity is a real-time demonstration of remote chamber validation capabilities for at least three labs of diverse geography, industry served, and measurement needs in the United States and Canada. An engineer (one of the presenters) will be shown remotely controlling testing at all sites simultaneously from the Symposium during the presentation. The remote test site participants represent a large segment of the EMC and SIPI community and provide relevance to different market segments of manufacturers and service providers in the Symposium audience. The development and implementation of remote chamber validation with autonomous measurements presents a significant efficiency improvement to the industry, while requiring lower on-site competency. Attendees will learn the advantages of remote testing, watch a live demonstration of its practical application, and have an opportunity to interact with the presenters for a question period.

Several commercial and private lab owners have expressed commitment to the demonstration including automotive labs wishing to demonstrate the CISPR 25 long-wire testing and OEM labs with Near Field Scanning facilities. The presenters will select a group that contains:

- A commercial test lab with 3m SAC in the Southwest United States
- A private Canadian R&D reverberation chamber
- An EMC manufacturer with an internal SAC

PRESENTERS

Nika Amralah¹, Phillip Miller² ¹Raymond EMC Enclosures, Canada; ²RATLR, USA



TUESDAY, AUGUST 1



A NOVEL CYLINDRICAL MODE FILTERED SVSWR METHOD FOR ABOVE 18 GHZ EMC TEST SITE EVALUATION 2:00 PM - 4:00 PM

Exhibit Hall Exp Demo 3

Sponsored by TC-1

It has been shown that the conventional SVSWR measurement method does not extrapolate well to above 18 GHz. A novel SVSWR method based Cylindrical Mode Filtering is being actively considered in both ANSI C63.25 and CISPR 16. In the new method, the transmit antenna (typically a low gain omni-directional antenna) is placed at the edge of the turntable, and a single cut vector pattern measurement is acquired. The vector S21 as a function of turntable angle at each frequency is transformed to the cylindrical mode spectrum, where an appropriate filter can be applied to mathematically remove the chamber effects. The SVSWR is derived by comparing the original pattern in the chamber to the "clean" filtered pattern. Compared to the traditional SVSWR method, the mode filtered SVSWR method is easier to perform, faster, more repeatable, and provides a more comprehensive evaluation of the quiet zone. In this demonstration, we will show the measurement process in real time and explain the post processing procedures. Several recent advances will be discussed, including the statistical based robust calculation of SVSWR, and a new post processing algorithm which greatly relaxes turntable positioning accuracy requirements.

PRESENTER

Zhong Chen ETS-Lindgren, USA



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TU-PM-ED4

EXPERIMENTS &

DEMONSTRATIONS

TECHNICAL PROGRAM

TUESDAY, AUGUST 1

CABLING AND SHIELD TERMINATIONS 2:00 PM - 4:00 PM Exhibit Hall Exp Demo 4 Sponsored by TC-8

Cabling and shielding are among of the most important aspects of any system for establishing electromagnetic compatibility. Despite this, they are frequently misunderstood and/or overlooked. This demonstration examines cabling and shielding techniques in order to provide a practical understanding of how shielding works and what types of terminations work best for different applications.

PRESENTERS

John C. McCloskey, Jen Dimov NASA/Goddard Space Flight Center, USA





TUESDAY, AUGUST 1



SPECTRUM ENGINEERING, CHARACTERIZATION AND MODELING, DESIGN, ADAPTIVE INTERFERENCE MITIGATION 4:30 PM - 5:00 PM

Gallery Overlook G

Sponsored by TC-6

Chair:

Sarah Seguin, *Resonant Frequency, Maple Grove, MN, USA*

PLANNED SPEAKERS & TOPICS

A Versatile Fourier Domain Filtering Library for Diverse Applications

Yibo Wang¹, Zhong Chen¹, Andrew Shyne², Dennis Lewis² *IETS-Lindgren, USA; ²The Boeing Company, USA*

Fourier domain filtering is a commonly applied data post processing technique used in many engineering applications, e.g., time domain gating is often used to remove or isolate responses in a multiple reflective environment. Many commercial vector network analyzers (VNAs) include the gating algorithm as a "black box" function. A user has little recourse to reprocess or further process the data once the data has been downloaded from a VNA. A versatile Fourier domain filtering library has been developed recently, giving users much more flexibility and convenience over the VNA-dependent process. It is well known that the gated results can exhibit significant "band edge effects" due to the band limited measurement data. The new library toolset incorporates the standard edge treatment techniques often found in commercial VNAs. In addition, it includes a newly developed spectrum extension technique which improves the gated data accuracy significantly for many practical applications. The library works equally well for spatial and spectrum applications, such as for image processing and spectrum analyses in antenna measurement applications.

WELCOME TO FURNITURE CITY!

Early success in Grand Rapids is made possible by the Grand River, surrounding geography, and ingenuity of the people. Plentiful in timber from surrounding woodlands, Grand Rapids became a hub for manufacturing furniture. As early as 1848, merchants traveled to Grand Rapids to restock their stores. In 1878, more formal markets rose



and mass manufacturing began. West Michigan fostered nearly 800 furniture makers from past to present, and became known as the "Furniture City," pioneers in quality and style throughout the industry. To emphasize their title and standards across the nation, Grand Rapids began using their name as a trademark- so prestigious that retailers outside of Grand Rapids attempted to use the logo fraudulently! Today, many furniture makers still thrive in Grand Rapids.

VISIT THE GRAND RAPIDS PUBLIC MUSEUM FOR MORE INFO

IEEE EMC SOCIETY: ENJOY THE BENEFITS OF BELONGING

You deserve the best in your professional and personal life and the IEEE EMC Society is a great way to get what you need. Join, engage, support and contribute to the many technical, standards, education and social activities that make engineering EMC fun and fulfilling.

Get involved in an international group that will put you on a path for lifelong success.

Who knows? You will make new friends. So go ahead!

Join the EMC Society today!











REGISTRATION/INFO DESK HOURS

Wednesday - 8:00 am to 5:00 pm

COMPANION SUITE (Registered Companions Only) Gerald Ford Ballroom – Amway Grand Monday – Thursday: 7:00 am – 10:00 am

STANDARDS WEEK SESSIONS

Join us for this special track on current and emerging International EMC and SIPI Standards! Attend open Working Group meetings with opportunities to contribute and ask questions.

LEMC+SIP



WEDNESDAY, AUGUST 2



EM INTERFERENCE CONTROL, SHIELDING, GASKETS, CABLES, CONNECTORS, **GROUNDING AND PCB LAYOUT** 8:00 AM - 4:30 PM

Gallery Overlook D

Sponsored by TC-4

Chair:

Daryl Beetner, Missouri University of Science and Technology, Rolla, MO, USA

Co-Chair:

Davy Pissoort, Katholieke Universiteit Leuven, Bruges, Belgium

Charles Jullien, Safran Electrical and Power, Blagnac, France

Srinath Penugonda, Missouri University of Science and Technology, Milpitas, CA, USA

8:30AM

Analysis of Methodology of Breakpoint Detection Method for 22.9kV Submarine Power Cable Based on the Time Domain Reflectometer (TDR)

Hyunwoong Kim¹, Sanguk Lee¹, Jong-Man Joung², Bumjin Park³, Seungyoung Ahn¹

¹Korea Advanced Institute of Science and Technology, Korea; ³Korea Electric Power Corp, Korea; ³Samsung Electronics, Korea

This paper proposes and analyzes the breakpoint detection method for a long 22.9 kV submarine power cable based on a time domain reflectometer (TDR) depending on the various fault situations. Appropriate conditions are required in the fault situations to apply the detection method based on TDR impedance. The detection method requires that the rising time of the input source should be short enough to detect the length of the breakpoint. The shorter the rising time is, the more advantageous it is to detect the breakpoint, but a long power cable can significantly attenuate the highfrequency signal. Therefore, it is derived through analysis that the performance of the breakpoint can be determined depending on the input source and rising time.

9:00AM

Comparison of Suppression Effect by CMF for UTP and **STP Lines Using Chain Parameter Matrix**

Nobuo Kuwabara, Tohlu Matsushima, Yuki Fukumoto Kvushu Instiute of Technology, Japan

Common-mode filter (CMF) is a vital device to improve electromagnetic compatibility (EMC), and the analysis of the CMF effect is essential to improve the design quality of EMC. This paper analyzes the suppression effect of CMF used for telecommunication lines using a chain parameter matrix. The chain parameter matrix represented the CMF and the interface cable, and the S21 at the far end of the cable was calculated. The analytical method was validated by comparing measurements using unshielded twisted pair (UTP) and shielded twisted pair (STP) cables. The results showed that the analysis method was appropriate for analyzing the suppression effect. Using the analysis method, the suppression effect was evaluated by the common mode (CM) current at the cable input and the radiated electric field. The result showed that the characteristic impedance and the transmission loss of the CM transmission line affect the suppression effect. The result also showed that the suppression effect by the radiated electric field could be estimated from the suppression effect by the CM current at the cable input.

9:30AM

Near Field Scanning-Based EMI Radiation Root Cause Analysis in an SSD

Xiangrui Su¹, Wenchang Huang¹, Junghee Cho², Joonki Paek², Chulsoon Hwang¹ 1Missouri University of Science and Technology, USA; ²SK hynix Inc., Korea

BEST EMC STUDENT PAPER FINALIST

In modern portable electronic devices, solid-state drives (SSDs) are commonly used and have been identified as one of the dominant electromagnetic interference (EMI) noise sources that can cause RF desensitization issues. In this paper, the EM emission source from an SSD module is identified and analyzed using near field scanning and dipole moment source reconstruction. The identified noise current path including the power management integrated circuit and the decoupling capacitor is validated with the assistance of full-wave simulation. The measured noise voltage is used as an excitation in the simulation and the simulated near fields showed a good correlation with measured near fields in both pattern and magnitude. Based on the validated radiation mechanism, an optimized layout is proposed and validated in simulation reducing the far field radiation by 10 dB.



WEDNESDAY, AUGUST 2

10:30AM

Two Advanced Types of Air Vent for Improved EMI Shielding and Air Flow

Jianquan Lou¹, Alpesh Bhobe², Jerry Pianin², Joel Goergen²

¹Cisco Systems (China) R&D Co., Ltd., China; ²Cisco Systems, Inc., USA

BEST EMC PAPER FINALIST

Air-vents on a system chassis are designed to allow efficient air flow to cool the system, while at the same time shield unwanted electromagnetic energy. With the speed and power consumption of systems increasing with new product generation, striking a balance between reducing EMI and meeting thermal requirements has become more challenging. This paper investigated two novel types of air vent for better shielding effectiveness (SE) and air flow performance. First one is air vent with openings of random size and location, dozens of cases were simulated and demonstrate that there exist some random cases which have better SE in certain frequency range without impacting on air flow performance. The other one is called air vent with non-uniform cross section, based on the Bernoulli's principle, several cases of air vent with different non-uniform cross section types were modeled, and both simulation data and measurement results show the improvement in EMI shielding effectiveness and pressure drop of air flow.

11:00AM

EMI Performance of Multilayered Al-CoTaZr Films in Shielded Power Inductors

Ghaleb AL Duhni¹, Mohammad Mohtasim Hamid Pial¹, Mudit Khasgiwala², John L. Volakis¹, Pulugurtha Narkondeya Raj² ¹Elorida International University, USA:

¹Florida International University, USA; ²Applied Materials, USA

This paper examines the performance of multilayered Al-CoTaZr films as electromagnetic interference (EMI) shields. The first part of the paper simulates the shielding effectiveness (SE) of several combinations of multilayered stacks of AI and CoTaZr of 10 Qm thickness. Using the NSA 65-6 standard in the frequency range of 1-100 MHz, four and five layers of [AI (2 layers)-CoTaZr (2 layers) and AI (2 layers)-CoTaZr (3 layers)] are shown to provide SE of 10-62 dB. By comparison, commercial EMI shielding, such as Cu, shows only 6-41 dB in the same frequency range. Alternatively, using the IEEE 299 standard, the same thickness of AL and CoTaZr samples give 40-70 dB SE as compared to that of Cu which ranges from 12-46 dB. The second part of the paper studies the impact of various multilayers of Al CoTaZr to mitigate undesired magnetic radiation of power inductors. The last part of the paper compares the SE of thin multilayered samples (5Qm) versus thick films of Copper and AI (10 Qm). It is demonstrated that four and five-layer stacks of Al and CoTaZr (5 Qm thick) based on the NSA 65-6 standard, exhibit similar shielding performance as commercial materials of 10 Qm of Cu and Al.

11:30AM

Design and Optimization of the Porous Metamaterial EM Absorbers in X-band

Kanat Anurakparadorn, Alan Taub, Eric Michielssen University of Michigan, USA

A strategy that combines experiment and simulation to design and optimize electromagnetic (EM) metamaterial absorbers containing a periodic porous structure is described. The approach provides the ability to produce absorbers that meet multiple user-specified objectives. Using the measured intrinsic properties of the baseline materials as an input to EM-field based computational modelling and optimization, absorption by the studied metamaterials measured by their reflection loss (RL) increases significantly. The resulting metamaterials have the potential for lower cost and lighter weight while providing greater protection than traditional metal gaskets and foams.

1:30PM

Simulation and Measurement Characterization of the Test Volume of an Indoor EMP Generator

Ali Yaqoob, Edrees Al Mansoori, David Martinez, Islem Yahi, Chaouki Kasmi, Felix Vega Directed Energy Research Center, Technology Innovation Institute, Abu Dhabi, United Arab Emirates

This paper discusses the experimental and numerical characterization of the test volume of an E1 EMP generator compliant with MIL-STD-461. Because the test volume is neither defined in the literature nor in the standard for an indoor EMP generator it is important to characterize it in order to perform RS105 testing that is compliant with the standard. Moreover, the work aims to check the field characteristics when deviating from the test volume boundaries.

2:00PM

Interference in RF Shielded Rooms Due to Potentials between Grounded Surfaces

Marc Gaidosh Fujifilm Healthcare Americas, USA

Potentials between 'grounded' surfaces in a RF shielded room can cause interference in sensitive equipment. RF shielded rooms such as those used for Magnetic Resonance Imaging (MRI) scanners are examples of equipment susceptible to interference as a result of imperceptible arcs. These tiny arcs are usually intermittent making them problematic for troubleshooting.



WEDNESDAY, AUGUST 2



COMPUTATIONAL ELECTROMAGNETICS, MODELING AND SIMULATION, MULTI-PHYSICS TECHNIQUES, TOOLS, AND APPLICATIONS 8:00 AM - 12:00 PM Gallery Overlook E

Sponsored by TC-9

Co-Chairs:

Scott Piper, General Motors Corp, Canton, MI, USA Shaowu Huang, Marvell Semiconductor Inc, Cupertino, CA, USA Patrick DeRoy, Analog Devices Inc, Norwood, MA, USA

8:00AM

Understanding the Time Reversal Symmetry in Classical Electrodynamics

Bohao Zhang, Shaoyin He, Yanzhao Xie Xi'an Jiaotong University, China

In this paper, the time reversal operation of physical laws with covariant forms is analogous to a generalized Lorentz boost. Based on this ideation, a time reversal form of the classical Maxwell's equations is proposed, which is intended to provide theoretical support for relevant research in the field of EMC/EMI based on electromagnetic time reversal technique.

8:30AM

Isogeomtric Analysis Using C2 Interpolating Splines for Curved Objects in EMC Problems

Tadatoshi Sekine, Nobuhisa Tanaka, Shin Usuki, Kenjiro T. Miura

Shizuoka University, Japan

This paper describes an electromagnetic simulation technique based on isogeometric analysis (IGA) using C^2 interpolating splines. Since the C^2 interpolating splines pass through control points of curves and surfaces, boundary conditions can be directly applied on the control points in the proposed IGA formulation.

9:00AM

A Data-Driven Approach to Multiresolution Analysis of Near-Field Scanning

Yanming Zhang, Lijun Jiang The Chinese University of Hong Kong, China

Near-field scanning has been widely adopted as a valuable tool in diagnosing electromagnetic compatibility (EMC) and electromagnetic interference (EMI) problems. This paper proposes a multiresolution dynamic mode decomposition (MRDMD)-based method for analyzing time-varying near-field radiation. MRDMD executes the traditional DMD method recursively and hierarchically. The distribution of DMD eigenvalues determines the slow and fast modes in a level's decomposition, in which the slow modes are reserved. and the fast modes are utilized to generate the input data for the next level. Finally, the multiresolution timefrequency representation of the near-field radiation field is obtained. And the spatial distributions corresponding to each frequency component are also extracted. A numerical example of turning three loop antennas on and off is conducted to validate the proposed MRDMD method. The multiresolution time-frequency representation of the near-field radiation shows a good agreement with the actual ones regarding the excitation duration and frequency components. Besides, the spatial distributions in the scanning plane radiated by each loop antenna are derived correctly. Hence, our work offers a multiresolution analysis tool for nearfield scanning, especially when the spatial-temporal information of each frequency component is needed.



WEDNESDAY, AUGUST 2

9:30AM

Data Assessment Method Based on the Statistical Analysis

Beatrice Jiang¹, Lisa Ryder¹, Ping Li² ¹Westlake High School, USA; ²Shanghai Jiao Tong University, China

Data quality assessment for results from computational electromagnetics (CEM) tools and experimental data is an important and necessary part of electromagnetic compatibility (EMC), signal integrity (SI) and power integrity (PI) studies. This problem was addressed by the popular feature selection validation (FSV) method that has been taken into IEEE P1597 standard for CEM. In this paper, we propose a new idea by using a statistical method and the Data Science tool R to quantitatively analyze the differences between two data sets. The Pearson correlation coefficient r and the coefficient of determination R2 are both employed as quantified indicators to analyze the pattern of data sets and their mutual agreement respectively. It further calculates the shift between datasets. By removing the shift, it can disclose their hidden relationship. Benchmarks for transient and spectrum cases are used to demonstrate its effectiveness. The proposed method will serve as a convenient addition to existing methods in IEEE P1597.1 and P1597.2 adopted by the IEEE EMC community. It will be released as a web tool coded for the EMC society by the time of conference.

10:30AM

Magnetic Noise Calculations in the Presence of Three Torque Rods for Spacecraft Applications David Norte

Ball Aerospace, USA

This paper addresses magnetic noise calculations in the presence of X, Y, and Z directed torque rods for spacecraft, and where it is desired to obtain the magnetic noise, in units of nT/ \sqrt{Hz} , at the location of a magnetically sensitive instrument that is characterized with an extremely low bandwidth (0.5 - 20.0) Hz. The instrument, characterized with a maximum ambient magnetic noise level of 1.0 nT/ \sqrt{Hz} that cannot be exceeded, is either 0.5m, 1.0m, or 1.5m from the set of torque rods, and where the torque rods are controlled through PWM signals. Exceeding this level (1.0 nT/ \sqrt{Hz}) can interfere with the intended operation of the instrument.

11:00AM

The Impacts of On-Board ESD and Time-Division Multiplexed Switching Events on the Magnetic Noise from Solar Panels for Space Applications Rachel Lumnitzer, David Norte Ball Aerospace, USA

Regarding the management of power derived from solar panels for space missions, it is of interest to understand how switching events can cause magnetic noise from the panels, which might then interfere with the success of the mission. In this paper, the magnetic noise resulting from the time-divisionmultiplexed switching of groups of strings of solar cells to regulate the current that is available from the panel is addressed. In addition to these switching events, it is also of interest to understand how ESD events, originating from the spacecraft itself, can cause high-frequency secondary magnetic noise from the panel. By characterizing these noise sources, it can be determined, for example, if the strengths of these interferences cause degradations in the intended operation of the mission. In this paper, these determinations are based upon the use of the magnetic transfer function from the panel to a given location of interest on the spacecraft. Once the frequency spectrum of the interfering event is characterized, then the product of this spectrum with the magnetic transfer function produces the expected interference at the location of interest, after which it can be determined if any mitigation is required.

11:30am

Magnetic Fields and Minimum Safe Distances for UAS during Transformers Inspection

Dulana Rupanetti, Issam Boukabou, Landon Foust, Selma Benouadah, Naima Kaabouch *University of North Dakota, USA*

Nowadays, Unmanned Aerial Systems (UAS) play a crucial role in inspecting and maintaining powerline systems, such as transmission towers, power lines, transformers, etc. UAS operating in the vicinity of these high-voltage components are constantly affected by the emitted magnetic fields, such as large power transformers, which can impact the electronic components of the UAS, resulting in collisions, casualties, and injuries. Minimal work has been done to estimate these fields and the safe distances from transformers for UAS to operate. This paper uses three-dimensional (3D) finite element analysis to analyze the minimum safe operating distances for UAS around power transformers emitting low-frequency magnetic Fields. We Examine a three-phase 2500 kVA pole-mounted transformer and a bank of singlephase pole-mounted 20 kVA transformers using finite element analysis and provide analyzed data on the safe operational distances for UAS.



WE-AM-F

TUTORIAL

TECHNICAL PROGRAM

WEDNESDAY, AUGUST 2

LESSONS LEARNED FROM NASA EMC: LOOKING BACK AND FORWARD 8:00 AM - 12:30 PM Gallery Overlook F

Sponsored by TC-8

Chair:

Jen Dimov, *NASA, Greenbelt, MD, USA* **Co-Chair:**

Manuel Soriano, NASA-Jet Propulsion Laboratory, Los Angeles, CA, USA

With several big flagship programs getting launched, this is an opportune year to take some time for a retrospective on the lessons learned applicable to large aerospace programs – what went well and can offer an example of good practices? What went poorly and serves as an example of what not to do? – from both long and short programs.

PLANNED SPEAKERS & TOPICS

Twenty Years with the James Webb Space Telescope John McCloskey

NASA Goddard Space Flight Center, USA

JWST Deep Dive - The NIRCam Instrument-Level Test Jim Lukash

Lockheed Martin Space Systems, USA

Preventable Disasters: What Not To Do

Annabelle Epplin, Robert Houle NASA Goddard Space Flight Center, USA

Roman Space Telescope EMC Testing

Nick Davis NASA Goddard Space Flight Center, USA

Heavy Metal: EMC and Magnetics for the Psyche Mission

Manuel Martin Soriano NASA - Jet Propulsion Laboratory, USA

PACE - Adventures in Magnetics

Jen Dimov NASA Goddard Space Flight Center, USA

THE DAY THE MUSIC CAME TO LIFE...

In 2011, 5,000 citizens of Grand Rapids worked together to help save the city's reputation after being voted "Most Boring City in America" by Newsweek. To show just how wrong the magazine truly was, they assembled in the downtown area and created an inspiring music video set to the beloved song "American Pie" by Don McLean. The eight-minute long video was shot in one seamless take, with a camera following a myriad of singing and dancing residents against a backdrop of marching bands, pillow fights, and fireworks.

Unsurprisingly, Grand Rapids' video went viral with almost 6 millions views. Recently it was even featured in a documentary about the history of the song: "The Day the Music Died: The Story of Don McLean's 'American Pie'". But more importantly, they proved that boring was definitely NOT something that could describe their talented city.



WATCH THE VIDEO



WEDNESDAY, AUGUST 2



CUTTING THROUGH THE COPPER TAPE: GETTING TO ROOT CAUSE WHEN TROUBLESHOOTING 8:00 AM - 12:30 PM Gallery Overlook G

Sponsored by TC-4

Chair:

Kajsa Johnson, *Microsoft Corp, Redmond, WA, USA*

Co-Chair:

Karen Burnham, Electro Magnetic Applications, Inc., Lakewood, CO, USA

The lab called, your product is failing. Now what? What does it take to fully understand the problem, and fix it at its root cause? Join us as we explore some common areas for bugs (emissions, ESD, and transients), how to quickly get to root cause, and arrive at more effective solutions.

PLANNED SPEAKERS & TOPICS

Radiated Emissions Troubleshooting 102: Understanding and Fixing the Problem (at the Rootcause!) Kajsa Johnson *Microsoft Corporation, USA*

Debug Conducted Issues

Patrick André André Consulting, Inc., USA

Benchtop Troubleshooting Top Two Immunity Issues Kenneth Wyatt *Wyatt Technical Services LLC, USA*



Photo by Patrick Andre



WEDNESDAY, AUGUST 2



SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE 8:00 AM - 5:30 PM

Gallery Overlook H

Sponsored by TC-10

Chair:

DongHyun Kim, *Missouri University of Science* and Technology College of Engineering and Computing, Rolla, MO, USA

Co-Chair:

Yuandong Guo, Missouri S&T EMC Laboratory, Missouri University of Science and Technology, Rolla, MO, Foster City, CA, USA

Yin Sun, *Missouri University of Science and Technology, Rolla, MO, USA*

Baolong Li, Cadence Design Systems Inc, San Jose, CA, USA

Tao Wang, *Teradyne Inc, Agoura Hills, CA, USA*

Hanqiao Zhang, *Meta Platforms Inc, Redmond,* WA, USA

8:00AM

System Level PDN Impedance Optimization Utilizing the Zeros of the Decoupling Capacitors

Yifan Ding¹, Shuang Liang¹, Francesco de Paulis², Matteo Cocchini³, Samuel Connor³, Matthew S. Doyle³, Albert Ruehli¹, Chulsoon Hwang¹, James Drewniak¹ ¹Missouri University of Science and Technology, USA; ²University of L'Aquila, Italy; ³IBM, USA

System-level power distribution network (PDN) impedance optimization utilizing the zeros of the decoupling capacitors (decaps) is discussed in this paper. An example of a practical PDN application is proposed to validate the poles and zeros algorithm (P&Z) presented. The system-level PDN is with the printed circuit board (PCB), package (PKG), and chip, as well as the low-frequency decaps on the PCB and the on-PKG decoupling capacitors. The PDN optimization results are compared with those from the genetic algorithm (GA) to show the reasonableness and validity of the P&Z algorithm.

8:30AM

Augmented Genetic Algorithm v2 with Reinforcement Learning for PDN Decap Optimization

Haran Manoharan¹, Jack Juang¹, Hanfeng Wang², Jingnan Pan², Kelvin Qiu², Xu Gao², Chulsoon Hwang¹ ¹Missouri University of Science and Technology, USA; ²Google LLC, USA

Genetic algorithms (GAs) use many hyperparameters, and tuning these parameters can determine the optimization performance. A GA with an augmented initial population was proposed for decap optimization but it had convergence issues by getting stuck in the local minimum. This work uses a reinforcement learning (RL) approach to adaptively tune the hyperparameters of GA during its operation. With this approach, the agent tries to change the parameters so that the GA does not get stuck in the local minimum. The proposed method combining the RL agent and Augmented GA showed better performance in terms of solution quality and time cost. Overall, in all the cases tested, the proposed method showed better performance than the Augmented GA without RL.

9:00AM

Die Capacitance and Power Distribution Network Modeling Method through Measurement of Resonant Frequency

Marie Peyrard^{1,2}, Gilles Jacquemod¹, Nicolas Froidevaux², Mélanie Moign²

¹Universite Cote d'Azur Institut Universitaire de Technologie, France; ²STMicroelectronics, France **BEST SIPI STUDENT PAPER FINALIST**

This paper presents a modeling method of the die capacitance and Power Distribution Network (PDN) of a microcontroller (MCU), using the measurement of its main resonant frequency. Occurring between the die capacitance and the microcontroller's interconnect inductance, this resonance is an important concern for the power integrity of an MCU power supply. Therefore, modeling the PDN and simulating this frequency is crucial during the design phase. The die model is usually established for a defined worst-case activity, hard to correlate with measurements. In this paper, we present a method to model the die capacitance independently of any specific MCU operation. The model is built and validated using a previously developed measurement method for several decoupling configurations [1]. The resonant frequency measurement and simulation results showed good correlation.

TECHNICAL PROGRAM WEDNESDAY, AUGUST 2



9:30am

An Analysis on the Effectiveness of 2 and 3 Terminal Capacitors in PDN Design

Jack Juang¹, Jiahuan Huang¹, Anfeng Huang¹, Kelvin Qiu², Hanfeng Wang², Yansheng Wang³, Zhiping Yang⁴, Chulsoon Hwang¹

¹Missouri University of Science and Technology, USA; ²Google LLC, USA; ³Rivos Inc., USA; ⁴Waymo LLC, USA

The parasitic inductance of a capacitor depends on its physical structure. Due to the geometry of 3-terminal capacitors, they boast a lower parasitic inductance compared to 2-terminal capacitors of the same and possibly smaller package sizes. While the parasitic inductance of a single 3-terminal capacitor may be lower, using multiple 2-terminal capacitors may result in similar performance. In this work, the inductance of 2-terminal (0201, nominal 2.2 uF) and 3-terminal (0402, nominal 4.3 uF) capacitors is extracted and compared through measurements. From our de-embedding method and characterized capacitors, the inductance of 2-terminal capacitors is only about ~20 pH higher than the characterized 3-terminal capacitor. On a power net of a real product, 3-terminal capacitors of the same type as characterized were replaced with 2-terminal capacitors of the same type as characterized. From measurement results, the measured inductance at 100 MHz is lower by only

10:30AM

Signal Integrity Comparison of Commercially Available Sockets for the 50Gbps Ethernet Channel

Nupur Basak, Oluwafemi Akinwale Intel Corporation, USA

As the demand for data center networking bandwidth proliferates, improving the test sockets available in the market is imperative. This paper looks at two commercially available sockets, the elastomer and pogo pin sockets, to investigate the feasibility of Ethernet speeds of 50 Gbps and beyond. 3D FEM (Finite Element Modeling) Ansys HFSS software, along with COM (Channel Operating Margin), is used to evaluate the performance delta between socket-less, elastomer, and pogo-pin sockets. The results show that the elastomer socket performs similarly to the socket-less case and is transparent during channel analysis despite additional components in the channel path. The pogo pin socket has only a slight performance degradation due to the resonance interaction between the pin and channel.

11:00AM

Noise Performance Comparison: ENRZ, NRZ, PAM3, and PAM4

Sherman S. Chen¹, Armin Tajalli², Brian Holden¹, Francesco de Paulis³, Bob (Pushui) Xu⁴ ¹Kandou Bus, United Kingdom; ²The University of Utah, USA; ³University of L'Aquila, Italy; ⁴Analogix Semiconductor Inc., USA

The noise performances of four line codes, i.e., Ensemble Non-Return-to-Zero (ENRZ), Non-Returnto-Zero (NRZ), Pulse Amplitude Modulation of 3-level (PAM3), and Pulse Amplitude Modulation of 4-level (PAM4) are investigated. The closedform signalto-noise ratio (SNR) formulas of the four codes are deduced. The method of injecting noise onto highspeed channels is described. Channel simulation running at 128 Gbps (for NRZ, PAM3, and PAM4) and 256 Gbps (for ENRZ) is performed and the resulting eye diagrams are compared. In addition, a brief categorization of external and internal noise types is also presented. The study shows that ENRZ and NRZ demonstrate less degradation than PAM3 and PAM4 under the influence of Gaussian thermal noise.

CONTINUED ON NEXT PAGE



11:30AM

High-Speed Differential Via Optimization using a High-Accuracy and High-Bandwidth Via Model

Chaofeng Li¹, Kevin Cai², Manish Kizhakkeveettil Mathew¹, Seyedmehdi Mousavi¹, Muqi Ouyang¹, Bidyut Sen², DongHyun Kim¹

¹*Missouri University of Science and Technology, USA;* ²*Cisco Systems, Inc., USA*

A physics-based equivalent model of the highspeed differential via pair with high accuracy and high bandwidth is proposed for the first time. The proposed physics-based equivalent circuit model of the differential via pair includes the effect of adjacent ground (GND) vias. The proposed model is verified using 3D full-wave numerical simulation results. In addition, the change in electrical performance due to change in anti-pad radius, the via pitch and the GNDvia- -to-differential-via distance is analyzed. Based on the analysis, electrical performance of differential via pair can be accurately and rapidly optimized with respect to design parameters, such as the via pitch, the anti-pad radius and the GND-via-to-differentialvia distance using the proposed model, to provide pre-layout design guide for high-speed channel designers. By using the proposed high-accuracy and high-bandwidth physics-based via model, the via optimization time can be drastically reduced with high accuracy.

1:30PM

Analysis of Mesh Ground Impact on Microstrip Lines in Flexible Printed Circuits

Yuchu He, Hanfeng Wang Google LLC, USA

Meshed ground (GND) planes are widely used in flexible printed circuit boards to reduce weight and increase flexibility. However, analyzing the impact from the meshed GND in a transmission line structure can be challenging. In this paper, an extraction method is proposed to obtain the characteristic impedance of a transmission line over the meshed GND planes. With the proposed method, a systematic study was carried out to investigate the relationship between the meshed GND plane geometric parameters and the trace characteristics.

2:00PM

Modeling of a Microstrip Line Referenced to a Meshed Return Plane

WEDNESDAY, AUGUST 2

Ze Sun¹, Jian Liu², Xiaoyan Xiong², Yuan Liu², Victor Khilkevich¹, DongHyun Kim¹, Daryl Beetner¹ ¹Missouri University of Science and Technology, USA; ²Cadence Design Systems Inc., USA

Transmission lines referenced to meshed return planes are widely used because of the physical flexibility imparted by the meshed plane. Poor accounting for the meshed ground, however, can lead to severe signal integrity and radio frequency interference issues. Full-wave simulation can characterize the electrical performance at an early design stage, but it is both time and computational resource consuming. To make the simulation more efficient, a method is proposed in this study to model transmission lines with a meshed reference ground using 2D analysis. The 2D analysis is performed at several locations along the length of the trace above the meshed return to determine per-unit-length RLGC parameters and partial selfand mutual-inductances of the trace and meshed return. The partial self-inductance of the return is then corrected to account for the current direction along the mesh. Cascading the corrected S-parameters for each segment is then used to estimate the overall characteristics of the transmission line. Results found using this approach closely match those found with 3D full-wave simulation.



WEDNESDAY, AUGUST 2

3:30PM

Simplifed Equivalent Golden Finger Port Setup for Fast and Accurate High-Speed Channel Simulation

Chaofeng Li¹, Kevin Cai², Mehdi Mousavi¹, Manish Kizhakkeveettil Mathew¹, Bidyut Sen², DongHyun Kim¹ ¹Missouri University of Science and Technology, USA; ²Cisco Systems, Inc., USA

A simplified equivalent golden finger port setup is proposed for efficient, accurate 3D full-wave simulation for high-speed channels. The bent connector pins, which mate with the golden finger, are simplified as equivalent cylindrical pins to meet the wave port setting requirements for 3D full-wave simulation. The effects of the equivalent cylindrical pin location and diameter are analyzed through 3D full-wave simulation. A closedform expression is newly proposed to correlate the location and diameter of the equivalent cylindrical pin with respect to the widely used bent connector pin. On the basis of the closed-form expression, the bent connector pin can be accurately replaced by the simplified equivalent cylindrical pin structure in 3D fullwave simulation. Practical examples using commercial high-speed connector pin models with gold fingers verify that the proposed modeling method is accurate and efficient up to 40 GHz.

4:00PM

A Comparative Study of Performance of Eigenvalue Solvers for Parallel Vector Fitting in Multiport Tabulated Data Modeling

Vinay Kukutla, Ramachandra Achar Carleton University, Canada

Modelling of high-speed modules such as electronic packages and non-uniform transmission lines based on multi-port tabulated measured or EM simulated data is becoming increasingly important in modern designs. Vector Fitting (VF) was first introduced as an algorithm for system identification via rational function approximation from tabulated data. Since the algorithm is iterative in nature, minimizing its computational cost and parallel efficiency on mixed CPU and GPU environments is critical in reducing the overall time needed for convergence. One of the expensive steps in these parallel VF approaches is computing the complex eigenvalues of thousands of small, square matrices that result from the All-Splitting method of the parallel VF algorithm. The computational expense of this step tends to vary vastly based on the solver as well as the multi-core CPU architecture used, hence it is useful to the designer to know which solver and platform to use for efficient use of the algorithm. For this purpose, a comparative performance study of the state-of-the-art eigenvalue solvers when using prominent multi-core platforms of AMD and Intel is presented in the context of parallel VF. Results demonstrate that the architecture as well as the type of solver used can significantly impact the efficiency.

4:30PM

Near-Field EMI Analysis of LPDDR5 DRAM at Idle Mode Jun-Bae Kim¹, Chang Ki Kwon¹, Taeho Kim¹, Sangwook Park¹, Yoo-Chang Sung¹, Jeong Don Ihm¹, Seung-Jun Bae¹, Jingook Kim² ¹Samsung Electronics, Korea; ²Ulsan National Institute of Science and Technology, Korea

We conducted an analysis to reduce Electro- Magnetic Interference (EMI) from mobile Dynamic Random Access Memories (DRAMs) by measuring baseline EMI radiation, specifically during idle modes of LPDDR5 DRAMs. We measured the peak H-field over LPDDR5 dies and compared it against our High Frequency Structure Simulation (HFSS). Our observation showed that the peak H-field's frequency components are well correlated with the harmonic frequency spectrum of the internal LPDDR5 Command and Address (CA) path's Common Mode (CM) currents that pass through chip power or ground Re- Distribution Lines (RDL), package power or ground layers, and Printed Circuit Board (PCB) substrate layers. Both near H-field maps of our measurement and simulation showed reasonable agreement on the peak H-field radiation mostly through the CM current's power or ground paths. This finding suggests that the other radiation through external CA signal paths can be neglected, particularly during the idle modes.

ART PRIZE

Though ArtPrize the international artist competition in Grand Rapids, MI won't be in full swing during the 2023 IEEE International Symposium, you'll still be able to enjoy many of the past entries around the city! In the meantime, check out a few incredible pieces here:

VISIT THE ART PRIZE WEBSITE

FINAL PROGRAM | <u>WWW.EMC2023.ORG</u> 69 TABLE OF CONTENTS



WEDNESDAY, AUGUST 2

WE-AM-ATE ASK THE EXPERTS SIGNAL INTEGRITY CHALLENGES OF SERDES INTERFACES 10:00 AM - 11:30 AM Exhibit Hall

Chair:

James Drewniak, Missouri S&T EMC Laboratory, Rolla, MO, USA

Bring your questions or simply listen and learn!

PLANNED PANELISTS INCLUDE:

John Golding, *Siemens* Stephen Scearce, *Cisco* Krzysztof Russa, *E3 Compliance* Tom Brady, *Analog Devices* Hanfeng Wang, *Google* Songping Wu, *Rivos*

A Serializer/Deserializer (SerDes) is a pair of functional blocks used in high speed communications that convert data between serial and parallel interfaces in each direction. SerDes provides data transmission over a single lane differential pair in order to minimize the number of I/O pins and interconnects. As data rates continue to increase toward 800G, the signal and power integrity challenges associated with SerDes design at the package and PCB levels increase, including cross-talk, inter-symbol interference (ISI), power-net noise and others. High-speed issues are not specific to SerDes design, and insight into high-speed design in general for SI will be an outcome. A brief summary of SerDes design and challenges will be given and then Q&A with the industry experts that each have many years of experience.





WEDNESDAY, AUGUST 2

WE-AM-ED1 EXPERIMENTS & DEMONSTRATIONS

DEMONSTRATING EMI GENERATION FROM BATTERY PACKS AND A FIELD CANCELLATION METHOD FOR MITIGATION 10:00 AM - 12:00 PM Exhibit Hall Exp Demo 1

Sponsored by TC-7

PRESENTERS

Yongjun (Alan) Zhang, Chenming Zhou National Institute for Occupational Safety and Health, USA

While EMI has been extensively studied for decades, it appears that EMI generation from battery packs is not well known and has not been well investigated. In this demonstration, we will show that a lithium-ion battery pack used for powering a wearable electronic device commonly used in US underground coal mines (i.e., a continuous personal dust monitoring (CPDM)) can generate strong EM emissions that interfere with other mining safety equipment, such as proximity detection systems. We will also show that the EM emissions generated by the battery pack can be effectively mitigated by a novel EMI mitigation method that is based on a field cancelation technique.

Background: The CPDM is a mandatary device for underground coal miners, according to the Mine Safety and Health Administration (MSHA) regulation (30 CFR § 7S.1732). It protects the health of the miners by monitoring a miner's dust exposure. Unfortunately, not long after the CPDM was placed in the field, it was discovered that the electromagnetic energy emitted by a CPDM interfered with another critical device, called the proximity detection system (PDS), which monitors the distance between miners and mining equipment and protects miners from being accidentally pinned or crushed by mining equipment.

After the incidents of EM interference, an investigation followed, and it was concluded that the battery was the major culprit of the EM emission of the CPDM. Several electromagnetic interference (EMI) mitigation methods were then proposed by vendors and by researchers at the National Institute for Occupational Safety and Health (NIOSH). These include, but are not limited to, a copper-mesh pouch made by Strata (the PDS vendor), shielding on the battery pack, administrative control on the miners (maintaining sixinch distance between CPDM and PDS device), and others. Each method has its pros and cons; yet none of them has addressed the issue satisfactorily. In this demonstration, we will present a new method that we discovered during our research. It can effectively address the problem. The new method is based on the concept of magnetic field cancellation. The idea is to utilize the coherent nature of the currents in battery cells and rearrange the cells in such a way that the magnetic fields produced from the cells are cancelling each other.

First, we will show that the difference of the EM emission between the stock battery and the newly designed battery when each of them is powering the circuit board of a CPDM. To isolate the EM emission of the battery from that of the circuit board, a halfmeter-long shielded cable will connect the battery to the circuit board. The circuit board is then housed in a shielded enclosure. The new battery has the same serial and parallel configuration of battery cells as the stock battery, which is 2S/SP. The new battery also has the same shape and size so that it can replace the stock battery in existing CPDM devices. The experiment uses an RE101 passive loop antenna and a spectrum analyzer to measure EM emission. The result will show that the EM emission is reduced on every side of the battery.

Then, we will install the battery pack into the CPDM device and measure EM emission from the CPDM device. It will once again reveal that the CPDM with a new battery, compared to the one with a stock battery, has less EM emission on most of the sides, especially in the area close to the battery. The new battery design has been reviewed by the CPDM manufacturer and is being considered for implementation in their future product.



WEDNESDAY, AUGUST 2

WE-AM-ED2 EXPERIMENTS & DEMONSTRATIONS

DIRECT RADAR PULSE MEASUREMENT AND OTHER APPLICATIONS OF FAST E-FIELD PROBES 10:00 AM - 12:00 PM Exhibit Hall Exp Demo 2

Sponsored by TC-2

Radar pulse measurements are usually performed in the signal chain between generator and transmitting antenna.

LUMILOOP will demonstrate direct measurement of radar pulses in the electric field, exactly at the location of a DUT. A LSProbe high-speed E·Field Probe and a LSPM RF power meter are combined to evaluate the typical 3 Qs pulses used in automotive component testing.

The demo will also feature high-speed E-Field mapping. A LSProbe E-field probe, a LSPM Powermeter and a RF signal generator are orchestrated by our PixEdust® software. PixEdust utilizes the frequency sweep capability of all these devices to iterate quickly through a frequency list. This method reduces measurement time per spatial point down to single-digit seconds. A complete IEC 61000- 4-3 17 point field uniformity evaluation can easily be performed in under one hour. We will demonstrate this live in a sma II-scale setup.

PRESENTER

Samuel Hildebrandt LUMILOOP GmbH, Germany




WEDNESDAY, AUGUST 2



EFFICIENT ANALYSIS OF ELECTRICALLY LARGE EMC PROBLEMS USING PARAMETRIZED SPHERICAL WAVE BASED MACRO MODELS 10:00 AM - 12:00 PM

Exhibit Hall Exp Demo 3

Sponsored by TC-9

Traditional full-wave electromagnetic (EM) simulation tools offer a high degree of flexibility to efficiently model EM emission, immunity, and radiated coupling for a wide range of 3D geometries in complex electromagnetic environments. However, for practical EMC problems, these full-wave solvers can be computationally intensive, particularly when analyzing complex structures in an electrically large environment, where the broadband and unintentional radiation characteristics of DUTs interactions need to be considered. To address this issue, we proposed an efficient framework that utilizes the Spherical Wave Expansion (SWE) theory. This framework decomposes the computational domain into pre-computed parameterized macro models and subsequently combines the individual results using appropriate system level simulation engines. The proposed theory offers a suitable SWE higher order mode truncation scheme that allows for the coupling of spherical modes between DUTs with high precision in both the nearfield and farfield regions, without the requirement of running a combined model. Decoupling the macro model simulations leads to significant reductions in memory/ disk requirements and overall simulations times by an order of magnitude or more in typical situations. A subset of the parametric/what-if EMC investigations especially those involving changes in orientation and separation between DUTs are extremely faster comparing to traditional methods. The performance and accuracy of the proposed method is evaulated using several examples including complex PCBs and standard antenna types commonly used in anechoic chambers.

PRESENTER

Moein Nazari Cadence Design Systems Inc., USA



WEDNESDAY, AUGUST 2



IMPACT OF A DECOUPLING CAPACITOR AND TRACE LENGTH ON SIGNAL INTEGRITY IN A CMOS INVERTER CIRCUIT 10:00 AM - 12:00 PM Exhibit Hall Exp Demo 4

Sponsored by TC-4

This demonstration shows the impact of the decoupling capacitors on the signal integrity at the VCC and GND pins in a CMOS inverter circuit. The length of the traces from the power source to the load is varied to change the loop inductance of the circuit. Waveforms at the VCC and GND pins, with respect to the source ground, with and without the decoupling capacitors are measured. The impact of the trace length and the capacitors on the power rail collapse and ground bounce is explained.

PRESENTERS

Mathew Yerian-French¹, Bogdan Adamczyk² ¹E3 Compliance, USA; ²Grand Valley State University, USA





WEDNESDAY, AUGUST 2



CONDUCTED AND RADIATED CROSSTALK BETWEEN SHIELDED CABLES, USING FAST STOCHASTIC SIMULATION 12:00 PM - 2:00 PM Exhibit Hall Exp Demo 1

Designing cables, connectors and enclosures for EMC compliance at system-level and at high frequencies is difficult, due to coupled conduction and radiation paths, shield/joint/seam leakage, connector and cable penetration uncertainties, excitation field complexity, etc. For most EMC engineers, numerically-meshed, full wave models are too large, expensive and slow to be an interactive design tool - particularly at high frequencies 1GHz and above. New, statistically reduced order models by comparison, are a more natural solution for his class of problem, applicable up to 10 Ghz and beyond.

STOCHASTICA software from RobustPhysics will be used to demonstrate how the new stochastic simulation facilitates fast, interactive EMC environment predictions - both currents on cables and coupled electric fields in reverberant enclosures - in minutes rather than days.

Combined Tutorial and Software demonstrations for three (3) different EMC design applications will be presented:

- Shielding Effectiveness Design to 10 GHz and beyond, using Fast Stochastic Simulation (TU-PM1-ED2)
- Conducted and Radiated Crosstalk between Shielded Cables, using Fast Stochastic Simulation (WE-PM1-ED1)
- Predicting Integrated System EMC Levels for Test Level Tailoring, using Fast Stochastic Simulation (WE-PM-ED4)

PRESENTERS

Weitao Dai, Reza Afra, Arielle Frank RobustPhysics, USA



WEDNESDAY, AUGUST 2

WE-PM-ED3 EXPERIMENTS & DEMONSTRATIONS

SIGNAL COMPARISON IN TIME DOMAIN AND FREQUENCY DOMAIN

12:00 PM - 2:00 PM

Exhibit Hall Exp Demo 3

Sponsored by TC-2

In this experiment, the presenter will compare the signal waveform in the time domain and frequency domain. The measurements will show the results from the Oscilloscope and Spectrum Analyzer. From the Oscilloscope, the presenter will use the time domain and FFT results and from the Spectrum analyzer, and show the frequency domain and zero span results. The Zero span feature of the spectrum analyzer enables the time domain measurements. Lastly, the presenter will compare different waveforms and the results from both Oscilloscope and Spectrum analyzer and compare the results, and in conclusion, show the advantages and disadvantages of each method and measurement facility.

PRESENTER

Reza Yazdani Missouri University of Science and Technology, USA

WE-PM1-ATE TECHNICAL COMMITTEE SHOWCASE TC7

LOW FREQUENCY EMC, POWER EMC, CONDUCTED EMISSION, TRANSPORTATION & ELECTRICAL VEHICLES, GRID 12:00 PM - 12:30 PM

Exhibit Hall AtE

Chair: Flavia Grassi, *Politecnico di Milano* **Co-Chair:** Petre-Marian Nicolae, *University of Craiova*

WE-PM2-ATE TECHNICAL COMMITTEE SHOWCASE TC8

AERONAUTICS AND SPACE EMC, AIRCRAFT, ATMOSPHERIC ENVIRONMENT, DRONES, SPACECRAFT, MISSILES 1:30 PM - 2:00 PM

Exhibit Hall AtE

Chair: Jen Dimov, *NASA* **Co-Chair:** Jim Lukash, *Lockheed Martin Space Systems*



WEDNESDAY, AUGUST 2



PREDICTING INTEGRATED SYSTEM EMC LEVELS FOR TEST LEVEL TAILORING, USING FAST STOCHASTIC SIMULATION 2:00 PM - 4:00 PM **Exhibit Hall Exp Demo 4**

Designing cables, connectors and enclosures for EMC compliance at system-level and at high frequencies is difficult, due to coupled conduction and radiation paths, shield/joint/seam leakage, connector and cable penetration uncertainties, excitation field complexity, etc. For most EMC engineers, numerically-meshed, full wave models are too large, expensive and slow to be an interactive design tool - particularly at high frequencies 1GHz and above. New, statistically reduced order models by comparison, are a more natural solution for his class of problem, applicable up to 10 Ghz and beyond.

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- Conducted and Radiated Crosstalk between Shielded Cables, using Fast Stochastic Simulation (WE-PM1-ED1)
- Predicting Integrated System EMC Levels for Test Level Tailoring, using Fast Stochastic Simulation (WE-PM-ED4)

PRESENTERS

Weitao Dai, Reza Afra, Arielle Frank RobustPhysics, USA

Photo by Patrick Andre





WEDNESDAY, AUGUST 2



POSTER SESSIONS 1:30 PM - 3:30 PM Exhibit Hall Posters

The Application of a High-Precision Spherical Calibrator to Millimeter-Wave Radar Product Production Test

Yu Tian¹, YongChang Jiao¹, Zibin Weng¹, Yunlong Luo², Jun Li³, Yihong Qi⁴

¹Xidian University, China; ²Southwest Jiaotong University, China; ³Dalian Maritime University, China; ⁴General Test Systems Inc., China

Millimeter wave (mmWave) radar has demonstrated good target monitoring capabilities in total multiple domains for its low cost and good environmental adaptability, such as smart home, health monitoring, autonomous driving, and in-vehicle applications. For these mission-critical applications, the performance of radar has become the key to the safe application of products. A widely used method for evaluating the performance of radar systems is to calibrate the antenna link pattern of radar transceivers by using calibrators. For mass production applications of mmWave wave sensors with critical performance, the use of trihedral corner reflectors as calibration objects may require a lengthy calibration process. In this paper, the spherical ball is proposed as a calibration target for radar system performance evaluation, and its scattering characteristics are analyzed. The simulation analysis and experimental test of the radar cross section (RCS) stability of different calibration objects are carried out, which proves that the scattering performance of the spherical ball reflector is more stable than that of trihedral corner reflectors stable and ensures higher calibration accuracy. In addition, using the spherical ball reflector as a calibration object can also reduce the overall size of the test system.

A Study on the Prediction Method for Electromagnetic Field Strength of Near-Field Immunity Test Jaw Won Lee, Jang Kyu Lim *HL Mando, Korea*

Recently, the exposure of automotive electronic components to electromagnetic waves in the nearfield has become a serious concern due to the rapid increase in the application of wireless communication technology in vehicles. Hence, having a good performance for near-field electromagnetic immunity becomes highly required. However, many automotive electronic components face challenges in meeting the requirements of near-field immunity tests. One of the primary reasons for this problem is the lack of robust design for electromagnetic immunity during the design phase, as the level of radiated field strength at the DUT (Device Under Test) is not known. Despite this necessity, studies on near-field strength prediction methods lack. In this paper, the test environment of near-field immunity test that the requirement highly increased recently was studied and the prediction method of field strength using simulation is proposed. The use of two designed antennas was proposed to increase the coincidence rate of the pre-prediction, and the validity was performed under various conditions that considered the real test conditions. As a result, the proposed prediction method satisfies the error rate +/-10% compared to the measurement result. Since it is possible to consider the electromagnetic field strength in the design stage, we expect that it will be possible to reduce development costs and increasing design work efficiency by strengthening the design and reducing failure cases.





WEDNESDAY, AUGUST 2

A Voltage Limiter with Lower Capacitance for Long Cable Relaxation Experiment

Yizhe Shang¹, Yanzhao Xie¹, Zetong Li¹, Ning Dong¹, Zhenghong Xu¹, Cenyue Gao², Shuang Tian³ ¹Xi'an Jiaotong University, China; ²Guodian Suqian Thermoelectricity Co., Ltd., China; ³Xi'an Thermal Power Research Institute Co., Ltd., China

In order to research relaxation in long cables and record the trailing signal under rectangular pulse, TVS diode is deployed to limit the magnitude of the measured signal. However, the large junction capacitance values of conventional transient voltage suppressor (TVS) diode can cause some serious problems like high insertion loss and waveform distortion of the trailing signal. A TVS diode based voltage limiter that features low capacitance values is proposed. Its circuit is essentially a series and parallel circuit of diodes and TVS diode. The TVS diode based protection circuits were measured under rectangular pulse with their protection effects recorded. The results show that the voltage limiter makes an effective protection of the oscilloscope and limits the degradation of signal integrity, improving the wave quality of the recording trailing signal.

Research and Application of Coverage Compensation Rapid Optimization Based on Antenna Weights

Chenxi Zhang, Feng Gao, Wentao Zhu, Fei Liu, Kankan Jin, Jinpeng Xu

China Mobile Group Design Institute Co. Ltd., China

Today, the application range of electromagnetic compatibility technology in communication network continues to expand, making the interference problems among antenna devices in the network obviously reduced, which are also the basis for these devices to achieve normal network coverage. In this paper, the antenna optimization technology and the common coverage problem in the network would be studied as the analysis object. In order to respond to the coverage invalidation problems caused by equipment shutdown or configuration errors of existing network base stations, the rapid optimization design scheme of coverage compensation based on the soft adjustment method of antenna weight parameters is proposed. The coverage compensation mechanism is mainly triggered by the base station alarm information. Based on network data and intelligence simulation technology, the coverage ranges to be compensated for the invalid base stations are identified. By calculating and determining the adjacent base stations that meet the optimization conditions and analyze the weight optimization schemes one by one, judging the coverage effect simultaneously, and then outputting the current optimal weight scheme to complete the dynamic compensation of the coverage. The actual verification shows that the optimization schemes achieved coverage compensation optimization goal of the expired base station better on the basis of keeping the original coverage indicators of the compensated base station stable. The research scheme has obvious optimization effect on the coverage invalidation problems and has the positive effect on ensuring stability of network quality.

Research and Application of 4G or 5G Antenna Beam Weight Intelligent Dynamic Optimization

Chenxi Zhang, Feng Gao, Wentao Zhu, Yuan Wu China Mobile Group Design Institute Co. Ltd., China

Currently, the common antenna weight parameter optimization strategies in wireless communication industry include manual adjustment and geometric relationship judgement of multiple cell locations. The above methods mainly apply measurement report data and antenna weight parameters. However, these methods have problems, for instance, high optimization cost, large adjustment errors and inability to identify the real user distribution, which are resulting in waste of spectrum resources. Therefore, the research paper focuses on proposing one method of antenna weight intelligent dynamic optimization base on minimization drive test data. Based on user network quality requirements, reducing base station loads. Applying artificial intelligence technology and high-precision data, identifying and aggregating user distribution grid. Simultaneously, it could solve coverage and capacity problems. In consideration of flexible weight parameter configuration capability of large scale array antenna technology, it could achieve the goal that antenna radiation directions follows the user distribution dynamically. More importantly, it is helpful to provide technical references for more refined wireless network optimization field and greatly improves network optimization efficiency.

A Broadband VHF Probe Antenna Based on Common-Mode Current Suppression

Kaibin Xue¹, Tao Ni², Ge Sun¹, Chao Zhang¹, Zibin Weng¹, Dian Liu¹

¹Xidian University, China; ²The Xi'an Research Institute of Navigation Technology, China

The low-frequency part of Square kilometer array(SKA-Low) antennas helps the radio astronomy community to explore the universe's origin further. However, due to the large volume, the radiation characteristics of SKA-Low antennas in the working environment cannot be measured by microwave anechoic chambers, which limits the further application of SKA-low antennas. To solve this problem, some scholars have successfully performed far-field calibration of radio telescopes through unmanned aerial vehicles (UAV). However, limited by the performance of existing drones and probe antennas, it is difficult to obtain the large amount of data required for near-field measurement at one time. In order to make measurements conveniently and efficiently, this article proposes a broadband probe antenna based on common-mode current suppression. By introducing a selfbalancing balun structure, the common-mode current on the coaxial feed line is suppressed ensuring the probe pattern's stability and reducing cross-polarization. Then through the impedance loading theory, the working bandwidth of the probe is further expanded. The VSWR bandwidth of the probe antenna is 158MHz-225MHz (35%), the crosspolarization is greater than 25dB, and the dimensions the maximum operating wavelength). In addition, the antenna has the advantage of a stable pattern and is nearly omnidirectional, especially in the front half space, which is positive for antenna measurement.

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WEDNESDAY, AUGUST 2



POSTER SESSIONS 1:30 PM - 3:30 PM

Exhibit Hall Posters

Research on Intelligent Circumvent Scheme for 5G Sub-beam Interference

Wentao Zhu¹, Jinpeng Xu¹, Yuan Wu¹, Chenxi Zhang¹, Rumeng Tan²

¹China Mobile Group Design Institute Co. Ltd., China; ²China Telecom Research Institute, China

The beam polling strategy is introduced in NR system by 3GPP to achieve more flexible coverage, however, it may lead to SSB interference in same frequency and time slot. To solve this problem, this paper analyzes two interference optimization schemes, sub-beam separated by mod3 and sub-beam random configure scheme, and proposes an interference circumvent scheme based on user distribution and dynamic beam configuration(UDDBC). The proposed scheme uses multiple ways to reducing the overlapping coverage probability and improving the accurate coverage rate. To evaluate beam level optimization scheme, a kind of sub-beam level simulation solution is also proposed. Simulation and actual network verification results show that the proposed UDDBC optimization scheme has certain advantages in terms of interference reduction and coverage improvement, and it is feasible and practical to promote the actual network performance.

Eliminating the Gibbs Ringing Artifact in Band-Limited Scattering Parameters

Aditya Rao, Eric Bogatin, Melinda Piket-May University of Colorado Boulder, USA

Scattering parameter capture using a Vector Network Analyzer (VNA) is a common practice to analyze and characterize physical structures. The nature of captured S-parameters is such that they are band limited and thus can lead to the presence of artifacts when viewed in the time domain. This effect is the most apparent in high-speed Time Domain Reflectometer (TDR) measurements using captured S-parameters, where an artifact known as Gibbs ringing can appear. This paper investigates underlying phenomenon which causes Gibbs ringing and details ways to avoid this artifact.

Failure Mechanisms Analysis in GaN HEMTs under High-Power Microwave Pulses

Yue Zhang, Liang Zhou Shanghai Jiao Tong University, China BEST EMC STUDENT PAPER FINALIST

The study aims at studying failure mechanisms including the thermal, inverse piezoelectric, and trap effects of GaN HEMTs under high-power microwave (HPM) pulses. Traps are generated due to the thermal and inverse piezoelectric effects under HPM injection, resulting in reduced 2DEG density and drain current decrease.

Analysis of Electromagnetic Interference Problems Caused by Split Reference Plane on High-Speed Multilayer Boards

Xin Fang¹, Chulsoon Hwang¹, Michelle Liu², Rodrigo Rodriguez Navarrete² ¹Missouri University of Science and Technology, USA; ²Tesla Inc., USA

Digital/Analog ground partitioning has been used to isolate noisy digital and power current from sensitive analog currents in high-speed multiplayer printed circuit boards. This design, however, breaks the current return path for signal traces that cross the two separated grounds, which causes undesired effects such as signal distortion and radiated emission. Electromagnetic mechanism associated with them needs to be understood to control and suppress these undesired effects. In this paper, equivalent circuit diagrams are presented to explain the current path in a practical camera device with the separated ground. Finally, optimal stitching via locations is determined to provide a good return current path and thus suppress the radiated emission. Numerical simulations are conducted for validation in frequency ranges from 10MHz to 2GHz.



WEDNESDAY, AUGUST 2

Comprehensive Optimization of Differential via Design for High-Speed Applications

Nick K.H. Huang, Jim Lai *Hewlett Packard Enterprise, USA*

The significance of signal integrity is increasingly paramount, as there exists a strong imperative to ensure high-quality signals in all components, including the smallest elements such as via design. Generally, via design on a printed circuit board (PCB) does not hold a substantial role until data rates reach 10 Gbps and beyond, especially with respect to PCIe Gen5 and Gen6, where the Nyquist frequency attains 16 GHz. To minimize undesirable noise and maintain signal integrity, it is highly critical to design via impedance and loss. In this study, we explore the impacts of drilled hole size, pad size, anti-pad size, via pitch, via length, and stub on via designs. A comprehensive optimization of each parameter is performed to evaluate the dominant effects.

Experimental Investigation of Side-Channel Information Leakage from Printed Circuit Board with Split Ground Planes

Kengo lokibe, Kohei Shimoda, Masaki Himuro, Yoshitaka Toyota

Okayama University, Japan

Side-channel attacks, which break encryption by analyzing the physical behavior leaked from cryptographic devices, have become information security threats. This paper experimentally studied a standard evaluation board for side-channel attacks, SASEBO-G, and identified the source of side-channel information leakage superimposed on the commonmode (CM) current. Regarding the source of the CM current, we examined the effects of split ground planes for cryptographic and control FPGAs and an imbalance difference between SASEBO-G and power cables. We observed CM currents flowing through the cables. The correlation power analysis was performed by changing the separation of the ground plane and the amount of mode conversion caused by the imbalance difference. As a result, the CM current and information leakage intensity varied significantly depending on the ground plane separation. The ground separation on SASEBO-G is a potential cause of side-channel information leakage superimposed on the CM current.

Impact of Different Cable Types and Positions on CISPR 15 Radiated Disturbance Measurement

Pedro Machado Neto¹, Cesar Pagan¹, Gustavo Morais², Elinaldo Reis², Fernando Araujo² ¹Universidade Estadual de Campinas, Brazil; ²Eldorado Research Institute, Brazil

This paper deals with an empirical evaluation of variables that may impact radiated emission measurement mainly for CISPR 15 lamp tests. Edition 9 of CISPR 15 brought modifications that improve reproducibility, the most notable of which are the obligation of using a coupling/decoupling network (CDN) and the reference to the CISPR 16-2-3. The practical tests in this study showed that both the use of CDN and the use of one single cable placement have an impact of up to 74% and 59%, respectively, on the results. Other possible improvements were evaluated. The use of a pre-amplifier and the turntable rotation speed had no impact at all as long as CISPR 16-2-3:2016 setup is used. Tests with cables of different section areas, even when applying the same positioning pattern, resulted in relevant differences (up to 7.26 dB and 6.92 dB at 34 MHz and 200 MHz, respectively). Further studies are currently underway to clarify how the cable acts like an antenna and how to properly consider it in future CISPR 15 versions. The results indicate that, for better reproducibility, CISPR 15 edition 9 must be adopted instead of older editions, although improvements can still be achieved by considering the impact of different cables.

Phaseless Planar Near-Far Field Transformation Based on Low-Rank Matrix Completion Method

Ge Sun¹, Tao Ni², Kaibin Xue¹, Chao Zhang¹, Zibin Weng¹, Ding Hou¹

¹Xidian University, China; ²The Xi'an Research Institute of Navigation Technology, China

With the diversified development of antenna shapes, outdoor near-field measurement technology for large antennas and electromagnetic equipment has received extensive attention. However, the required near-field scanning plane is large and time-consuming for such antennas. In addition, the positioning accuracy of sampling points decreased due to the use of mobile devices instead of near-field scanning frames. In order to solve the problems mentioned above, this paper proposes a phaseless near-far field transformation method based on low-rank matrix completion for outdoor near-field measurement. In this paper, the Square Kilometre Array (SKA) element is taken as the antenna under tested (AUT), the Ansoft HFSS and MATLAB software are used for simulation. It is found that for 50% sparse matrix and 60% sparse matrix, the relative error of electric field amplitude completion is less than 0.0334 and 0.0118, respectively. The far-field pattern of the AUT is calculated by substituting a 50% sparse matrix into the near-far field transformation method proposed in this paper. The average error between the calculated value and the simulated value of the pattern is less than 0.5684dB. It can be considered that the proposed method can realize phaseless planar near-far field transformation under sparse sampling.



WEDNESDAY, AUGUST 2



POSTER SESSIONS 1:30 PM - 3:30 PM Exhibit Hall Posters

Wireless Coexistence: Impact in the Mining Industry Ronald D. Jacksha, Robert H. Bissonette CDC NIOSH, USA

The ability of safety critical wireless systems—e.g., voice communication, proximity detection, teleremote operation, telemetry, etc.—to function satisfactorily (coexist) in the presence of other wireless systems is critical to the safety and health of mine workers. The failure of wireless systems to coexist could result in the delay, corruption, or outright loss of critical data. However, no mining-sector-specific regulations, standards, or guidelines exist to ensure the safe coexistence of wireless systems.

Improvement of TLP-HMM's Load Dependence

Masahiro Yoshida¹, Yusuke Yano¹, Takeshi Ishida², Jianqing Wang¹ ¹Nagoya Institute of Technology, Japan; ²Noise Laboratory Co.,LTD, Japan

The ESD generator and transmission line pulse – human metal model (TLP-HMM) have different output structures and are calibrated with different calibration targets. This results in that the first peak current of TLP-HMM is different from ESD generator even for the same device under test (DUT) because the reflections at the DUT are changed from the calibration. In this study, we proposed a new TLP-HMM structure to improve the TLP-HMM's load dependence.

Extracting Material Parameters for Differential Stripline Modeling

Kaisheng Hu *Ciena, Canada*

The Material parameters, such as Dk (Relative Permittivity), Df (Loss Tangent), and surface roughness, are key factors for SI modeling. However, using the parameters within vendor's datasheets can result in a significant offset between simulation and test results due to production variations. To address this issue, a simple and effective method is proposed to extract laminate parameters for differential stripline based on laboratory measurements.

Influence of Antenna Height Scan in Radiated Emission Measurement above 1 GHz

Fuminori Kanahara¹, Kunihiro Osabe¹, Hidenori Muramatsu² ¹Sony Global Manufacturing and Operations Corp., Japan; ²VCCI Council, Japan

CISPR 32 Ed. 2.1:2019 added antenna height scan in radiated emission measurements above 1 GHz. This document describes the impact of the change in measurement method.

Emissions and Immunity of Wireless Systems Installed in Underground Mines

Carl B. Sunderman, David P. Snyder, Ronald D. Jacksha CDC NIOSH, USA

It is generally accepted in the mining sector that Federal Communications Commission (FCC) rules will ensure that installed communication systems will operate interference free. However, that's not generally the case, as the FCC imposes few restrictions on the operation of wireless equipment in mines and tunnels. This paper will clarify the rules and regulations related to the operation of wireless equipment at underground mines and discuss the responsibilities and liabilities of mine operators for use of various classes of wireless equipment.

An H-Field Simulation Method to Solve Wireless Desensitization Due to the DDR Noise

Fu Luo-Larson, Amrithaa Seshadri, Akshay Mohan Amazon Lab126, USA

Most consumer electronics nowadays integrate multiradios and high-speed memory interfaces into a very compact form-factor. High speed digital noise is one of common aggressors for desensitization. In this paper, a comprehensive EM simulation workflow is used to analyze the coupling mechanism from the DDR power plane, and optimize the decoupling capacitor value and location to minimize the desense to the WiFi antenna. The concrete measurement has been done to prove the significant improvement with the mitigation.



WEDNESDAY, AUGUST 2

Application of Surface Roughness to Improve Accuracy of Harness Attenuation Estimation Ryo Watanabe, Miyuki Mizoguchi, Shinji Ohoka Soken, Inc., Japan

Model Based Development (MBD) is attracting attention in vehicle development as a method to shorten the period. Even in the case of in-vehicle communication, MBD analysis is performed to determine the communication capability between ECUs (Electronic Control Unit) connected by harness, which is reflected in the product design. As communication speeds have increased in recent years, it has become increasingly necessary to accurately estimate the amount of attenuation in harnesses, and the reduction of errors in high-frequency bands has become a problem. We propose a method for measuring surface roughness using a laser microscope , and show accuracy improvement by modeling the surface roughness.

In-Situ Qualification of Semi-rigid and Flexible RF Gaskets by Means of S-parameter Measurements Susanne Bauer¹, Christian Türk², Klaus Roppert¹ ¹Technische Universität Graz, Austria; ²Ministry of Defence of Austria, Austria

The behavior of RF gaskets changes over time due to aging and corrosion and this leads to a degradation of their shielding effectiveness. To determine the condition of the gasket, this work presents a possibility of in-situ characterization of RF gaskets based on the measurements of the scattering parameters.

Benefits of Electrically Conductive Silicone Composites as EMI Shielding Solutions

Julia Sunderland, Dan Zhao, Shuangbing Han, Kyle McDonald, Brandon Swatowski, Rosalyn Kent, Brandon Crosby, Alex Axtell, Seth Sawin, Joe Sootsman *The Dow Chemical Company, USA*

The requirements of advanced elastomeric materials for automotive, communications and consumer electronics become more demanding as devices continue to miniaturize and receive data at wider ranges of frequencies. Electrically conductive and EMI shielding silicone composites are advanced elastomeric solutions for shielding, grounding, and bonding and offer broad application temperatures, high purity, low flammability and toxicity, fast processing speed, and thermal aging stability. Tunable electric and mechanical performance of these silicones is discussed and compared to other organic resin solutions such as epoxy and polyurethanes.

Matching Network for MIPI CPHY on XR Devices

Hanqiao Zhang, Grace Yu Meta Platforms Inc., USA

The paper explores an inductive matching network to compensate for impedance discontinuities on highspeed MIPI CPHY links on XR development, prototyping and production platforms, such as the intrinsic low characteristic impedance of a Multiplexers (MUX). A 5.5 PI spiral matching network improved impedance and return loss from 30 to 450hms and at least 5 dB, respectively. The eye width and eye height also improved across different data rates. The matching network was designed with PCB area in consideration to accommodate the ultra-compact nature of XR devices. It also should not add extra cost to PCB manufacturing.



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NANOTECHNOLOGY AND ADVANCED MATERIALS 1:30 PM - 3:00 PM Gallery Overlook E

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Chair:

Emmanuel Decrossas, NASA Jet Propulsion Laboratory, Pasadena, CA, USA

1:30PM

On the Permittivity of XT-CF20

Aaron Harmon, Wei Zhang, Victor Khilkevich Missouri University of Science and Technology, USA

In this work, the permittivity of a 3D-printed carbon fiberloaded anisotropic material, XT-CF20, is examined further. The microstructure of XT-CF20 is first examined via optical imaging and is shown to be composed of inclusions that are aligned with the print direction of the sample. The permittivity tensor for the aligned microstructure is then measured using a capacitive measurement technique and simulations are provided to demonstrate the validity of this measurement method. The simulated permittivity values for XT-CF20 samples with varying infill structures are then presented and compared to the measured permittivity values of said samples. An error of less than 12% between the simulated and measured permittivity values was observed validating the measured permittivity tensor and claims about the cause of the anisotropy presented in this work. The pronounced effect of a sample's infill on the permittivity tensor of the sample is then discussed along with the conclusions of this work and possible future topics of work for the authors.

2:00PM

Thickness Optimization of 5G Graphene-Based Absorbing Textiles

A.G. D'Aloia, H.C. Bidsorkhi, M. D'Amore, M.S. Sarto Universita degli Studi di Roma La Sapienza, Italy

A new method to design graphene based absorbing textiles is proposed. These textiles consist of graphene based coatings acting as lossy layers, of textiles acting as spacers and supported by metallic layers functioning as perfect electric conductors. Polyester fabrics are selected as textiles and coatings are made of polyvinylidene fluoride (PVDF) matrices filled with different amounts of graphene nanoplatelets (GNPs). The developed method is used to evaluate the ideal thicknesses of the graphene based coatings and of the textiles. The optimal thicknesses are calculated for frequencies of 25.8 GHz and 27.9 GHz to achieve a -10 dB bandwidth that covers the 5G frequency bands between 23.8 and 40 GHz. The absorption performances of the resulting absorbing structures will be evaluated in the 5G high frequency range.

2:30PM

Solventless Electrically Conductive Silicones for EMC Applications

Dan Zhao, Shuangbing Han, Kyle McDonald, Joe Sootsman, Brandon Crosby, Scott Fleming, Dan Marple, Yanhu Wei, Tom Bekemeier, Julia Sunderland *The Dow Chemical Company, USA*

Electrically conductive silicones have been used in applications including automotives, communications, and consumer electronics. These applications are expected to significantly grow with the evolving technologies in autonomous driving, electrical vehicle, and 5G ecosystem. Here we present two novel solventless electrically conductive silicones (one silver based, one nickel-coated graphite based) with excellent conductive, shielding, and adhesive performance designed for electromagnetic compatibility (EMC) as an adhesive, a form-in-place gasket (FIPG), or a cure-in-place gasket (CIPG).



WEDNESDAY, AUGUST 2



EMC MEASUREMENTS, TECHNIQUES, TEST INSTRUMENTATION AND FACILITIES, STANDARDS AND REGULATIONS AND MEASUREMENT UNCERTAINTY 1:30 PM - 5:30 PM

Gallery Overlook F

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Chair:

Thomas Fagan, Aerospace Corporation El Segundo, CA, Vail, AZ, USA

Co-Chair:

Monrad Monsen, Oracle, Broomfield, CO, USA

1:30PM

Coaxial versus Bifilar Transmission Lines as Constituents of Transmission-Line Transformers and Baluns

James McLean TDK Corp., USA

A broad and useful class of transmission-line transformers (TLTs) is based on the series/shunt interconnection of commensurate, two-conductor transmission lines combined with integral commonmode (CM) chokes. Therefore, such a section of uniform transmission line with integral CM choke has aptly been termed a "fundamental building block" of this class of TLTs. Various transmission-line geometries for this building block can be employed provided the characteristic impedance and phase velocity of the desired mode satisfy the requirements of the design procedure. In particular, both bifilar transmission line and coaxial transmission line geometries are frequently used interchangeably. However, published analyses of this "building block" treat the bifilar geometry exclusively. We show that the characteristics of the fundamental building block when implemented with coaxial transmission line are guite different from those obtained when bifilar transmission line is employed. This has implications for many transformer, balun, and hybrid designs. Two new models are presented for the coaxial "building block": one which is appropriate when the CM structure behaves in a lumped manner and one when it behaves in a distributed manner. We show analytically the effect of the shield on TLT operation, specifically for a simple 3-port choke/current balun topology. Then, two 3-port, series-series, 1:1 baluns implemented with coaxial and bifilar media are analyzed using the model and also with a commercial finite element simulator. It is seen that little performance difference exists between the bifilar and coaxial implementations. This is shown to be due the series-series balun topology effectively employing both a coaxial delay line and an "inverted" coaxial phase inverter. The degraded performance of the latter cancels the performance gain obtained by the former.

2:00PM

Implementation of a Method for Measuring Low-Frequency Radiated Electromagnetic Emissions in the Vicinity of a Railway Rail from Passing Rolling Stock Bartlomiej Nagórny, Krzysztof Sieczkarek, Adam

Maćkowiak, Tomasz Warzyński, Michał Rokossowski, Radosław Szczepański *Lukasiewicz Research Network - Poznan Institute of*

Technology, Poland

The article presents our own software solutions for automating the measurement of emission of magnetic disturbances coming from rolling stock. The algorithm is made in LabView environment. The article presents not only the software part of the test set-up for Measuring Low-Frequency Radiated Electromagnetic Emissions coming from Passing Rolling Stock, but also the hardware part, including the dedicated measurement antennas as well as the data acquisition system.

2:30PM

Examination of the SVSWR Methods Using the Monte Carlo Method

Alexander Kriz Seibersdorf Labor GmbH. Austria

Site Voltage Standing Wave Ratio (SVSWR) based EMC test site validation methods for the frequency range 1 to 18 GHz are analyzed with the Monte Carlo method. Simulations with a simple ray tracing simulation model are performed with certain assumptions for chamber size and absorber return loss. Since none of the methods define a measurand a proposal is given which can be applied to several measurement methods. This creates a possibility to compare the different methods but leads to negative systematic errors. The magnitude of the systematic error depends on the site validation method itself. The higher the number of measurement points of a method the lower is the systematic error. Another outcome of the Monte Carlo simulation is the repeatability for each method. It can be shown that the repeatability is improved by the application of a post processing filter as proposed by the Time Domain SVSWR method. A second approach to improve the repeatability is a large number of measurement points.

CONTINUED ON NEXT PAGE



3:30PM

Noise Source Impedance Extraction Method of Switched-Mode Power Supply (SMPS) in PC according to the Frequency Range

Jaewon Rhee¹, Hyunwoong Kim¹, Kwanguk Chu², Seungyoung Ahn¹

¹Korea Advanced Institute of Science and Technology, Korea; ²Electronics and Telecommunications Research Institute, Korea

Impedance is essential information in solving electromagnetic compatibility problems. This paper proposes a method to measure the noise source impedance of a switched-mode power supply (SMPS) in a PC under operating conditions. Unlike previous research, impedance measurements at low frequencies below 1 MHz increase the received signal using the proposed dual current probe (DCP) method. In particular, unlike conventional research, this method can increase accuracy by increasing the number of wire turns without an amplifier or attenuator. Therefore, the proposed noise source impedance extraction method can be used to solve electromagnetic compatibility (EMC) problems such as electromagnetic interference filter design or to analyze the influence of external electromagnetic pulse.

4:00PM

Development of 2D Near Field Scanner for Electromagnetic Noise Visualization

Akihiro Tatsuta¹, Shinichi Tanimoto¹, Shinkuro Fujino¹, Taiga Miyai², Shota Nakamura², Satoshi Yagitani² ¹Panasonic Connect Co., Ltd., Japan; ²Kanazawa Daigaku, Japan

In the development of electronic equipment, noise source identification techniques are generally used to solve EMC problems. However, conventional noise analyzers has poor portability and the operation is complicated which moves the position of the electromagnetic (EM) field sensor two- or threedimensionally. In this paper, we developed a stacked metasurface absorber that absorbs EM waves from the 100 MHz or less to GHz-band and a compact visualization system that can intuitively sense EM waves in a two-dimensional plane in real time using the metasurface absorber. We visualized the EM noise radiated from commercial products and identified the noise sources with our developed system.

WEDNESDAY, AUGUST 2

4:30PM

The Impact of Cable Support Material on Conducted Susceptibility Test Results John G. Kraemer

Collins Aerospace, USA BEST EMC PAPER FINALIST

The material used to support cables above the ground plane during EMI compliance tests can influence test results, as well as constitute an item which can lead to differences between test and electromagnetic (EM) field simulation results. The paper shows RF Conducted Susceptibility (CS) test results, with explanations of the observed trends, associated with three common cable suspension materials. Additionally, 4-port S-parameter measurements are made on a shielded wire supported by different materials; follow-on RF CS simulation in an advanced circuit solver using the data confirms the trends seen in the EMI compliance test results. It is shown how these processed S-parameter measurements can be used to determine the effective relative permittivity of the support material as a homogenous background material to allow its proper consideration when using popular 2.5D cable effectsfocused EM field solver tools. Other factors influencing apparent test repeatability and correlation between EM field simulation and test results are also discussed.

5:00PM

Analyzing Repeatibility during Air Discharge ESD Tests

Mohit Gopalraj, Thane Sanford Analog Devices Inc., USA

Analyzing variabilities that occur during Air Discharge ESD tests is a tough ordeal. Variables such as environmental conditions, test setup, different ESD guns, ESD gun approach speeds and angles can all cause discrepancies in test results. This paper recommends a verification method to record and analyze variability involving the air discharge method prior to test. The use of a robot arm is explored as well.



WEDNESDAY, AUGUST 2



RECENT ADVANCEMENTS IN HPEM, HEMP, AND IEMI PROTECTION – A GLOBAL PERSPECTIVE 1:30 PM - 6:00 PM Gallery Overlook G

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Chair:

Tara Kellogg, ETS-Lindgren, Cedar Park, TX, USA

Co-Chair:

Chaouki Kasmi, *Technology Innovation Institute, Abu Dhabi, United Arab Emirates*

Despite the threats posed by High-Power Electromagnetic (HPEM), High-Altitude Electromagnetic Pulse (HEMP), and Intentional Electromagnetic Interference (IEMI), insufficient emphasis has been placed on the design development of HEMP/IEMI hardening solutions in order to mitigate the potential risk to "critical infrastructures". The focus on the resiliency of critical infrastructures is increasing globally with governments and industries placing more urgency on the need for protection from the effect of HPEM, HEMP, and IEMI. Even with the heightened emphasis on protecting critical infrastructures, industries continue to struggle to quantify the threat posed by HPEM, HEMP, and IEMI and to identify cost effective yet viable protection solutions.

Speakers in this tutorial will address the challenges to those industries considered "critical infrastructure", such as utilities (power, water, gas) and services (data, financial, communication). The tutorial includes an overview of filtering power and signals to harden facilities. An example will be shared of an HPEM/HEMP/IEMI grid hardening solution with a focus on overall resiliency - including the design, deployment, and cost benefit analysis. The tutorial also provides a global review by experts from industry and government, who will discuss their respective R&D activities and test methodologies. Attendees will receive a global overview on HPEM/HEMP/IEMI protection solutions currently being implemented in the United States, Europe, South America, and the Middle East.

PLANNED SPEAKERS & TOPICS

High Power Electromagnetics: Effects Detection and Classifications through System Instrumentation

C. Kasmi¹, F. Vega¹, N. Mora², J. Lopes-Esteves³ ¹Directed Energy Research Centre, United Arab Emirates; ²National University of Colombia, Colombia; ³ANSSI, France

Protection with Power/Signal Filters for HPEM Applications including the New MIL-STD-188-125-1A HEMP Requirement Sergio N. Longoria *ETS-Lindgren, USA*

Electrical Grid HPEM/HEMP/IEMI Mitigation Strategies Ryan Marietta *CenterPoint Energy Inc., USA*

Tolerance Values and Confidence Level of HEMP System Tests

Frank Sabath Bundeswehr Research Institute for Protective Technologies and NBC Protection, Germany



WE-PM-AtE

ASK THE EXPERTS

TECHNICAL PROGRAM

WEDNESDAY, AUGUST 2

CHALLENGES IN MEDICAL EMC 2:00 PM - 3:30 PM

Exhibit Hall

Chair:

Larry Banasky, Stryker Medical

Bring your questions or simply listen and learn!

PLANNED PANELISTS INCLUDE:

Matt Owen, *Stryker Instruments* Jeff Silberberg, *FDA* David Schaefer, *Element Materials Technology* Curt Sponberg, *Medtronic*

The safety of patients and caregivers is vitally important when considering the design of medical devices. Safety considerations, along with the increased use of electronics in environments of use, make medical device EMC a difficult process. This discussion will focus on the challenges in medical EMC and will include panelists with experience from different facets of the medical device world.





WEDNESDAY, AUGUST 2



COMMON MODE CURRENTS, LOOP IMPEDANCE, AND THE USE OF FERRITES 2:00 PM - 4:00 PM Exhibit Hall Exp Demo 1

Sponsored by TC-4

Understanding Common Mode Current and how it is generated is important for the control of radiated emissions. This demonstration will discuss and show how the loop impedance affects the return path of the current over frequency. There will be an explanation of the physics behind the signal path taken for the return signal. Finally, a discussion on how the use of ferrites can influence the return path of the signal, and limitations on the use of ferrites at high frequency.

PRESENTER

Patrick G. André Andre Consulting, Inc., USA



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WEDNESDAY, AUGUST 2



IMPACT OF DECOUPLING CAPACITORS AND EMBEDDED CAPACITANCE ON IMPEDANCE OF POWER AND GROUND PLANES 2:00 PM - 4:00 PM Exhibit Hall Exp Demo 2

Sponsored by TC-4

In Part I we investigate two four-layer PCBs with the power- and ground-plane pairs spaced 3 mils and 30 mils apart, respectively. The boards are populated with decoupling capacitors of the same value (InF), placed at three different distances from the measurement point.

In Part II we use the 30-mil boards and populate them with multiple capacitors of the same value, as well as with the capacitors of different values, decades apart. The location of the capacitors for all cases in this study is 1 inch away from the measurement point.

PRESENTERS

James E. Teune¹, Bogdan Adamczyk² ¹E3 Compliance , USA;²Grand Valley State University, USA

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WEDNESDAY, AUGUST 2

WE-PM2-E TECHNICAL PAPERS

EM ENVIRONMENT 3:30 PM - 5:30 PM Gallery Overlook E

Sponsored by TC-3

Co-Chair:

Karen Burnham, *Electro Magnetic Applications, Inc., Lakewood, CO, USA* Frederick Heather, *Lexington Park, MD, USA*

3:30PM

Statistics of Electromagentic Fields within Aperture-Coupled, Nested Reverberant Cavities

Marshall D. Sowell, James C. West Oklahoma State University, USA

An empirical study has been performed to measure the statistics of the fields excited within the inner cavity of overmoded, nested cavities when a small chamber is weakly coupled to a large chamber. Both the external and internal cavities were mechanically tuned during measurements. Two distributions were fit to the measured fields, the double-Rayleigh and exponential. The goodness-of-fit of each distribution was evaluated using rigorous statistical tests. The double-Rayleigh distribution gave a poor fit to the measured field statistics under all conditions considered. The exponential distribution gave a good fit at higher frequencies and with large coupling, indicating that the two chambers are acting as one resonant cavity. These results suggest that a more accurate statistical description is needed when high-precision results are required.

4:00PM

An Alternative Perspective on Time Domain Electromagnetic Field Measurement in Hospital Environment

Ridvan Aba¹, Robert Vogt-Ardatjew¹, Frank Leferink^{1,2} ¹Universiteit Twente, Netherlands; ²Thales Nederland BV, Netherlands

Electromagnetic environment characterization of complex environment such as a hospital is a challenging issue due to the dynamic characteristics like field fluctuations over time as well as space, and multiple interference sources within. This paper proposes an alternative perspective on electromagnetic environment characterization depending on E-field probe measurements. A hospital is known to be a semi-reverberant, and often undermoded environment. For this reason, in this paper, it is considered to be similar in behavior to a vibrating intrinsic reverberation chamber (VIRC), operating in undermoded region. The measurements were performed using 3-axis E-field probes at nine different locations inside a VIRC. It was aimed to characterize the environment using 3-axis E-field probe measurement results by considering the concept of ergodicity. Finally, the probability distributions were observed.

4:30PM

Electromagnetic Environment around Overhead Parallel Extra-High-Voltage Transmission Lines for UAS during Powerline Inspection

Issam Boukabou, Dulana Rupanetti, Naima Kaabouch, Landon Foust

University of North Dakota, USA

Unmanned aircraft systems (UAS) are increasingly replacing expensive crewed helicopters for powerline inspections. However, UAS can be affected by electromagnetic interference, especially when operating close to energized high-voltage infrastructure. This interference can result in safety hazards, such as collisions, equipment losses, casualties, or injuries. Despite these risks, no research has been conducted to investigate the electromagnetic fields around parallel powerlines and how they affect UAS safety missions. This paper aims to describe the magnetic fields of parallel extra-high-voltage (EHV) transmission lines in the U.S. power grid. The electromagnetic fields generated by two parallel extra-high-voltage powerlines were modeled and simulated using the Quickfield software based on the 2D finite element method. Three sets of transmission lines were investigated: 345 kV, 500 kV, and 765 kV. The results were compared with the fields generated by a single line. The results indicate that the magnetic fields are affected by the distance between the two parallel powerlines. Specifically, the presence of the second line reduced the field generated by the first line, except for the 345 kV when the UAS is circularly inspecting the powerline.

5:00PM

Method for Mapping and Analysis of Electromagnetic Background in Urban Area

Jan Nemec, Stanislav Kovar, Martin Pospisilik, Milan Adamek Univerzita Tomase Bati ve Zline Fakulta Aplikovane Informatiky, Czechia

This paper presents a method for mapping and analysis of electromagnetic background in an urban area. The uniqueness of our environment causes the inability to simulate electromagnetic fields of the real world as there is an unknown amount of sources and a near infinite amount of obstacles that could obscure the traveling wave or bounce it in a different direction altogether. The proposed method allows mapping an area of 64 hectares in less than 24 hours using only one person, antenna, softwaredefined radio, laptop, and optionally external drive to store data, which ensures the possibility of having multiple setups to multiply results. The general analysis of gathered data consists of three parts. The first is the compression ratio, a valuable byproduct of data compression for longterm storage. The second uses geographical locations to determine variance by distance, in a straight line and a cluster. The final tool for analysis is a Pearson's and Kendall's correlations to a baseline measurement to find potential errors and/or anomalies within a data set.

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THURSDAY, AUGUST 3



GETTING TO THE ROOT OF IT: TOOLS AND TECHNIQUES TO ENHANCE ROOT CAUSE ANALYSIS 8:00 AM - 12:30 PM Gallery Overlook B

Sponsored by TC-1

Chair:

Ryan Kidwiler, *American Association for* Laboratory Accreditation, Frederick, MD, USA

Co-Chair:

Megan McConnell, American Association for Laboratory Accreditation, Frederick, MD, USA

A2LA will provide a hands-on workshop and training for test laboratories, TCBs, and other organizations performing a root cause analysis. The workshop will discuss the importance of performing an in-depth root cause analysis and the role it plays in improving quality and sucess in your organization. Attendees will also learn about useful tools and techniques for performing an effective root cause analysis which can be implemented across various fields and industries. The second half of the workshop will include a hands-on activity in which attendees will breakout into smaller groups and have the opporutnity to perform their own root cause analysis using the tools and techniques provided in the training. Each group will be provided with a nonconformance and scenario for a which a root causes analysis will need to be performed. Each group will share the results of their analysis and all attendees will discuss. The workshop will end with a brief Q&A.

PLANNED SPEAKERS & TOPICS

Getting to the Root of It: Tools and Techniques to Enhance Root Cause Analysis Ryan Kidwiler, Megan McConnell A2LA, USA



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THURSDAY, AUGUST 3



HIGH POWER ELECTROMAGNETICS, ESD AND TRANSIENTS, EMP, IEMI AND LIGHTNING, GEOMAGNETIC STORM EMC 8:00 AM - 5:30 PM

Gallery Overlook D

Sponsored by TC-5

Chair:

William Radasky, *Metatech Corporation, Goleta, CA, USA*



8:00AM

Early-Time Electromagnetic Pulse Response Validation of Surge Arrester Models

Tyler Bowman, Thomas Kmieciak, Laura Biedermann Sandia National Laboratories, USA BEST EMC PAPER FINALIST

High-altitude electromagnetic pulse events are a growing concern for electric power grid vulnerability assessments and mitigation planning, and accurate modeling of surge arrester mitigations installed on the grid is necessary to predict pulse effects on existing equipment and to plan future mitigation. While some models of surge arresters at high frequency have been proposed, experimental backing for any given model has not been shown. This work examines a ZnO lightning surge arrester modeling approach previously developed for accurate prediction of nanosecond-scale pulse response. Four ZnO metaloxide varistor pucks with different sizes and voltage ratings were tested for voltage and current response on a conducted electromagnetic pulse testbed. The measured clamping response was compared to SPICE circuit models to compare the electromagnetic pulse response and validate model accuracy. Results showed good agreement between simulation results and the experimental measurements, after accounting for strav testbed inductance between 100 and 250 nH.

8:30AM

Electromagnetic Pulse Propagation Modeling and Measurements of a Termination Cabinet

Tyler Bowman, Ian Timmins, Nathan Strachen Sandia National Laboratories, USA

This work developed a methodology for transmission line modeling of cable installations to predict the propagation of conducted high altitude electromagnetic pulses in a substation or generating plant. The methodology was applied to a termination cabinet example that was modeled with SPICE transmission line elements with information from electromagnetic field modeling and with validation using experimental data. The experimental results showed reasonable agreement to the modeled propagating pulse and can be applied to other installation structures in the future.

TECHNICAL PROGRAM THURSDAY, AUGUST 3

EMC+SIPI

9:00AM

HFSS Enables the Simulation of Electromagnetic Pulses and Predicts its Effects

Shahid Ahmed

Ansys, Inc., USA We have considered a full-wave three-dimensional transient simulation of EMP propagation and interaction in real-time. Also, we have adopted a hybrid approach by combining a full-wave frequency domain simulation with the circuit where the EMP exposure has been accounted for through the scattering parameters. This hybrid approach greatly reduces the solve time and provides high-fidelity simulations of induced voltage or current across any component, which otherwise would have been difficult. Any geometry can be modeled for real-life applications, and frequency-dependent material properties can be considered. A comprehensive study illustrating various real-life case studies will be presented.

9:30AM

Wire Mesh Radiated EM Shielding Effectiveness: Time Domain Measurement and Theory Verification

Edward B. Savage, William A. Radasky Metatech Corporation, USA

It is well known that solid metal sheets provide good electromagnetic (EM) shielding effectiveness, and simple basic EM theory predicts the shielding of metal sheets. However, the same cannot be said about metal wire mesh, which is sometimes used instead for shielding. Here we cite one theory for wire mesh shielding. We then present a new time domain approach for measuring the shielding. The measurement approach has advantages over the traditional method. We then give some measurement results, and compare these with theory.

10:30AM

Reconstruction of Sound Information Leakage Signals Obtained from Multiple Demodulation Methods Taiki Kitazawa, Seiya Takano, Yuichi Hayashi Nara Institute of Science and Technology (NAIST), Japan BEST EMC PAPER AND BEST STUDENT PAPER FINALIST

Speakerphones used in remote work environments have been reported to leak audio information through electromagnetic (EM) emanations. A method to improve information reconstruction quality has been proposed by simultaneous measurement of multiple leakage channels. However, acquiring sufficient reconstruction quality is difficult when the number of observable channels is limited due to limitations of measurement resources. In this study, we propose a method to increase the number of leakage channels virtually in order to reconstruct audio information with sufficient quality, even if observable channels are limited. We assume that leaked EM waves are modulated by multiple schemes and simultaneously extract audio information from a single leakage channel by amplitude and frequency demodulation methods. Furthermore, we synthesize audio signals obtained from different demodulation methods by a phasealigned-spectrum-averaging method and indicate that the improvement in the reconstruction quality is comparable to measuring multiple leakage channels.

11:00AM

Detecting Hardware Trojans on Inter-IC Serial Data Links through Capacitance Sensors

Masahiro Kinugawa¹, Yuichi Hayashi² ¹The University of Fukuchiyama, Japan; ²Nara Institute of Science and Technology, Japan

Threats that cause electromagnetic information leakage by inserting Hardware Trojans (HT) into the signal traces around components on the printed circuit board have been reported. This threat occurs not only at the manufacturing stage but also in transit and the field, unlike HTs against ICs. This paper proposes the detection and monitoring method for the HT insertion on the inter-IC serial data link, which transmits sensitive information among the above-mentioned threats. The implementation uses only a microcontroller and does not require external analog components.

CONTINUED ON NEXT PAGE



THURSDAY, AUGUST 3

11:30AM

Fundamental Study on the Effect of the Duty Ratio of Clock Signal on Side-Channel Leakage

Daisuke Fujimoto, Shinpei Wada, Yuichi Hayashi Nara Institute of Science and Technology, Japan

In this paper, we firstly evaluate the effect of power supply noise due to clock signal on information acquisition to accurately acquire side-channel information from the cryptographic devices that radiates in the same frequency band as the clock signal. The result shows that the leakage evaluation result changes according to the duty cycle of the clock signal.

12:00PM

Enhanced Modulation Degree of Leakage Wave Induced by IEMI via Nonlinear Circuit Elements

Shugo Kaji, Daisuke Fujimoto, Yuichi Hayashi Nara Institute of Science and Technology (NAIST), Japan

This paper proposes a method to improve the modulation degree of the leakage wave in the threat of electromagnetic information leakage induced by intentional electromagnetic interference. Since the leakage wave from the target device occurs with the same frequency as the continuous wave (CW), the modulation degree of the leakage wave is decreased. This paper shows that the propagation of two CWs to nonlinear circuit elements inside the device causes frequency conversion, generating the leakage wave with a frequency different from the injected CWs. This method prevents degradation in the accuracy of information extracted caused by decreased modulation degree of the leakage wave.

2:00PM

Coupling Path Analysis for Smart Speaker Intentional Electromagnetic Interference Attacks

Tanner Fokkens, Shengxuan Xia, Aaron Harmon, Chulsoon Hwang

Missouri University of Science and Technology, USA

This paper shows an improved understanding of the coupling path for intentional electromagnetic interference (IEMI) attacks on smart speaker devices. This includes a method for finding the ideal attack angle and locating the region sensitive to the coupled EMI. In previous works, it was shown to be possible to send RF commands to a smart speaker and have these commands be interpreted as voice commands by the microphone. However, the attack still had some limited understanding in terms of the coupling path location and long-distance attack potential. Using the improved understanding of the attack, a longer attack distance is achieved (6 meters) with only 6.5 Watts of power.

2:30PM

Towards HPEM Pulse Characterization by Nonlinearly Loaded Narrowband Antenna Arrays

Robert Michels¹, Sven Fisahn², Martin Schaarschmidt², Frank Gronwald¹

¹University of Siegen, Germany; ²Bundeswehr Research Institute for Protective Technologies and CBRN Protection, Germany

In this contribution the general idea of both detecting and characterizing short high power electromagnetic pulses by means of nonlinearly loaded narrowband antenna arrays is presented. To this end, aspects of electromagnetic pulse response of nonlinearly loaded antennas are reviewed first. It is pointed out that short high power electromagnetic pulses can generate a rather long lasting dc voltage at a nonlinearly loaded antenna terminal which depends both on the pulse characteristics and the antenna itself. The corresponding dependencies are nontrivial and analyzed by means of numerical simulation methods. Results are shown which indicate the feasibility of obtaining electromagnetic pulse characteristics from multiple dc voltages which are recorded by multiple antennas that form a receiving antenna array.

3:00PM

Design and Construction of an Arbitrary Pulse Compressive Amplifier

Cody Goins, Aaron Harmon, Victor Khilkevich, Daryl Beetner

Missouri University of Science and Technology, USA

Compressive pulse amplifiers are a class of amplifiers that convert long low amplitude signals into very broadband pulses of high amplitude, yielding a very high instantaneous peak power output pulse. However, in the realm of electronic immunity and susceptibility testing, very broadband short pulses are not always desired. This work presents a design for a compressive amplifier that is aimed at creating arbitrary pulsed signals of varying bandwidths. Limitations of the achievable gain and methods used are discussed.



THURSDAY, AUGUST 3

4:00PM

ESD Behavior of RF Switches and Importance of System Efficient ESD Design

Seyed Mostafa Mousavi¹, Emil Tauber², Amin Pak2, David Pommerenke², Daryl Beetner¹, Ketan Shringarpure², Benjamin Lee³, Warwick Ka Kui Wong² ¹Missouri University of Science and Technology, USA; ²Technische Universität Graz, Austria; ³Google LLC, USA; ⁴Google LLC, Taiwan

RF switches are typically used in the RF front-end of portable devices such as antenna or matching tuners to improve the RF link performance. They are usually the first active devices after the antenna and are vulnerable to primary or secondary ESD discharges to the antennas. This paper investigates the ESD behavior of one of the high frequency switches used in the RF-frontend of portable devices and expresses the importance of the ESD pulse that passes through the switch and reaches the next stage in the RF path, possibly damaging the next stage.

4:30PM

Characterization and Modeling of Sparkless Discharge to a Touch Screen Display

Jianchi Zhou¹, Cheung-Wei Lam¹, Zhekun Peng², Daryl Beetner², David Pommerenke³ ¹Apple Inc., USA; ²Missouri University of Science and Technology, USA; ²Technische Universität Graz, Austria

Although corona discharge to a touchscreen display is not associated with the spark, it could cause soft and hard failures due to electromagnetic coupling to sensitive electronics beneath the glass. Experimental data were obtained to characterize these sparkless discharges and an equivalent circuit model was constructed to predict the resulting coupling to touchscreen electronics. Measurements and simulation indicate that a thinner glass and a higher touchscreen indium-tin-oxide (ITO) sense trace impedance both lead to higher ESD risk by delivering higher energy into the sensing IC. A CST co-simulation model is proposed and is shown to model the displacement current accurately. Charge movement and dissipation on the glass surface is represented using a disk with conductivity proportional to the reciprocal of radial distance. Dust figure measurements were used to study the effects of the glass type, glass thickness and voltage level on the corona discharge and the current coupled to the touchscreen patch on the display. These results can be used to drive full wave co-simulation models which try to anticipate the impact of sparkless discharges on the touchscreen electronics.

5:00PM

Numerical Modeling and Finite Element Analysis of Metamaterial-Based Wireless Power Transfer

Webster O. Adepoju¹, Indranil Bhattacharya¹, Olufunke Mary Sanyaolu³, Ismail Fidan¹, Ranger Buchanan¹ ¹Tennessee Technological University, USA; ²GasFleet Engineering Limited, Nigeria

This paper presents an equivalent circuit model to emulate the behavior of a Metamaterial (MM)-based Wireless Power Transfer (WPT) system. For this purpose, the electromagnetic finite element simulation of the proposed system is conducted in ANSYS High Frequency Structure Simulator (HFSS). In addition, the numerical analysis of the proposed structure is explored to evaluate the system transfer characteristics. The power transfer efficiency of the proposed structure is represented by the transmission scattering parameter (transmission and reflection coefficients). While some methods, including interference theory and effective medium theory, have been exploited to explain the physics mechanism of MM-based WPT systems, some of the reactive parameters and the basic physical interpretation have not been clearly expounded. In contrast to the existing theoretical model, the proposed approach focuses on the effect of the system parameters and transfer coils on the system transfer characteristics coupled with its effectiveness in analyzing complex circuits. A numerical solution of the system transfer characteristics, including the scattering parameter, and power transfer efficiency, is performed in a Matlab simulation environment. The calculation results based on numerical estimation validate the fullwave electromagnetic simulation results, effectively verifying the accuracy of the analytical model



THURSDAY, AUGUST 3



POWER ELECTRONICS EMC, POWER CONVERSION, AUTOMOTIVE, AEROSPACE, MEDICAL, CONSUMER ELECTRONICS 8:00 AM - 5:30 PM

Gallery Overlook E

Sponsored by SC-5

AM Session Chair: Chulsoon Hwang AM Session Co-Chair: Cong Li

PM Session Chair: Shuo Wang PM Session Co-Chair: Dehong Liu

8:00AM

Investigation of Common-Mode EMI in Three-Phase Split-Phase Inverter

Abdul Basit Mirza, Abdul Muneeb, Sama Salehi Vala, Fang Luo Stony Brook University, USA BEST EMC PAPER FINALIST

Compared with the traditional two-level (2L) inverter, two-level Split-Phase topology (2L-SP) provides better cross-talk immunity without deadtime between the top and bottom devices. From the Common Mode (CM) EMI perspective, split inductors in 2L-SP tend to increase the CM noise path impedance and decrease the dV/ dt across the device during the switching transition due to the interaction between split inductors and the semiconductor device's parasitic capacitance. This phenomenon, in turn, reduces the dV/dt of the CM voltage, making 2L-SP topology a promising candidate with lower CM emission for Wide Band Gap (WBG) devices-based 2L inverters, switching at high frequency. However, the CM EMI of 2L-SP and its comparison with 2L have yet to be analyzed comprehensively. This paper investigates conducted CM EMI emission of a SiC-based 2L-SP three-phase inverter with SPWM. At first, the derivation of the CM equivalent circuit model through frequency domain analysis is presented. This is followed by a comparative study of CM emission of 2L-SP three-phase inverter on a hardware prototype for different values of split inductance. The results show that increasing split-inductance significantly lowers the CM magnitude with a maximum reduction of 17.85 dB.



TECHNICAL PROGRAM THURSDAY, AUGUST 3

EMC+SIPI

8:30AM

Simulation-Based Approach for Boost Converter Using Black-Box Modelling for System Level EMC Analysis

Adish Kaushal^{1,2}, Suraj R. Rao², A. Devi², Joe Sivaswamy², D. Gope², Shanthi P¹

¹Simyog Technology Pvt. Limited, India; ²R.V. College of Engineering, India; ³Simyog Technology Pvt. Ltd., India

With the development of faster and denser electronic networks in today's automotive industry, EMC Compliance tests have become more stringent. Therefore, it is proving to be difficult to predict and mitigate these System-level emissions. Hence, frontloading is an excellent approach to analyzing and monitoring the EMI/ EMC performance from the design stage (Pre-prototype) to the verification stage (post-Prototype), allowing a cost-effective resolution of any upstream issues. A major pain point faced by EMC engineers is the lack of accurate models for Integrated Circuits, currently IBIS models and SPICE simulations are being taken to model the ICs behavior which are not useful at higher frequency ranges. Therefore, the motivation of this work is to develop a DC-DC Boost converter IC model using the Nonlinear IC-Emission Modelling method and to analyze different EMI mitigation methods to reduce the PCB emissions during the design phase. The proposed model is implemented on the DUT with the Boost converter IC fabricated on the PCB. The System-level- simulation using the ICEM model is validated with measurement.

9:00AM

Using Full Wave 3D Simulation to Evaluate Buck SMPS EMC Emissions

Patrick DeRoy¹, Anisha Dok¹, Hemanthchender Sreeperumbudur², Nicklas Koeller³, Alexander Pearson³, Scott Mee³, Bogdan Adamczyk⁴

¹Analog Devices Inc., USA; ²Analog Devices India Private Limtied, India; ³E3 Compliance, USA; ⁴Grand Valley State University, USA

This paper demonstrates the use of 3D electromagnetic (EMC) modeling to simulate the conducted emissions of a switched-mode power supply (SMPS). The simulations are performed using CST Studio Suite from Dassault Systemes and measurements of a fully functional SMPS converter are performed according to CISPR25 (an automotive test specification). The simulations are compared to the measurements and demonstrate a reasonable level of correlation. Several SMPS design modifications are evaluated using simulation and compared to measurements. The benefits of using simulation early in the development process to help prevent EMC failures is highlighted.

9:30am

Reduction of CM Conducted Emission with a Small Dummy Leg and the Delay Compensation Technique Erica Raviola¹, MIchele Roman², Luca Zai², Franco Fiori¹ ¹Politecnico di Torino, Italy; ²Eldor Corporation S.p.A., Italy

Passive EMI filters are usually placed at the input of power circuits to attenuate the conducted emission delivered. However, their volume may not be negligible, especially when targeting power automotive applications. The output delay compensation technique may or may not reduce the CM conducted EMI at low frequency, as a fine alignment of the output voltage phases should be achieved. This paper aims at improving the already proposed technique by exploiting a small dummy leg. In such a way, switching losses and cost of the auxiliary circuit required to implement the delay compensation technique can be reduced. From the circuit analysis, it was found that the small dummy leg can achieve a 40 dB CM EMI reduction up to 5 MHz, with one seventh the switching losses of a traditional auxiliary leg.

10:30AM

Susceptibility to Radio Frequency Interference of eGaN Power Switching Legs Franco Fiori

Politecnico di Torino, Italy

Power switching circuits like those used in inverters and DC-DC converters are usually investigated with the purpose of increasing the power efficiency or lowering the electromagnetic emissions. Considered that, the reliability of such modules is also a key aspect, especially in safety critical applications, this work focuses on the susceptibility of such circuits to radio frequency interference. To this purpose, an e-mode GaN power switching leg in a real application environment is considered. A circuit comprising the nominal active and passive components, their stray inductances and capacitances as well as those due to the PCB wiring is presented. The effect of radio frequency interference injected into the output terminal by means of a bulk current injection clamp is analyzed with the purpose of evaluating the risk that such interference propagated through the circuit could induce temporary or permanent failures.

CONTINUED ON NEXT PAGE



THURSDAY, AUGUST 3

11:00AM

Analytical Approach of the High Susceptibility Frequencies of a Battery Management System during Direct Power Injection. Methods of Improvement. Badr Guendouz¹, Kamel Abouda¹, Alexandre Boyer², Sonia Ben Dhia², Olivier Tico¹, Jeremy Ruau¹ ¹NXP Semiconductors, France; ²Laboratoire d'Analyse et d'Architecture des Systemes du CNRS, France

When it comes to the electromagnetic interference (EMI) immunity of a Battery Management System Integrated Circuit (BMS IC), Printed Circuit Board (PCB) traces and external components (ECs) arrangement define the high susceptibility frequencies (HSF) of the IC during Direct Power Injection (DPI) tests. This work first aims at defining the root causes of those HSF in a realistic and measurement correlated environment, then, formulating them in order to provide a realistic prediction in the early design stages. Moreover, the configuration of the ECs raises a crucial tradeoff between the overall price of the system and the immunity of the IC. This work, then, also aims at analyzing this tradeoff and proposing alternative configurations of the ECs that reduce the overall price but also lead to lower injection levels during DPI.

11:30AM

Reactive Shielding Method for Wireless Power Transfer Systems with High Power Transfer Efficiency Using Frequency Split Phenomena

Changmin Lee¹, Seongho Woo¹, Yujun Shin², Jaewon Rhee¹, Seungyoung Ahn¹

¹Korea Advanced Institute of Science and Technology, Korea; ²Keimyung University, Korea

BEST EMC PAPER FINALIST

EMI reduction could be achieved using the method suggested by the wireless power transmission system. Leakage magnetic fields occur in the process of transmitting power wirelessly from the transmitter part to the receiver part. This leakage magnetic field negatively affects the human body or other electronic devices. The previous reactive shielding method could reduce the leakage magnetic field, but it had the disadvantage of reducing the power transfer efficiency (PTE). Using frequency split phenomena from the overcoupling, the reactive shielding method can reduce the EMI components with high PTE WPT system. In this paper, a reactive shielding method that can reduce the magnetic field while increasing PTE is proposed. In addition, a method for calculating a coupling coefficient for designing a structure in which magnetic field reduction can be maximized is also proposed. The theoretical analysis based on each part's impedance strongly correlates with the measurement results. As a result of the experiment, the PTE is increased by about 3.9%, and EMI components at odd harmonic frequency can be reduced by up to 8.85 dB in a 20 W-WPT system. Also, the proposed method can be applied when the other WPT system to be shielded is determined.

12:00PM

Review on Modeling and Emissions from EMI Filters in Power Electronics: Inductors

Yanwen Lai, Shuo Wang, Yirui Yang, Qinghui Huang, Zhedong Ma *University of Florida, USA*

The issue of electromagnetic interference (EMI) is a critical and complex matter in power electronics. In the current landscape of rapidly evolving power electronics applications, high switching frequencies are widely adopted to reduce the size of devices and components, increase power density, and improve overall efficiency. Magnetic components, such as inductors, play vital roles in power converters and EMI filters. Consequently, many researchers have focused on studying inductors in EMI filters to enhance equipment performance. Building upon existing research, this paper will begin by presenting the fundamental inductor model and various methods for optimizing inductor design. Subsequently, the impact of inductors on conducted EMI in converters will be discussed. Lastly, this paper will introduce the radiation model of inductors, including near magnetic field and near electric field radiation.

2:00PM

Analysis and Modeling of the Near Magnetic Field Distribution of Toroidal Inductors

Yirui Yang, Qinghui Huang, Yanwen Lai, Zhedong Ma, Yimeng Liu, Shuo Wang *University of Florida, USA*

The near magnetic field produced by magnetic components may compromise the performance of nearby devices. This paper analyzed the near magnetic field distribution around toroidal inductors. The mechanism of the field's origination was studied in this article and modeled with the combination of magnetic dipoles and quadrupoles with clear physical meaning. Intuitive conclusions were drawn from the model and verified by simulation and experiments.



THURSDAY, AUGUST 3

2:30PM

dV/Dt Impact on Turn-to-Turn Overvoltage Distribution in Motor Windings

Yalda Azadeh¹, Abdul Basit Mirza¹, Kushan Choksi¹, Xiaolong Zhang², Fang Luo¹, Kiruba S. Haran² ¹Stony Brook University, USA; ²University of Illinois Urbana-Champaign, USA

Cable connected motor winding insulation is prone to failures owing to standing wave overvoltages (OV), caused by switching transition dV/dt. Standing wave is impacted by the motor drive system differential mode and common mode impedance interactions, as well as excitation frequency dV/dt. Winding and cable impedance create a complex combination of resonances and antiresonances. Wide band gap power electronics generate high dV/dt that exacerbates the OV phenomenon. According to the literature, the overvoltage across the motor winding is not distributed evenly between the turns. First turns are reported to be under higher overvoltage where OV is lower and more similar for the subsequent turns. However, in this paper with the accurate HF modeling of the motor drive system, the overvoltage distribution across the turnto-turn (TT) of the motor winding for different dV/dt is investigated. It is proved that the voltage distribution trend does not remain constant. First, it is due to the different resonances across different TT in an unsymmetric network of drive system. Second, according to the trapezoidal waveform, different dV/ dt excitation introduces different bandwidth of the secondary harmonics contributed to the OVs. So, not always the first turn is under highest voltage. Not clear understanding of the OVs could cause insulation overdesign for the first turns or easier degradation of the lateral turns. In this regard, this paper gives a guideline to study the system in regards of impedance interactions with excitation dV/dt in the WBG applications. Therefore, based on this study the appropriate insulation or filtering design to alleviate the OVs can be decided. The ground truth experimental validation for high frequency modeling of the system under test is provided.

3:00PM

Measurement, Analyses and Discussion on Noise Induced on Gate Driver Logic Signal Traces in Medium Voltage SiC-based Power Converters He Song, Dushan Boroyevich

Virginia Polytechnic Institute and State University, USA

The fast-switching speed of the silicon-carbide (SiC) devices, along with the needs for higher power, higher voltage, and higher power density, gives rise to more salient EMI challenges. Unlike the converter-level noise emissions, the noise inside the power converter (such as that on gate drivers) has no standard to follow, however, the gate driver is prone to be false triggered by the noise. Based on the noise propagation model proposed in the prior study, this paper shows more detailed noise measurements and quantitative analysis for the noise propagation between the PCB grounds and logic signal traces on gate driver PCB, and reveals more influential factors of the noise propagation. Several practical approaches to ensure measurement fidelity are adopted, and noise measurement and analyses under more practical test conditions are conducted and discussed to provide general design guidelines. The methodology is further expanded to be more generic by including other di/dt sources inside a power converter.

4:00PM

Multi-Objective Design of Filter Installed in Brush Motor by Artificial Neural Network Accounting for Cable Length

Shohei Kan, Norikazu Takahashi, Masaki Himuro, Akito Mashino, Kengo lokibe, Yoshitaka Toyota *Okayama University, Japan*

In the design process of automotive products, it is often necessary to find solutions that simultaneously satisfy multi-objective performance goals, which can sometimes include requirements that conflict. Such redundant solutions are expected to cover a wider feasible range of design parameters and meet an assortment of different lead time and price goals. In this work, we apply an artificial neural network (ANN)based machine learning algorithm to determine the cable length and design ranges of an EMI filter for an automotive-brush-motor system. We were able to find at least three interval solutions that satisfy the performance requirements, including a single interval solution obtained by our previous approach using Preference Set-based Design.



THURSDAY, AUGUST 3



EMC MEASUREMENTS, TECHNIQUES, TEST INSTRUMENTATION AND FACILITIES, STANDARDS AND REGULATIONS AND MEASUREMENT UNCERTAINTY 8:00 AM - 5:30 PM

Gallery Overlook F

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Thomas Fagan, Aerospace Corporation El Segundo, CA, Vail, AZ, USA

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Sarah Seguin, *Resonant Frequency, Maple Grove, MN, USA*

8:30AM

Accurate Measurement and Control Sytem for RF Broadband Power Amplifier

Maxime Schutz¹, Jean-David Bertaux¹, Ludovic Bacqué² ¹INOVEOS, France; ²Prâna Recherche et Développement, France

A new measurement system has been developed for broadband RF power amplifiers dedicated to EMC applications. The system allows the power output of the amplifier to be measured while correcting the variations of broadband coupler's frequency response. This is achieved by measuring, simultaneously, the power and the frequency of the RF signal. These measurements are made using a developed broadband RF frequency meter and a power detector. Tests are presented and carried out using industrial amplifiers to evaluate the proposed solution. Measuring the RF signal frequency passing through the amplifier is an additional information that allows more accurate power level measurement and improves the monitoring of the amplifier.

9:00AM

Joint Radio-Frequency Transmission and DC Resistance Measurements of a T-slot Interlocking Metasurface

Jon W. Wallace, Jeffrey A. Osterberg, Benjamin Young, Philip J. Noell, Brad L. Boyce Sandia National Laboratories, USA BEST EMC PAPER FINALIST

Simultaneous DC resistance and radio-frequency (RF) transmission measurement of interlocking metasurfaces (ILMs) is proposed to characterize ILM shielding properties and gauge the level of ILM contact present in an RF fixture. This joint information is useful to determine whether the in-fixture results are representative of RF properties that would be present in practice. Future RF modeling work could also benefit from having correlated DC resistance and RF properties. The method is demonstrated for a T-slot ILM, where transmission is measured in a WR-340 fixture in the 2 to 3.7-GHz range. The results show that the technique is valuable for identifying cases where the RF properties measured in an RF fixture may not be representative of the properties of a free sample or a sample subject to external forces. An experiment with many ILM mating cycles suggests that wear of the ILM features can degrade shielding performance dramatically, indicating a need for low-wear ILMs and practices that minimize wear.

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THURSDAY, AUGUST 3

9:30AM

Analysis on Extraction of Potential Radiated Emission Limit Line for Data Center Equipment from 10 GHz to 40 GHz

Zhekun Peng¹, Wei Zhang¹, Jong-Hwa Kwon², DongHyun Kim¹ ¹Missouri University of Science and Technology, USA; ²Electronics and Telecommunications Research Institute, Korea

The radiated emission (RE) potential limit line for router system is analyzed from 10 GHz to 40 GHz based on CISPR TR 16-4-4 standard. Statistical data is collected for the limit line extraction from measurement, numerical analysis, 3D full-wave simulation and literature studies. All the factors considered in limit line calculation are analyzed for data center equipment operation. The result of extracted potential limit line shows the rising limit line between 10 GHz and 40 GHz frequency band for potential future radiated emission limit line above 40 GHz targeted for highspeed equipment radiated emission. This paper is not a standard document, but provides insight to the trend for future limit lines above 40GHz.

10:30AM

Analysis on the Effect of Averaging Duration on Radio Frequency Dosimetry in Residential Environments

Reza Asadi¹, Hadi Aliakbarian², Amir Sahraei², Reza Yazdani¹, DongHyun Kim¹ ¹Missouri University of Science and Technology, USA;

²KN Toosi University of Technology, Iran

The potential hazards of electromagnetic waves have raised concerns in related authorities to propose standards and limit lines on the electromagnetic field levels. Most of the radio frequency (RF) dosimetry measurement procedures referred to in safety compliance standards, suggest 6-minute averaging, in addition to spatial averaging, which can be timeconsuming for primilary measurements. Measurement analysis in residential environment in this paper demonstrates that lowering the time interval of measurements to about 30 seconds, which suggests the possibility of reducing the measurement time with minimal reduction to measurement accuracy. For all measurement results shown in this paper, having a 30-second averaging time, the relative error, compared to 6-minute averaging and spatial averaging, is less than 5% for radio frequency (RF) level in the environment. This paper provides a potential solution to precompliance RF dosimetry process with less required time and cost.

11:00AM

A Real-Time Microwave Camera Prototype with Zero-Bias Diode Detectors for EMI Source Imaging

Xin Yan, Liang Liu, Victor Khilkevich Missouri University of Science and Technology, USA BEST EMC PAPER FINALIST

Emission source microscopy (ESM) could be utilized to localize the Electromagnetic Interference (EMI) sources that contribute to the far-field radiation. In those cases, the electrical field over a two-dimensional plane is collected by mechanical scanning, resulting in a long measurement time and the presence of mechanical errors. In this work, a microwave camera based on a two-dimensional array of elliptical slot antennas and diode detectors is presented. Multiplexers are utilized to access the output of each detector and the scanning of the whole array could be done multiple times per second.

11:30AM

Issues on AC Mains Cable Termination by CMAD Kunihiro Osabe¹, Nobuo Kuwabara², Hidenori Muramatsu¹

¹VCCI Council, Japan; ²VCCI Council, Japan; ³Kyushu Institute of Technology, Japan

A common mode absorption device (CMAD) is listed in CISPR16-1-4 for use in terminating the mains cable of equipment under test (EUT) to improve measurement reproducibility in radiated disturbance tests. However, there are several issues in the termination of CMAD, such as differences in terminating impedance from that in real-world conditions, the need to maximize disturbance levels, and invalidation of CMAD characteristics due to cable type. This paper addresses these issues and suggests specifying termination impedance using a Very High-Frequency line impedance stabilization network (VHF-LISN) as a termination device for AC mains cable in lieu of CMAD.

12:00PM

Effects and Usage of Isolated Probes for Balanced Differential Measurement in RF Immunity Testing

Md Kamruzzaman Shuvo¹, Patrick DeRoy¹, Pete Sealey², Abhishek Ramanujan³, William Dixon⁴ ¹Analog Devices Inc., USA; ²Analog Devices Ltd., UK; ³Analog Devices International, Ireland; ⁴Tektronix Inc., USA

This paper examines the use of a galvanically isolated probe with high CMRR for measurements of differential noise in the presence of external RF noise injection during the RF conducted immunity (BCI) test. The probe is investigated in detail to understand the effects of its asymmetries, and a workaround for maintaining measurement integrity is presented.

CONTINUED ON NEXT PAGE



THURSDAY, AUGUST 3

2:00PM

Wall Shaking Amplitude Effects on Vibrating Intrinsic Reverberation Chamber Characteristics

Makoto Hara^{1,2}, Jianqing Wang¹, Frank Leferink³ ¹Nagoya Institute of Technology, Japan; ²Kawasaki Heavy Industries, Ltd., Japan; ³University of Twente, Netherlands

The vibrating intrinsic reverberation chamber characteristics, such as goodness-of-fit to Rayleigh distribution and spatial field uniformity, have been investigated by measurements according to the wall shaking amplitude as stirring conditions. The measurement results contribute to derive a guideline for VIRC design for the practical applications.

2:30PM

Using Modeling and Simulation to Enhance E3 Test Validity

Rajendra Khadka¹, Marsellas Waller¹, Lloyd Riggs¹, Steve Wong²

¹US Army Redstone Test Center, USA;²AFRL/RCM, Wright-Patterson AFB, USA

In implementing electromagnetic vulnerability (EMV) testing on operational manned and unmanned air and ground vehicles fielding a variety of avionics and communication systems, the test as spelled out in MIL-STD-464D [1] and ADS-37A-PRF [2] requires test labs to operate the high-power source amplifiers/antennas very near the test item to reach required peak and RMS test levels for Electromagnetic Environmental Effects (E3) testing. Questions naturally arise concerning the efficacy of such testing with respect to both the manner of coupling of the fields to the electronics system of the air or ground vehicle as well as the levels required to achieve reasonable confidence in the coupling effect.

3:00PM

Investigation of Reducing Test System Dependence for Automotive Ethernet EMC Evaluation

Yusuke Yano, Hideki Iwasaki, Jianqing Wang Nagoya Institute of Technology, Japan

To reduce test system dependence in the electromagnetic compatibility test of automotive Ethernet, we experimentally investigated the CM (common mode) termination impedance matching. The resistance of CM termination on a board, which simply emulates communication equipment, was changed to match the CM characteristic impedance of a cable, and the matching condition was evaluated by S-parameter. The result shows that good matching can be obtained at frequencies below 3 MHz. It is also found that a mismatch occurs at frequencies above 3 MHz due to parasitic capacitance around a UTP connector on the board.

4:00PM

Power Amplifiers Harmonic Emission Measurement Comparison Using RE103 and CE106 Methods

Islem Yahi, Edrees Almansoori, David Martinez, Chaouki Kasmi, Felix Vega

Technology Innovation Institute, United Arab Emirates

This paper presents the experimental analysis of the harmonic levels of a power amplifier system, the measurement is based on the two methods described in the MIL-STD-461, the CE106 conducted emissions and the RE103 radiated emissions methods. The objective is to make multiple analyses, mainly on the comparability of the two measurement methods results, but also the impact of the antennas, the modulation, or the performance related to the amplifier topology on the harmonics content level.



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THURSDAY, AUGUST 3

TH-AM-G TECHNICAL PAPERS

LOW FREQUENCY EMC, POWER EMC, CONDUCTED EMISSION, TRANSPORTATION AND ELECTRICAL VEHICLES, GRID 8:00 AM - 12:30 PM

Gallery Overlook G

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Flavia Grassi, *Politecnico di Milano, Milano, Italy* **Co-Chairs:**

Petre-Marian Nicolae, University of Craiova, Craiova, Romania

8:30AM

Analysis of LF Disturbances and Immunity Improvement Techniques for Automotive Distance Ranging Sensors

Raffi Kalayciyan, Michael Kunz, Harry Litz, Özkan Palabiyik, Bastian Hafner, Philipp Maurer, Frédéric Boyron

Valeo Schalter und Sensoren GmbH, Germany

This paper presents improvement potentials and noise mitigation techniques at the use case of ultrasonic distance ranging sensors for automotive applications. The key element of the product development for improved immunity behavior against noise sources in the low frequency band of below 200 kHz was the fusion of chip level noise quantification using system plausibility check features with the electromagnetic compatibility design optimization of electromechanical sub-components. For this purpose, empirical and 3D simulation data are generated and analyzed. In addition, radiated immunity measurement methods are presented for the final component evaluation of the low frequency electric and magnetic immunity performance below 200 kHz.

9:00AM

Common Mode Current Estimation for Filter Design for Non-ideal Back EMF of a PMSM

Patrick Koch1, Niek Moonen1, Frank Leferink1,2 1Universiteit Twente, Netherlands; 2Thales Nederland BV, Netherlands

This paper describes different modeling steps to estimate Common Mode (CM) currents with a Permanent Magnet Synchronous Machine (PMSM) as load, dependent on the cable constellation and cable length. Which is load with a non-ideal load inducing a non-Ideal Back Electromagnetic Force (EMF). The effects of these 3 different parameters on the CM current have been simulated. It can be observed that the cable length and constellation have an impact on the emissions of the CM current. If a symmetrical Back EMF is applied, it does not contribute to CM emissions, which should be considered in the design of the Electromagnetic Interference (EMI) filter.

9:30AM

Non-invasive Identification of a Degraded Passive Filter Component

Ivan Struzhko1, Robert Vogt-Ardatjew1, Frank Leferink1,2

1Universiteit Twente, Netherlands; 2Thales Nederland BV, Netherlands

The development of modern technology makes the use of low-pass filters increasingly necessary to protect sensitive equipment from the impact of highfrequency noise. However, filters are often exposed to harsh operating conditions that can cause a significant influence on the condition of the filter components themselves. Affecting any element of the filter will result in a change in the performance of the filter as a whole. Therefore, it is possible to determine the nature of changes that occurred in a damaged filter from the changes in its performance. This paper presents an application of the previously proposed method for identifying the culprit filter component using a simple combination of measurements and simulations. A simple filter, in which one component was changed to mimic its degradation, was selected as a case study. Measurements in common mode were made to estimate the magnitude of that effect in terms of insertion loss (IL). Monte Carlo simulations with variable component values were performed to fit the IL of the damaged filter and identify the culprit component. It is shown that the proposed approach can be used as a tool for finding the possible cause of changes due to filter damage.

TECHNICAL PROGRAM THURSDAY, AUGUST 3

EMC+SIPI

10:30AM

A Frequency-Domain Model of Common-Mode and Differential-Mode Sources in Three Phase Diode Rectifier Systems

Zhaoqing Zhang, Andrea Zingariello, Gerd Griepentrog Technische Universität Darmstadt, Germany

This paper develops a frequency domain model to estimate the spectra of the conducted emissions caused by three phase diode rectifiers. Based on Fourier analysis, the common and differential mode excitation sources generated by the grid side voltage including harmonics are derived in the frequency domain. The Non-linear behaviour of three phase rectifiers and the influence of input harmonics are investigated. Calculated emission spectra are validated with timedomain simulations and laboratory measurements. The results show a good agreement. The proposed method allows emission spectra to be predicted without a specialist circuit simulators and the results can also be used for further study of filter design and defining new harmonics standards.

11:00AM

Using the Wavelet Packet Transform to Evaluate Weights of Clustered Harmonics Using Lookup Tables Ileana-Diana Nicolae, Petre-Marian Nicolae, Marian- efan

Nicolae University of Croiova, Pomania

University of Craiova, Romania

The paper deals with an original technique used to evaluate the weights of sets of harmonic orders (H1 and H2) clustered in an almost exclusive manner to pairs of terminal nodes from a Wavelet Packet Tree (WPT). The total harmonic contribution (SH1H2) of such harmonics can be retrieved from the analyzed signal by using original computational techniques. The total root mean square of SH1H2 can be used to deduce, by using a lookup table, a larger set of possible solutions in terms of harmonic weights for H1 and H2. This set can be afterward reduced by imposing conditions related to the energies of the associated terminal nodes, making use of another table. The final selection of the approximated solution relies on harmonic phase-shifts estimations provided by solutions of linear systems. The technique requires a highly acceptable small runtime while considering less complicated operations and is a good alternative for analysis of periods with nonsymmetric half-periods.

11:30AM

Optimization of Ferrite Structures in Inductive Power Transfer System for Electric Vehicles

Yao Pei1,2, Lionel Pichon1,2, Mohamed Bensetti1,2, Yann Le Bihan1,2 *1Université Paris-Saclay, France; 2Sorbonne Université, France*

The paper presents a fast multiobjective optimization procedure to improve the design of inductive power transfer systems for electric vehicles. It relies on the combination of metamodeling techniques with a topology optimization process. The approach is applied to a practical system developed in the laboratory. Numerical predictions show that the global volume of ferrite can be strongly reduced while keeping rather the same transmission performances as the initial structure. The influence of a conductive shielding placed above the receiver is also analyzed.

12:00PM

Simulation Based Approach for Low Frequency Electromagnetic Field (EMF) Exposure Assessment Nitin Parsa, Varittha Sanphuang Ford Motor Company, USA

This paper discusses the simulation technique to estimate the low frequency Electromagnetic Field (EMF) exposure using weighted peak method (WPM). A simulated model of three-axis isotropic magnetic field probe was developed and validated. Furthermore, a simulation-based EMF exposure method was developed and validated with a commercially available exposure level tester instrument. In both the cases mentioned above, seat heater coils were used as a source to generate the magnetic fields.



THURSDAY, AUGUST 3

TH-ALL-H TECHNICAL PAPERS

SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE 8:00 AM - 5:30 PM

Gallery Overlook H

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Tao Wang, *Missouri University of Science and Technology, San Diego, CA, USA*

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Wei Zhang, *Missouri University of Science and Technology, Rolla, MO, USA*

Chulsoon Hwang, Missouri University of Science and Technology, Rolla, MO, USA Sungwook Moon, Foundry Business Division, Samsung Electronics Co. Ltd., Hwaseong-si, Korea (the Republic of) Kundan Chand, Meta Platforms Inc. Bothell

Kundan Chand, *Meta Platforms Inc, Bothell, WA, USA*

8:00AM

Novel Pinout and Padring Architecture to Reduce Noise Coupling

Rishi Bhooshan, Pawan Gupta, Swapnil Tiwari, Ajay Kumar Sharma

NXP Semiconductors India Pvt Ltd, India

With technology shrinking and higher integration of multiple functionality of high speed interfaces imposes challenges to reduce the noise coupling at system level to meet the power integrity and signal integrity specification. This requires multi-layer PCB with multiple ground plane, multiple VSS layer in the package, large number of VSS balls/pins and large number of VSS pads at the die level to reduce the overall noise coupling in the system. This leads to increase die size and package size and hence the cost. Here in this paper we propose a novel method of pinout and padring architecture without increasing VSS pads at die level and VSS pins/balls (hence saves cost) to reduce the overall noise coupling in the system to meet the signal integrity and power integrity (SIPI) requirement for the high speed interfaces. This has been implemented in automotive Soc in C40 technology for RGMII interface and Si is working fine.

8:30AM

Modeling Power Supply and Ground-Bounce Induced Jitter for a Voltage-Mode Driver Circuit Driving Long Transmission Lines

Vinod Kumar Verma, Dinesh Junjariya, Jai Narayan Tripathi Indian Institute of Technology Jodhpur, India BEST SIPI PAPER FINALIST

This work presents an efficient approach to estimate power supply and ground-bounce induced jitter for a voltage-mode driver (VMD) circuit driving long transmission lines. Considering the spatial and temporal components of long transmission lines, a semi-analytical method is used to determine jitter at the differential output response of VMD. It uses slope-based method to model the timing uncertainty and requires only onebit simulation for the estimation of jitter. The results obtained from the proposed method are compared with the results obtained using SPICE based simulator to validate the proposed methodology for estimating jitter.

9:00AM

SI/PI Co-design of 12.8 Gbps HBM I/O Interface Using Bayesian Optimization for PSIJ Reduction

Taein Shin¹, Hyunwook Park¹, Daehwan Lho¹, Keunwoo Kim¹, Boogyo Sim¹, Seongguk Kim¹, Jihun Kim¹, Seonguk Choi¹, Jiwon Yoon¹, Jinwook Song², Sunghoon Chun², Joungho Kim¹ ¹Korea Advanced Institute of Science and Technology, Korea; ²Samsung Electronics, Korea

In this paper, we propose SI/PI co-design method using Bayesian optimization (BO) for power supply noise induced jitter (PSIJ) reduction in 12.8 Gbps high bandwidth memory (HBM) I/O interface. PSIJ is becoming significant SI/PI problem as the operating speed increased, in particular HBM with huge I/O counts. SI/PI co-design is needed for accurate PSIJ prediction since it is determined according to the not only power domain such as power distribution network (PDN) and jitter sensitivity of circuit, but also channel loss. First, PSIJ is modeled analytically. Each target design parameters are RLC circuit components of interposer and on-chip for PDN, circuit delay of I/O driver for jitter sensitivity, and physical dimensions of interposer for channel. Then, these eleven design parameters are optimized in the continuous space based on PSIJ value using BO. As a result, SI/PI co-design is effectively performed through PSIJ-based BO, and the system-level trend of each I/O interface component can also be analyzed. Also, the proposed method based on BO is verified to outperform compared to random search (RS) algorithm.
THURSDAY, AUGUST 3



9:30AM

Experimental Method for Measuring the Jitter Sensitivity Function of SERDES IP Circuits

Joonhyun Kim, Seonha Lee, Seungki Nam, Jungil Son, Sungwook Moon

Samsung Electronics Co. Ltd., Korea

This work proposes an experimental method to measure the jitter sensitivity function (JSF) of SERDES IP circuits. The noise monitoring position of the test chip is designed to directly measure the on-chip power noise. By controlling the output amplitude of an external function generator through PDN impedance adjustment, a constant power noise can be applied to the circuit. Finally, the JSF can be evaluated by measuring the total jitter increase and on-chip power noise. The measurement results show that the HO value of the JSF measured from 10 MHz to 100 MHz is within the expected range considering the silicon's corner conditions.

10:30AM

PI Design for 3DIC Implementaion

Sungwook Moon, Minseok Kang, Duhyoung Ahn, Seungki Nam Samsung Electronics Co. Ltd., Korea

It is challenging to design the target power integrity (PI) performance of a power supply when implementing 3DICs. To address this issue, we propose a design optimization method to improve PI characteristics from a system perspective. As a result, we observed a 53% improvement in overall IR drop characteristics by optimizing PI resource and using package decoupling capacitors in the system-level power delivery network (PDN).

11:00am

A Thermal-Aware DC-IR Drop Analysis for 2.5D IC

Shengxuan Xia¹, Baris M. Dogruoz², Yansheng Wang², Songping Wu², Siqi Bai², Chulsoon Hwang¹, Zhonghua Wu²

¹*Missouri University of Science and Technology, USA;* ²*Rivos Inc., USA*

BEST SIPI STUDENT PAPER FINALIST

With the trend of higher integration, 3D/2.5D IC solutions such as CoWoS (Chip-on-wafer-on-substrate) have become more popular in recent years. Power integrity (PI) is always a critical part of the design especially when the power consumption requirements are important specs for high-performance computing. DC-IR drop is one of the criteria within power integrity considerations. However, ordinary electrical-only simulation for DC-IR drop will be an underestimation because it neglects the copper conductivity dropping due to the temperature rising. Thus, an engineering solution for electrical-thermal co-simulation is important to help to provide both an accurate PI analysis and the proper mitigations of the IR drop along the power rails. This paper uses a 2.5D IC chiplet as an example to conduct the thermal-aware DC-IR simulation workflow. By iterating and exchanging the power map and temperature map files between an electrical simulator and a thermal simulator, detailed layer-by-layer IR drops and the temperature map results can provide good insights for efficiently mitigating the IR drop for PI by establishing a better cooling condition in thermal solution.

CONTINUED ON NEXT PAGE



THURSDAY, AUGUST 3

11:30AM

On-Silicon Capacitor Sharing Technique Based on Package Power Merging for PDN Optimization Wei Liu, Guang Chen, Lei Hua, Jenny Xiaohong Jiang

Intel Corporation, USA

In this paper, the on-die decoupling capacitor (OPD) sharing from package technique is presented for power delivery network (PDN) design optimizations with next generation Field-Programmable Gate Array (FPGA). The paper mainly focuses on AC coupling noise mitigation technique among channels for transceiver power delivery design on large FPGA packages. With the proposed method, on-package decoupling capacitor (OPD) can be eliminated to enable small-size, low-cost packages without compromising package noise performance for transceiver power rails. Package layout schemes, power sharing techniques within different layers, and comparison among sharing within different layers to alleviate noise coupling between channels to mitigate voltage droop and overshoots are presented and analyzed in detail. The power integrity (PI) challenges lying with high-speed transceivers on FPGAs is analyzed and enablement solutions on package level are proposed to meet noise specifications without additional costs. An accurate noise simulation methodology and package routing optimization method in noise optimization is essential to an efficient system evaluation and demonstrated in this paper.

1:30PM

Simplified Analysis for Silicon Capacitors

Jungil Son, Kunwoo Ku, Seungki Nam, Joonhyun Kim, Sungwook Moon

Samsung Electronics Co. Ltd., Korea

As chips become more powerful, the power density increases, resulting in increased voltage noise. Several capacitor solutions have been proposed to mitigate this problem, one of which is silicon capacitors. In the development of complex and expensive siliconbased processes, early-stage simulation-based design optimization is required to address manufacturing challenges. In this work, we propose a method to accurately and quickly model silicon capacitors, especially integrated stacked capacitors (ISCs), to predict their characteristics.

2:00PM

Machine-Learning-Based Optimization of Tx Equalization Parameters of a High-Speed Channel

Feng Ling¹, Yufeng Dan¹, Changhua Wan¹, Kevin Cai², Bidyut Sen²

¹Xpeedic, USA; ²Cisco Systems, Inc., USA

We propose a machine-learning-based optimization approach for the Tx equalization. Our target is practical high-speed channels used in systems requiring industrial communication protocols. We adopted Random Forest as our basic machine learning algorithm and applied it to low, medium, and high loss channels with 3-tap and 5-tap Tx equalization architectures. Our machine-learning-based optimization results showed the outstanding efficiency and accuracy of the approach.

2:30PM

Undesired-resonance Analysis and Modeling of Differential Signals Due to Narrow Ground Lines Without Stitching Vias

Chaofeng Li¹, Yuandong Guo¹, Yuanzhuo Liu¹, Siqi Bai², Bichen Chen², Srinivas Venkataraman², Xu Wang², DongHyun Kim²

¹Missouri University of Science and Technology, USA; ²Facebook Inc., USA

Undesired resonances on high-speed differential signals are studied in this paper, which is caused by the adjacent narrow ground line without stitching vias. Due to space limitations in the high-speed channel layouts of certain package applications, the ground (GND) line is often narrow and has insufficient stitching vias, potentially causing undesired resonance in highspeed differential signals. In this study, these undesired resonances were investigated using 3D simulations. revealing that they can be modeled as parallel-coupled half-wavelength resonance. The resonance frequency of the parallel-coupled half-wavelength resonance structure can be predicted well using the formula based on the GND line length. Moreover, three potential solutions to undesired resonance are proposed. providing a practical guide for GND line routing in specific applications.



THURSDAY, AUGUST 3

3:30PM

Power Delivery Measurement Correlation for Mixed Reality Rigid Flex Systems

Kundan Chand¹, Grace Yu¹, Steve Sandler² ¹Meta Platforms Inc., USA; ²Picotest.com, USA

It is difficult to measure and correlate power delivery network (PDN) for Mixed Reality (MR) Systems with Rigid Flex printed circuit (RFPC) designs using conventional techniques. This is due to high density routing and the small form factor. Traditional hybrid EM simulators are used to model PDNs for rigid single stackup PCBs, however these solvers run into limitations when working on multi-zone (MZ) or multistackup rigid flex designs. Moreover, accurate dynamic chip current simulation capability is lacking, which leads to errors in on-chip PDN droop correlation. This paper investigates various simulation best practices and measurement methods to achieve good correlation for power delivery of Mixed Reality Systems. Overall, this paper provides a valuable contribution to defining a PDN correlation flow of multi-zone RFPCs used in mixed reality design and has implications for the design of future MR systems.

4:00PM

A Physics-Based Genetic Algorithm for Decap Optimization in Power Distribution Networks

Ling Zhang¹, Li Jiang¹, Shurun Tan², Yuru Feng¹, Hanzhi Ma¹, Da Li¹, ErPing Li¹

¹Zhejiang University, China; ²Zhejiang University/ University of Illinois at Urbana-Champaign Institute, China

BEST SIPI PAPER FINALIST

Efficiently finding the optimal decoupling capacitor (decap) solutions for power distribution networks (PDNs) with an enormous search space has always been challenging. This paper presents a physics-based genetic algorithm (GA) that can rapidly converge to the optimal decap solutions. Firstly, the priority of the decap locations is determined by calculating and comparing their physical inductances. Then, an initial solution is obtained by selecting the best decap types to be sequentially placed on the prioritized decap locations. Subsequently, a GA is developed to find solutions better based on the initial solution by progressively removing the decap ports with lower inductance-based priorities. The proposed physicsbased GA demonstrates a much faster convergence to higher-quality solutions than the existing decap optimization approaches, and is robust and powerful to handle real-world applications.

4:30PM

An Innovative Power Delivery Solution for High Power CPU Support

Meng Wang¹, Yipeng Zhong¹, Xiaoning Ye² ¹Intel Corporation, China; ²Intel Corporation, USA

In this paper, we proposed an innovative energy saving and cost effective power delivery solution by implementingan external backside busbar on server motherboard, which can reduce dc resistance of CPU core power delivery path(Rpath) to meet high power CPU server performance needs as well as reduce system power consumption .Prototype systems were built and validated by simulation and measurement with proven benefits. The design results in 30% Rpath reduction, ~10W power saving per server system, 4~5C temperature drop at CPU socket, and provide extra routing space for signals at power corridor area. For a datacenter with 200k system configured with high power 350W CPU, it can help reduce total cost of ownership (TCO) up to 9M dollars.

5:00PM

PIPPON: Improve Impedance Prediction of Power Distribution Network Using Pole Proposal Network

Cheng-Hsueh Lu¹, Ling-Yu Tseng¹, Shih-Chieh Chang¹, Shih-Hsien Wu²

¹National Tsing Hua University, Taiwan; ²Industrial Technology Research Institute, Taiwan

While it is a difficult task to model and simulate a power distribution network's (PDN) impedance profile for printed circuit boards (PCBs) with irregular board shapes and multi-laver stackup, it is a crucial process for the design and performance evaluation of the PDN. This paper proposes a new deep learning method PIPPON for PDN impedance prediction, which contains a proposal network specializing in predicting impedance profiles in the range around a pole point. The result shows that PIPPON produces more accurate results (with a 30 percent relative error reduction) than the previous deep learning method and maintains the same level of fast computation time as the previous method. Meanwhile, PIPPON focuses on impedance pole points resulting in a more accurate picture of whether the impedance profile meets the target impedance requirement. Index Terms-Impedance, Prediction, Power distribution network, PDN, Neural network



THURSDAY, AUGUST 3



SELECTION OF MAGNETIC SHIELDING FOR OPTIMIZING NFC/RFID SYSTEMS 10:00 AM - 12:00 PM

Exhibit Hall Exp Demo 2

Sponsored by TC-4

Incorporating Near Field Communication (NFC) into embedded portable devices can lead to magnetic field interference due to the presence of conductive surfaces like batteries, ground planes, and metallic enclosures. To address this issue Flexible Sintered Ferrite Sheets (FSFS), represent an interesting shielding solution to prevent EMI problems related to NFC thanks to their ability to control the magnetic flux.

The characterization of FSFS effectiveness is analysed as a function of the sheet thickness in this contribution.

This is performed with the aim of determining which is the optimum thickness value to retune an NFC antenna to its original operation frequency value (13.56MHz) when it is affected by a near conductive surface.

A finite element method (FEM) simulation model is designed and corroborated with the experimental results to evaluate the performance of different FSFS thicknesses in terms of resonant frequency shift, magnetic field strength and communication distance.

This contribution studies the influences of different setups, on a demotool, of conductive surfaces close to the transmitting antenna and how they change its behaviour.

The results obtained show that the magnetic field strength is significantly attenuated, and the communication distance is highly shorted. Therefore, besides selecting a material that provides high reflection and low losses at 13.56 MHz, it must be considered the thickness to ensure the greatest communication effectiveness.

Consequently, the use of a wrong FSFS thickness could lead to shifting the resonance frequency to lower values than expected, detuning the communication.

PRESENTER

Victor Martinez Garcia Würth Elektronik GmbH & Co. KG eiSos, Germany



THURSDAY, AUGUST 3



A RECENTLY DEVELOPED GATING LIBRARY FOR ENHANCED POST-PROCESSING 10:00 AM - 12:00 PM Exhibit Hall Exp Demo 3

Sponsored by TC-6

Gating is a well-known technique to remove or isolate responses in a multiple reflective environment. The gating technique is widely used in vector network analyzers (VNAs). In this demonstration, we will first discuss the implementation of the gating function in commercial VNAs, and then highlight the benefit of applying the post-processing function as a software library. A software library has been developed recently to provide users with the convenience, flexibility and control of the process rather than relying on the limitations of VNAs. Users have the flexibility to process the measurement data anytime anywhere. The library can seamlessly integrate with conventional programming languages such as Matlab, Python and C. Apart from its convenience, the library has numerous applications that cannot be readily obtained using the gating function of VNAs. In the demonstration, the vector response will be measured between two antennas at a given distance. The antenna response will be gated in real time. We will utilize the library using a Matlab script and select the gate, e.g. gate center, gate width, gate type, gate shape, and edge treatment. Next, three cases will be demonstrated to show the benefits of the gating library compared to the time gating function within a VNA. For each case, we will use the library to process data in real time. The three cases include: 1. Time domain gating for antenna planar near field measurement; 2. EMC chamber VSWR debugging; and 3. Spectrum mode filtering for an antenna extrapolation range.

PRESENTERS

Yibo Wang¹, Andrew Shyne² ¹ETS-Lindgren, USA; ²The Boeing Company, USA

BRINGING THE KIDS TO THE EMC+SIPI 2023?

Be sure to visit the Frederik Meijer Gardens & Sculpture Park. The 158-acre campus boasts one of the country's most important sculpture and botanic collections, with Michigan's largest tropical conservatory, five indoor theme gardens, outdoor gardens, nature trails, a boardwalk, sculpture galleries, a permanent sculpture collection, a library, a café, a gift shop, an education center, and meeting rooms!

> VISIT THE MEIJER GARDENS WEBSITE



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TH-AM-ED4

TECHNICAL PROGRAM

THURSDAY, AUGUST 3

VIRC: SHAKE IT TILL YOU MAKE IT! 10:00 AM - 12:00 PM



VIRC: Shake It Tlii You Make It!

This E&D focuses on presenting a portable vibrating intrinsic reverberation chamber (VIRC) setup to explain the basic concepts of reverberation chambers (RCs). As opposed to conventional, rigidwall RCs, a VIRC is made from a flexible conductive material and therefore can be easily transported to perform both radiated emission and immunity tests on site, yet their underlying functionalities are similar. By performing a series of experiments, this E&D intends to educate the viewers for whom the statistical aspects of the techniques used in RCs are still a mystery, or would like to expand their understanding of this measurement technique.

PRESENTERS

Vasso Gkatsi, Robert Vogt-Ardatjew University of Twente, Netherlands





THURSDAY, AUGUST 3



ML/AI IN EMC AND SIPI: OPPORTUNITIES AND ROAD BLOCKS 10:30 AM - 12:00 PM Exhibit Hall

Sponsored by TC-6

Chair:

Alistair Duffy, De Montfort University, Leicester, England, UK

Bring your questions or simply listen and learn!

PLANNED PANELISTS INCLUDE:

Richard Gao Xianke, A*STAR Institute of High Performance Computing, Singapore Lijun Jiang, City University of Hong Kong, Lijun Moein Nazari, Cadence, USA Steve Scearce, USA, Cisco, USA

It seems that everyone is talking about AI these days! Even within our EMC and signal and power integrity communities, machine learning and artificial intelligence are starting to be used as serious tools to solve challenging problems. However, the knowledge base within this domain is developing but not yet well established. The EMC Society is keen to change this by building conversations and sharing information. If you have expertise in ML/AI, have "dabbled" or are simply "AI curious", please join this panel session where we will address your questions and listen to your experience about where there are immediate opportunities within the EMC and SIPI domain and what are the obstacles that will limit our collective ability to utilize these tools.



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THURSDAY, AUGUST 3

TH-PM-B TUTORIAL

LESSONS LEARNED CREATING RELIABLE COMPUTATIONAL MODELS FOR SI, PI AND EMC APPLICATIONS 2:00 PM - 6:00 PM Gallery Overlook B

Sponsored by TC-9

Chair:

Patrick DeRoy, Analog Devices Inc, Norwood, MA, USA

This tutorial will expose the attendees to the lessons learned by a number of industry experts over the years. The goal being that the attendees will benefit from the, sometimes painful, learning experiences of the presenters. Computational tools are very powerful and simulation is invaluable to the modern design engineer but there is still an art to using these tools effectively. In all disciplines, hindsight is perfect and the opportunity to learn from others is a valuable resource. This tutorial will not only show lessons learned but also expose the attendees to fundamental ways of thinking through their models to better ensure success. Examples relevant for Signal Integrity, Power Integrity and Electromagnetic Compatibility design will be shared.

TH-PM1-C SPOTLIGHT ON RECIPIENTS OF THE JOHN HOWARD MEMORIAL EMC EDUCATION GRANT 2:00PM - 2:30PM Gallery Overlook C

Presenters:

Dr Stanley.O. Kuja, *Rhodes University, Makana, South Africa* Ko Gabriel Odreitz, *Technische Universitat Graz, Graz, Austria*

PLANNED PANELISTS INCLUDE:

Model Validation Bruce Archambeault International Business Machines Corp, USA

What I Wish I Knew About EMC Simulation When I First Started Scott Piper General Motors Corp, USA

Details That Matter: Understanding Aspects That Can Help Mitigate the Differences between Measurements and Simulated Results for SI and EMC Juliano Mologni ANSYS, USA

Establishing Confidence in Field Solvers Eric Bogatin *University of Colorado Boulder, USA*

Reconciling EMC and Simulation Kyle Elsasser *Electro Magnetic Applications, Inc., USA*

Winning the Lottery with Power Integrity Simulations... What are the Odds? Heidi Barnes Keysight Technologies Inc., USA

Important Aspects of 3D Time Domain Field Simulation: Experiences and Lessons Learned Nivedita Parthasarathy Dassault Systèmes, France



THURSDAY, AUGUST 3



AERONAUTICS AND SPACE EMC, AIRCRAFT, ATMOSPHERIC ENVIRONMENT, DRONES, SPACECRAFT, MISSILES 4:00 PM - 5:30 PM

Gallery Overlook C

Sponsored by TC-8

Chair:

Jen Dimov, NASA, Greenbelt, MD, USA

4:00PM

Evaluation of Front-Door and Back-Door RFI Impacts on Small UAS Operation Safety

Jilu Li, Daniel Gomez-Garcia, Fernando Rodriguez-Morales, Carl Leuschen *The University of Kansas, USA*

Due to interferences from pervasive electromagnetic emissions, the likelihood of irregular performance and possibly loss of control of an unmanned aircraft system (UAS) grows as small commercial drones are deployed in more applications. The UAS electromagnetic compatibility has therefore become a crucial factor to consider in UAS design and operation to minimize any potential safety issues. A UAS may experience radio frequency interference (RFI), a subset of a broader range of electromagnetic interference (EMI), through its communication link or capacitive coupling of the RF electrical field. We conducted measurements both outside and within a chamber to assess the impacts of front-door and back-door RFI on the C2 (command and control) link and the subsystem components of two distinct drone models. In this paper, we describe the measurement setup and procedures, present the results, and analyze the safe distances of the drones from RFI sources such as cellphone base stations and airport surveillance radar (ASR) under the impacts from these two types of RFI in this study.

4:30PM

An Experimental Investigation into the Radiating Mechanisms of Unshielded Transmission Lines at Microwave Frequencies

Matthew K. Roth¹, Mazin M. Mustafa¹, James C. West¹, Charles F. Bunting¹, Paul G. Bremner², Gabriel Vazquez³ ¹Oklahoma State University, USA; ²RobustPhysics, USA; ³NASA Kennedy Space Center, USA

An empirical study has been performed to inves- tigate the radiation mechanisms that yield emissions from two- conductor transmission line circuits at microwave frequencies up to 8.5 GHz. The measured signal levels established by radiation from the test configurations within a reverberation chamber were compared with the levels radiated by a wide-band dual-ridge antenna in the same environment. Two basic test configurations were considered, one in which the transmission line segment and full feed structure, including balun and feed plate, were contained within the chamber cavity, and one in which the feed structure and feed plate could be isolated from the cavity. The measurements show that radiation from the line terminations dominates the emission within the cavity that contains it, including when only bulkhead SMA pin adapters were exposed to the cavity, independent of whether the line was a parallel-conductor twin- lead line or a twisted pair. Emissions from the twin-lead line exceeded that from the twisted-pair line only when the lines were passed through apertures in the chamber walls. Moment-method calculation of the radiation from an ideal, balanced twin-lead line showed overall lower emissions than that measured at the lower microwave frequencies considered. The results suggest that the emissions can be modeled by adding a radiation resistance element at the connector location to standard transmission line theory.

5:00PM

Tradeoffs of Centralized versus Localized Filtering Solutions for AEA

Leonardo C. Malburg¹, Niek Moonen¹, Frank Leferink^{1,2} ¹Universiteit Twente, Netherlands; ²Thales Nederland BV, Netherlands

All-electric aircraft (AEA) require an increased number of power converters, making it potentially more susceptible to electromagnetic interference (EMI). As aircraft rely on strict volume and weight limits, mitigation methods must be developed to minimize their impact on the overall bulkiness. The operation of a multi-converter distribution system supplied by a single dc power source is investigated in this paper. Filtering methods are typically implemented at each converter independently, however, a centralized approach is here investigated. Common and differential mode EMI levels are evaluated, resulting in the design of gamma-pi type EMI filters. The solutions are compared for centralized against localized filters, evaluating performance, variables influencing design decisions, and overall size optimization.



THURSDAY, AUGUST 3



ADVANCED EMC DESIGN BASED ON NEAR-FIELD MODELING AND METASURFACE 2:00 PM - 5:00 PM Gallery Overlook G

Co-Chairs:

Richard Xian-Ke Gao, A*STAR Institute of High Performance Computing, Singapore Xing-Chang Wei, Zhejiang University, China



2:00PM

An Effective Source Reconstruction Method in a Shielding Enclosure Based on Magnitude-Only Near-Field Scanning

Tian-Hao Song¹, Ze-Kai Hu¹, Qi-Han Xiao¹, Dong-Feng Guo²

¹Zhejiang University, China; ²OPPO, China

An effective source reconstruction method (SRM) in a shielding enclosure is proposed in this paper. Magnitude-only near-field scanning technology is employed to overcome the difficulty of precisely measuring the phase. After scanning the magnitudeonly near-field of the real unknown electromagnetic interference (EMI) source in free-space, a global optimization algorithm named differential evolution (DE) method is applied to obtain the equivalent dipole model. Then, the proposed equivalent dipole model can be used to represent the unknown EMI source in the shielding enclosure. The results of the numerical and measurement examples verify the effectiveness of the proposed method.

2:30pm

An Effective EMI Source Reconstruction Method Based on Adaptive Dynamic Differential Evolution

Dong-Hao Han¹, Liang-Jin Chen², Xing-Chang Wei¹, Tian-Hao Song¹

¹Zhejiang University, China; ²State Grid Zhejiang Power, China

In this paper, an effective electromagnetic interference source reconstruction method is proposed based on adaptive dynamic differential evolution. The performance of traditional dynamic differential evolution depends largely on the choice of the initial values. Compared with the traditional dynamic differential evolution method, the proposed method will update the hyperparameters adaptively. This hyperparameter adaptive mechanism will make the proposed method have stronger global search ability and more reliable convergence performance, thus reducing the impact of the initial values. By using the proposed method, the unknown source is replaced by equivalent dipoles based on the phaseless scanning magnetic fields. Simulation results demonstrate the effectiveness of the proposed method.

THURSDAY, AUGUST 3



3:00PM

A PEEC-Informed Deep Learning Approach for Inverse Electromagnetic Problem in Heterogeneous Integrations

Yang Jiang, Richard Xian-Ke Gao Institute of High Performance Computing, Singapore

In this paper, a partial element equivalent circuit (PEEC) informed deep learning approach is proposed for inverse electromagnetic scattering problems involving finite-sized dielectrics. To balance the enormous learning space and limited computation resources, a partial-relative-permittivity (PRP) model is proposed based on the compact PEEC model, which is capable to reveal the electromagnetic (EM) behavior of threedimensional (3-D) heterogeneous structures by a 2.5-dimensional (2.5-D) representation. A tailored generative adversarial network (GAN) is developed to learn the intrinsic relation between the PRP model and the near-field information. To imitate the realworld phenomenon with adequate and accurate data, a dedicated training dataset is built numerically. With the GAN model, a PRP model can be interpreted from the measured phaseless magnetic fields at a single frequency, resulting in a broad-band c-PEEC model that is especially useful in power integrity and radiated emission analysis.

4:00PM

Transmission Line Intra-pair Skew Analysis and Management on PCIe 6.0

Xinjun Zhang, Wenwu Wang, Weizhe Li, Mo Liu, Chenghai Yan, Kai Xiao, Xiaoning Ye Intel Corporation, China BEST EMC PAPER FINALIST

In this paper, the impact of the intra-pair skew of printed circuit board (PCB) trace and the related compensation scheme is studied at Peripheral Component Interconnect Express (PCIe) 6.0 Pulse Amplitude Modulation 4 (PAM4) 64 Gbps speed. The skew is introduced and compensated in the actual PCB layout and modeled in mixed 2-D and 3-D modeling tools for both stripline and microstrip. The intra-pair skew modeling method is verified through correlations between simulation and measurement results. The sensitivity of the link performance to the amount of skew, and compensation location is thoroughly analyzed. PCB trace skew management guidelines for PCIe 6.0 channels are provided.

4:30PM

The Prediction of Magnetic Near-Field Distribution Characteristics Based on Artificial Neural Network

Yuan Zhao, Yaowen Hu, Pengyuan Han, Renpan Lu, Chenyang He, Junyou Cao Chengdu University of Information Technology, China

In this paper, the magnetic near-field distribution characteristics of a printed circuit board (PCB) are predicted based on developed artificial neural networks (ANNs). ANN is capable of understanding how the trend of the radiation near-field varies when a PCB working at adjacent different frequencies, making the near-field prediction possess with higher accuracy and lower time-cost. The proposed method offers a fresh perspective on how to analyze the nearfield distribution characteristics in electromagnetic compatibility (EMC) issues.



FRIDAY, AUGUST 4 • SCHEDULE AT A GLANCE



SPEAKERS BREAKFAST

Grand Gallery DEF • 7:00am-8:00am • (Breakfast Only on the Day of Presentation)

REGISTRATION/INFO DESK HOURS

Friday - 8:00 am to 11:00 am

STANDARDS WEEK SESSIONS

Join us for this special track on current and emerging International EMC and SIPI Standards! Attend open Working Group meetings with opportunities to contribute and ask questions.



FRIDAY, AUGUST 4



SI AND PI SIMULATION AND MEASUREMENT CHALLENGES FOR ELECTRICAL PACKAGES 8:00 AM - 12:30 PM Gallery Overlook D

Sponsored by TC-10

Chair:

Heidi Barnes, Keysight Technologies Inc, Santa Rosa, CA, USA

Co-Chair:

Vladimir Okhmatovski, University of Manitoba Department of Electrical and Computer Engineering, Winnipeg, MB, Canada

The mission of the IEEE EPS EDMS Packaging Benchmarks Committee is to produce a Packaging Benchmark Suite that will encourage research and development by providing information about the electromagnetic, electrical, and circuit modeling and simulation problems encountered, and the stateof-the-art solution methods used when analyzing and designing electronic packages. This workshop builds on the tutorial content presented last year to bring a deeper dive into the latest challenges facing electronic packaging modeling and simulation. The workshop will step the audience through the state-of-the-art simulation and measurement techniques for electronic package design, the latest in power-aware signal integrity chip/package/board challenges, and what the future of heterogenous chiplet packaging will bring. The agenda is:

- Introduction to IEEE EPS EDMS Packaging Benchmarks
- Electromagnetic Analysis of IEEE EPS Benchmarks with Fast Layered Media Integral Equation Solvers
- IEEE EPS Benchmark Electrical Characterization and Measurement Technology
- Case Study Simulation and Measurement for Improving Power Integrity in Chip, Package, and Printed Circuit Board Design
- Next Generation of Packaging Challenges for Electrical Modeling and Simulation Tools

The format of the workshop will start with a look at the basic signal integrity and power integrity challenges for high-speed, high-density electrical packages. Separate speakers will cover the stateof-the-art tools and methods for creating realworld packaging benchmarks that are currently available. The workshop will conclude with a look forward at what changes are on the horizon for modeling and simulation of high-density heterogeneous chiplet packaging.

PLANNED SPEAKERS & TOPICS

Introduction to IEEE EPS EDMS Packaging Benchmarks Heidi Barnes

Keysight Technologies Inc., USA

Electromagnetic Analysis of IEEE EPS Benchmarks with Fast Layered Media Integral Equation Solvers Vladimir Okhmatovski University of Manitoba, Canada

IEEE EPS Benchmark Electrical Characterization and Measurement Technology

Zhichao Zhang, Cemil Geyik, Michael Hill, Sean Christ, Saikat Mondal, Zhiguo Qian, Stephen Smith, Kemal Aygun Intel Corporation, USA

Simulation and Measurement for Improving Power Integrity in Chip, Package, and PCB System Kaisheng Hu *Ciena, Canada*

Next Generation of Packaging Challenges for Electrical Modeling and Simulation Tools Pavel Roy Paladhi

IBM, USA



FRIDAY, AUGUST 4

FR-AM-E TUTORIAL

EMI CAN CAUSE FUNCTIONAL SAFETY (AND OTHER) RISKS THAT CAN'T BE COVERED BY EMC TESTING ALONE - SO WE NEED EM RESILIENCE 8:00 AM - 12:30 PM Gallery Overlook E

Sponsored by TC-1

Chair:

Davy Pissoort, Katholieke Universiteit Leuven, Bruges, Belgium

Co-Chair:

Martin K. Armstrong, Cherry Clough Consultants Ltd, Staffordshire, UK

Functional Safety is becoming vital for all equipment, vehicles (land, air, sea, space), machines, robots, etc., because they increasingly rely on programmable digital systems for their operation and safety. (Medical devices and systems suffer the same problem, except they use the term 'Essential Performance' instead of Functional Safety.)

But programmable digital systems are nonlinear, so we must never assume all their digital states would result in acceptable safety risks, based solely on testing a percentage of them. Unfortunately, they have far too many possible digital states to be thoroughly tested, even once (never mind the hundreds of times needed to prove EMI could not cause unacceptable risks).

The reasonably foreseeable unpredictability of all programmable digital systems means they can't ever be proven to be safe enough by any practical test programme. So, to control the Functional Safety risks that can be caused by EMI, we need to use Electromagnetic Resilience - the topic of this workshop.

PLANNED SPEAKERS & TOPICS

Why it is Now Important to Risk-Manage Electromagnetic Disturbances Using EM Resilience Martin K. Armstrong Cherry Clough Consultants Ltd, United Kingdom

Ongoing and Future Research in EM Resilience Davy Pissoort *Katholieke Universiteit Leuven, Belgium*

Managing Risks due to EMI

Martin K. Armstrong Cherry Clough Consultants Ltd, United Kingdom

IBIS SUMMIT ON FRIDAY MORNING, AUGUST 4: YOU'RE INVITED!

8:00AM - 12:00PM • Grand Gallery Overlook A

The IBIS Open Forum is holding its fourth IBIS Summit meeting at the 2023 IEEE International Symposium on EMC+SIPI on Friday, August 4, 2023, 8:00am – 12:00pm EDT. This hybrid virtual/in-person event is designed to promote interactions between model users, model makers, and EDA tool developers in the IBIS community as well as the IEEE EMC Society members. Presentations related to IBIS and IBIS-AMI basics and power integrity topics are highly encouraged, as well as other usual topics. Those interested in presenting at the event should contact Bob Ross (**bob@teraspeedlabs.com**). Those interested in attending the event should register with Randy Wolff (**vice-chair@ibis.org**).

For more information on the IBIS Open Forum visit <u>https://ibis.org/</u>.

The IBIS Summit is an open meeting for all registered in-person symposium attendees (IEEE members and nonmembers). However, symposium attendees should also register in advance with Randy Wolff to receive the meeting agenda and other pertinent information in advance of the IBIS Summit.



FRIDAY, AUGUST 4

FR-AM-F TUTORIAL MILITARY EMC TUTORIAL 8:00 AM - 12:30 PM Gallery Overlook F Sponsored by TC-3

Co-Chairs:

Carl Hager, NSWC Dahlgren, Dahlgren, VA, USA Robert Davis, Rochester Institute of Technology, Rochester, NY, USA

Achieving electromagnetic compatibility with military equipment, systems, and platforms requires significant effort. EMC must be considered at all lifecycle stages and involves first characterizing the operational electromagnetic environment (EME) and then design/testing military systems at various stages of production, assembly and integration. Numerous Military EMC standards and handbooks have been developed for electromagnetic environmental effects (E3) measurements and analysis to reduce the risk of equipment and systems failing to meet their operational performance requirements due to detrimental E3. The tutorial will focus on various considerations for Military EMC applications including Electromagnetic Interference (EMI), Hazards of Electromagnetic Radiation to Ordnance (HERO), Electrostatic Discharge (ESD), etc.

PLANNED SPEAKERS & TOPICS

MIL-STD-461 and MIL-STD-464 Updates and Status Finnbar O'Connor *Huntington Ingalls Industries*

NATO Electrical and Electromagnetic Environmental Conditions AECTP 250 Series with Updates Mark Waller US Army Redstone Test Center, USA

NATO Electromagnetic Environmental Effects Tests and Verification Methods: Updates to the AECTP 500 Series Andrew Rash NOSSA and NATO

HERO EID Response to Solid-State Radar Systems Carl Hager IV *Naval Surface Warfare Center, USA*

Electrostatic Discharge (ESD) to Ordinance Technical Agent

Phillip Melton Naval Surface Warfare Center, USA



FRIDAY, AUGUST 4

FR-AM-G WORKSHOP

CABLE/CONNECTOR ASSEMBLY SHIELDING EFFECTIVENESS CHARACTERIZATION FROM DC TO 40GHZ: THE NEW STANDARD P2855 8:00 AM - 12:30 PM



Gallery Overlook G Sponsored by TC-4

Chair:

Charles Jullien, *Safran Electrical and Power, Blagnac, France*

Co-Chair:

Huadong Li, Molex LLC, Naperville, IL, USA

This workshop will give a general introduction to the future standard in construction P2855 about cable/connector assembly shielding effectiveness characterization from DC to 40GHz. This standard provides recommended measurement techniques for evaluating, and methods for specifying, the capabilities or effectiveness of shielding on cable/connector assemblies for the control of Electromagnetic Interference (EMI) to allow product compliance to common Government, regulatory, and customer requirements, and for achieving system Electromagnetic Compatibility (EMC). This standard also provides measurement techniques to evaluate, and methods to specify, cable/ connector assemblies shielding capabilities for reducing the coupling of electromagnetic energy between cable/connector assemblies. Emphasis is placed on measurement techniques that have been adopted through incorporation into standards, both commercial and military, or that have been used extensively. A set of novelties will be presented on the methods that will be present in the standard.

The workshop is divided into topics as: Magnetic shield method, DC method, Triaxial method, Injection line method, Parallel plate method, Localized injection method, Anechoic chamber method, G-TEM cell method, Reverberation chamber, Shielding Effectiveness Measurands.

The workshop will help the audience to properly test and design cables, connectors and their assemblies for product EMC.

PLANNED SPEAKERS & TOPICS

Introduction to P2855 Standard : Recommended Practices for the Electromagnetic Characterization of Cable/Connector Assembly Shielding Effectiveness in Frequency Range of Direct Current to 40 GHz Charles Jullien¹, Huadong Li² 'Safran Electrical and Power, France; ²Molex LLC, USA

Shielding Effectiveness Measurands of Cables, Connected, and Their Assemblies Huadong Li *Molex LLC, USA*

Shielding Effectiveness Measurements of Connectors in Low Intensity Magnetic Fields Eugene Mayevksiy *TE Connectivity Ltd Berwyn, USA*

Use of Injection Line method to Determine Shield Performance in Automotive Applications Rich Boyer *Aptiv - Signal and Power Solutions, USA*

Localized Injection Measurement Up to 9 GHz Charles Jullien, Anca Dieudonne *Safran Electrical and Power, France*

Feasibility of Parallel Transmission Line Plate Method for Connector Cable Assembly EMC Gary Biddle Samtec, USA



FRIDAY, AUGUST 4



REVERBERATION CHAMBERS: RC YOU THERE! 8:00 AM - 12:30 PM Gallery Overlook H

Sponsored by TC-2

Chair:

Vignesh Rajamani, *Exponent Inc, Phoenix, AZ, USA*

Co-Chair:

Vasso Gkatsi, University of Twente, Enschede, Netherlands

Organizer:

Robert Vogt-Ardatjew, Universiteit Twente, Enschede, Netherlands

This workshop will provide an introduction to recent applications of reverberation chambers (RC). It is intended to provide EMC engineers who are interested in applying reverberation chambers to various measurement issues and the extension of reverberation chambers to solve a variety of EMC problems. The statistical methods used to evaluate the fields inside these chambers requires the collection of statistically independent samples. These samples can be generated by employing different stirring techniques such as mechanical mode stirring/ tuning, spatial, or frequency stirring.

This half-day workshop provides a brief overview of RC theory, followed by their recent applications. The workshop material will be updated to reflect recent research results and implications. The format will be a conference presentation style (lecture) followed by guestions moderated by the chairman. It is designed for both academics and people from industry who are involved in radiated emission or immunity testing of commercial or military systems using RCs, and is valuable to personnel evaluating the use of RCs as a complement to or replacement for other types of radiated test facilities, as well as for personnel trying to use statistical methods to characterize electromagnetic environments.

PLANNED SPEAKERS & TOPICS

Radiative Testing Using Reverberation Chambers Vignesh Rajamani Exponent Inc., USA

Complex Cavity Measurement Techniques for the Assessment of Aircraft Electromagnetic Environments Dennis Lewis

The Boeing Company, USA

Flexible Testing: Shaken, Not Stirred Frank Leferink

University of Twente, Netherlands

Stirring Up Trouble - Hidden Challenges in Stirred (and Shaken) Measurements John Ladbury National Institute of Standards and Technology, USA



FRIDAY, AUGUST 4

FR-PM-D TUTORIAL

SIGNAL INTEGRITY AND ESD -SIMULATIONS FOR ESD DESIGN 1:30 PM - 6:00 PM Gallery Overlook D

Sponsored by TC-10

Chair:

Andreas Hardock, *Nexperia, Hamburg, Germany*

The workshop briefly introduces the basics of electrostatic discharge and demonstrates some protection concepts using the examples of modern interfaces in automotive and mobile applications [1].

First, classical methods of signal integrity such as: S-parameter, Time Domain Reflectometry and eye diagrams will be introduced and their application to various ESD protection components are presented. It is discussed how modern ESD protection elements behave in the time and frequency domain and how these can be analyzed with the help of simulations. Therefore 3D fullwave simulations using CST MW Studio are shown as well as high-speed circuit simulations ADS on device and on system level are shown. In addition, the influence of ESD protection compared to other system components such as cables, connectors and other electrical components such as Common Mode Chokes (CMC), and the PCB itself is shown [3].

Subsequently, the topic of SEED simulations of transient ESD events is examined. First, the methodology of System Efficient ESD Design (SEED) is introduced. In particular, fully dynamic behavior-based SEED models are discussed and their advantages over guasi-static and smallsignal spice models are explained. In this context, the construction of such a fully dynamic model based on Transmission Line Pulse (TLP) [2] measurements is shown using implementation examples. Furthermore, using the examples of automotive and mobile applications such as automotive Ethernet e.g. 1000BASE-T1 and USB, the advantages of SEED simulations are demonstrated, whereby the influence of other discrete system components such as CMCs [4] as well as the positioning of ESD protection components is analyzed.

Therefore the block diagram and the specific circuitry of SEED modelling of a system simulation is presented. The specific of the modelling of each of the components in the circuitry is discussed.

In summary, it is shown that by applying SI and ESD simulations, the selection the ESD risk itself as well as the right choice of suitable ESD protection components can already be made in the concept phase of hardware development, resulting in significant time and resource savings and lowering the risk of a failure to a minimum.

PLANNED SPEAKERS & TOPICS

Introduction to ESD in Mobile and Automotive Applications Andreas Hardock Nexperia, Germany

Simulations with ESD-Protection Devices Signal Integrity and ESD Andreas Hardock, Sergej Bub Nexperia, Germany

SEED Simulations for Optimal System-Level ESD Sergej Bub¹, Sudhama Shastri²

¹Nexperia BV, Germany; ²Nexperia BV, USA



FRIDAY, AUGUST 4



INTERNATIONAL STANDARDS AND REGULATIONS WORKSHOP SPONSORED BY IEEE EMCS STANDARDS ADVISORY AND COORDINATION COMMITTEE (SACCOM) 1:30 PM - 6:00 PM Gallery Overlook F



Sponsored by TC-2

Chair:

Henry Benitez, *ElectroMagnetic Investigations, LLC, Hillsboro, OR, USA*

Experts:

Ghery Pettit, *Pettit EMC Consulting, Olympia,* WA, USA

Andrew Griffin, Cisco Systems Inc, San Jose, CA, USA

Kimball Williams, IEEE, Dearborn, MI, USA

The purpose is to provide information about EMC standards, the development process and regulations that utilize these standards. The plan is to have presentations from members of various IEC/CISPR/ANSI Standards development/ maintenance committees and from regulatory authorities such as Canada, USA, EU.

PLANNED SPEAKERS & TOPICS

Brief History of EMC IEC Standards Development Process IEC 61326 1 Product Family Standard for Measurement, Control and Laboratory Equipment Henry Benitez ElectroMagnetic Investigations, USA

CISPR A / CISPR H Andy Griffin *Cisco Systems*

CISPR SC I, CISPR 32 and CISPR 35 Ghery Pettit

Pettit EMC Consulting LLC, USA

CISPR D Automotive

Statistical Process Control for EMC Laboratories Kimball Williams *IEEE, USA*

Role of Accreditation Bodies with Regards to Standards and Regulations

Randy Long ANSI National Accreditation Board (ANAB), USA

Success of Mutual Recognition Agreements Nathalie Rioux National Institute of Standards and Technology, USA

FCC Overview

Panel Discussion

LAKE MICHIGAN BEACHES

There are 22 Lake Michigan beaches featuring 300 miles of shoreline within an hour's drive of down-town Grand Rapids? When you're at IEEE EMC+SIPI July 31 - August 4, block off some beach time!

VISIT THE AREA BEACHES WEBSITE



FRIDAY, AUGUST 4

FR-PM-G TUTORIAL

PRODUCT SAFETY COMPLIANCE AND GLOBAL MARKET ACCESS 1:30 PM - 6:00 PM Gallery Overlook G

Chair:

Grant Schmidbauer, British Columbia Institute of Technology, Burnaby, BC, Canada

The goal of most companies is not to only design products to be safe, perform according to customer demands, and to meet regulatory requirements, it is to sell those products globally. While your product must comply with the EMC and SIPI requirements, there are a myriad of other technical requirement that must also be considered to facilitate the sale of the product.

The plan for this tutorial is to delve into some of the "other technical requirements" that products must comply with, including product safety requirements (ie, concepts such as fire, shock, mechanical, temperature, and radiation); and then once your products are compliant, we will discuss the commercialization of the product through obtaining the many country approvals that are needed in order to legally sell the product around the world.

This tutorial should be attended by product realization managers, design engineers, test technicians, product regulatory personnel, project managers, marketing personnel, and others interested in learning more about product safety and global market access requirements.

PLANNED SPEAKERS & TOPICS

Compliance 101: The Basics of Product Safety and Global Regulatory Compliance Ken Kapur *University of the Pacific, USA*

Product Compliance Engineering

John Allen Southern Illinois University, USA

Part 3: Global Market Access

Grant Schmidbauer British Columbia Institute of Technology, Canada





FRIDAY, AUGUST 4



RECENT ADVANCEMENTS IN MEASUREMENT UNCERTAINTY 1:30 PM - 6:00 PM Gallery Overlook H

Sponsored by TC-2

Chair:

Zhong Chen, ETS-Lindgren, Cedar Park, TX, USA

Co-Chair:

Janet O'Neil, ETS-Lindgren, Cedar Park, TX, USA

Any kind of measurement, particularly when carried out for scientific or professional purposes, requires consideration of inherent measurement errors. Evaluation of measurement uncertainty in electromagnetic compatibility and antenna characterization applications is the common thread that connects the presentations in this workshop. Sophisticated data processing techniques and novel measurement methods are presented aiming at enhancing the accuracy of electromagnetic field measurements with specific reference to errors induced by the measuring environment (reverberation chambers and anechoic chambers), robotic positioning systems, and a model-based system engineering approach to understand contributions from various sources of uncertainties.

PLANNED SPEAKERS & TOPICS

I Have My Uncertainties, Now What? Randy Long ANSI National Accreditation Board, USA

Uncertainty Analysis from the Early Days to Modern Usage of Reverberation Chambers John Ladbury *National Institute of Standards and Technology, USA*

Site Contributions to MU for above 1 GHz EMC Measurements Zhong Chen ETS-Lindgren, USA

Evaluation of Measurement Uncertainties in a Multipurpose Robotic Antenna Test System Dennis Lewis *The Boeing Company, USA*



BEST SYMPOSIUM PAPER FINALISTS

BEST EMC PAPER FINALISTS

TU-AM-D EMC

ROOM: GALLERY OVERLOOK D ASSESSMENT AND EMI MODELLING FOR ELECTRICAL AND ELECTRONIC DEVICES IN THE LOW-FREQUENCY RANGE

11:00am

A Statistical Approach to Predict the Low Frequency Common Mode Current in Multi-Converter Setups

E. Ballukja¹, K. Niewiadomski¹, D.W.P. Thomas¹, S. Sumsurooah¹, M. Sumner¹, J. Bojarski² ¹University of Nottingham, United Kingdom; ²Uniwersytet Zielonogórski, Poland

TU-ALL-E

ROOM: GALLERY OVERLOOK E COMPUTATIONAL ELECTROMAGNETICS, MODELING AND SIMULATION, MULTI-PHYSICS TECHNIQUES, TOOLS, AND APPLICATIONS

11:30am

3-D Modeling and Characterization of Ferrite and Nanocrystalline Magnetic Cores for EMI Applications Rafael Suárez^{1,2}, María Tijero¹, Roberto Moreno¹, Aitor Arriola¹, Jose Manuel González² ¹Ikerlan Technological Research Centre, Spain; ²Universidad del Pais Vasco, Spain

TU-ALL-F EMC

ROOM: GALLERY OVERLOOK F WIRELESS TECHNOLOGIES, EMC PLANNING/TESTING/SPECIFICA-TIONS, WIRELESS COEXISTENCE 10:30am

RF Desense Risk Prediction Using EM Simulations Gokul Ramsubbaraj¹, Leo Cheng², Krishna Rao¹ ¹Google LLC, USA; ²Google LLC, Taiwan **2:30pm**

Static I-V based PIM Evaluation for Spring and Fabric-over-Foam Contacts

Kalkidan W. Anjajo¹, Yang Xu¹, Shengxuan Xia¹, Yuchu He², Haicheng Zhou², Hanfeng Wang², Jonghyun Park¹, Chulsoon Hwang¹

¹Missouri University of Science and Technology, USA; ²Google LLC, USA

TU-PM1-G

ROOM: GALLERY OVERLOOK G STOCHASTIC SIMULATION FOR EMC AND SIGNAL INTEGRITY 1:30pm

Recent Developments in Stochastic Power Flow Enable a New Solution for System-Level EMC Modelling

P.G. Bremner *RobustPhysics, USA* 4:00pm

Statistical Characterization of Cavity Quality Factor via the Stochastic Green's Function Approach

Shen Lin¹, Yang Shao¹, Zhen Peng¹, Bisrat D. Addissie², Zachary B. Drikas² ¹University of Illinois at Urbana-Champaign, USA; ²US Naval Research Laboratory, USA

WE-ALL-D EM

ROOM: GALLERY OVERLOOK D INTERFERENCE CONTROL, SHIELDING, GASKETS, CABLES, CONNECTORS, GROUNDING AND PCB LAYOUT

10:30am Two Advanced Types of Air Vent for Improved EMI Shielding and Air Flow

Jianquan Lou¹, Alpesh Bhobe², Jerry Pianin², Joel Goergen² ¹Cisco Systems (China) R&D Co., Ltd., China; ²Cisco Systems, Inc., USA

WE-PM-F EMC

ROOM: GALLERY OVERLOOK F MEASUREMENTS, TECHNIQUES, TEST INSTRUMENTATION AND FACILITIES, STANDARDS AND REGULATIONS AND MEASUREMENT UNCERTAINTY

4:30pm

The Impact of Cable Support Material on Conducted Susceptibility Test Results

John G. Kraemer Collins Aerospace, USA

EMC+SIPI

BEST SYMPOSIUM PAPER FINALISTS

BEST EMC PAPER FINALISTS

TH-ALL-D

ROOM: GALLERY OVERLOOK D HIGH POWER ELECTROMAGNETICS, ESD AND TRANSIENTS, EMP, IEMI AND LIGHTNING, GEOMAGNETIC STORM EMC

8:00am

Early-Time Electromagnetic Pulse Response Validation of Surge Arrester Models

Tyler Bowman, Thomas Kmieciak, Laura Biedermann, Sandia National Laboratories, USA **10:30am**

Reconstruction of Sound Information Leakage Signals Obtained from Multiple Demodulation Methods

Taiki Kitazawa, Seiya Takano, Yuichi Hayashi Nara Institute of Science and Technology (NAIST), Japan

TH-ALL-E

ROOM: GALLERY OVERLOOK E POWER ELECTRONICS EMC, POWER CONVERSION, AUTOMOTIVE, AEROSPACE, MEDICAL, CONSUMER ELECTRONICS

8:00am

Investigation of Common-Mode EMI in Three-Phase Split-Phase Inverter

Abdul Basit Mirza, Abdul Muneeb, Sama Salehi Vala, Fang Luo

Stony Brook University, USA

11:30am

Reactive Shielding Method for Wireless Power Transfer Systems with High Power Transfer Efficiency Using Frequency Split Phenomena

Changmin Lee¹, Seongho Woo¹, Yujun Shin², Jaewon Rhee¹, Seungyoung Ahn¹ ¹Korea Advanced Institute of Science and Technology, Korea; ²Keimyung University, Korea

TH-ALL-F

ROOM: GALLERY OVERLOOK F EMC MEASUREMENTS, TECHNIQUES, TEST INSTRUMENTATION AND FACILITIES, STANDARDS AND REGULATIONS AND MEASUREMENT UNCERTAINTY

9:00am

Joint Radio-Frequency Transmission and DC Resistance Measurements of a T-slot Interlocking Metasurface

Jon W. Wallace, Jeffrey A. Osterberg, Benjamin Young, Philip J. Noell, Brad L. Boyce Sandia National Laboratories, USA 11:00am A Real-Time Microwave Camera Prototype with

Zero-Bias Diode Detectors for EMI Source Imaging Xin Yan, Liang Liu, Victor Khilkevich Missouri University of Science and Technology, USA

TH-PM-G

ROOM: GALLERY OVERLOOK G ADVANCED EMC DESIGN BASED ON NEAR-FIELD MODELING AND METASURFACE

4:00pm

Transmission Line Intra-pair Skew Analysis and Management on PCIe 6.0

Xinjun Zhang, Wenwu Wang, Weizhe Li, Mo Liu, Chenghai Yan, Kai Xiao, Xiaoning Ye Intel Corporation, China



BEST SYMPOSIUM PAPER FINALISTS

BEST SIPI PAPER FINALISTS

TU-ALL-H

ROOM: GALLERY OVERLOOK H SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE

1:30pm

Power Supply Induced Jitter (PSIJ) Modeling, Analysis, and Optimization of High Bandwidth Memory (HBM) I/O Interface

Hyunwook Park¹, Taein Shin¹, Seongguk Kim¹, Keeyoung Son¹, Keunwoo Kim¹, Boogyo Sim¹, Hyungmin Kang¹, Seonguk Choi¹, Jiwon Yoon¹, Hyunwoo Kim¹, Chulsoon Hwang², Joungho Kim¹

¹Korea Advanced Institute of Science and Technology, Korea; ²Missouri University of Science and Technology, USA

3:30pm

Signal Integrity Analysis of Wire Bonding Finger Capacitance to Reduce the Reflection of Multi-Drop Topology for Low-Power Double Data Rate (LPDDR)

Hyunwoong Kim¹, Gagyeong Park¹, Seunghun Ryu¹, Jongwook Kim², Jaehoon Lee², Seungyoung Ahn¹ ¹Korea Advanced Institute of Science and Technology, Korea; ²SK hynix Inc., Korea

4:00pm

Design and Analysis of Double-Side Characteristic Impedance Compensation Structure in 2.5D / 3D Package for High-Speed Serial Link

Seonghi Lee1, Hyunwoong Kim1, Jiyoung Park2, Yongho Lee2, Sungwook Moon2, Seungyoung Ahn1 *IKorea Advanced Institute of Science and Technology, Korea; 2Samsung Electronics Co., Ltd., Korea*

TH-ALL-H

ROOM: GALLERY OVERLOOK H

SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE

8:30am

Modeling Power Supply and Ground-Bounce Induced Jitter for a Voltage-Mode Driver Circuit Driving Long Transmission Lines

Vinod Kumar Verma, Dinesh Junjariya, Jai Narayan Tripathi

Indian Institute of Technology Jodhpur, India

4:00pm

A Physics-Based Genetic Algorithm for Decap Optimization in Power Distribution Networks

Ling Zhang¹, Li Jiang¹, Shurun Tan², Yuru Feng¹, Hanzhi Ma¹, Da Li¹, ErPing Li¹

¹Zhejiang University, China; ²Zhejiang University/ University of Illinois at Urbana-Champaign Institute, China

BEST EMC STUDENT PAPER FINALISTS

TU-ALL-F ROOM: GALLERY OVERLOOK F EMC WIRELESS TECHNOLOGIES, EMC PLANNING/TESTING/ SPECIFICATIONS, WIRELESS COEXISTENCE

4:30pm

Challenges and Prospects of Vehicle OTA Spherical Near-Field Measurement Probes

Dao Lin¹, Zhanghua Cai², Lidong Chi², Fuhai Li¹, James L. Drewniak³, Gang Feng³, Yihong Qi² ¹Hunan University, China; ²LinkE Technologies Co., Ltd., China; ³Missouri University of Science and Technology, USA

WE-ALL-D

ROOM: GALLERY OVERLOOK D EM INTERFERENCE CONTROL, SHIELDING, GASKETS, CABLES, CONNECTORS, GROUNDING AND PCB LAYOUT 9:30am

Near Field Scanning-Based EMI Radiation Root Cause Analysis in an SSD

Xiangrui Su¹, Wenchang Huang¹, Junghee Cho², Joonki Paek², Chulsoon Hwang¹ ¹Missouri University of Science and Technology, USA; ²SK hynix Inc., Korea

WE-PM-PS

ROOM: EXHIBIT HALL POSTERS POSTER SESSION

1:30pm

Failure Mechanisms Analysis in GaN HEMTs under High-Power Microwave Pulses Yue Zhang, Liang Zhou

Shanghai Jiao Tong University, China

EMC+SIPI

BEST SYMPOSIUM PAPER FINALISTS

BEST EMC STUDENT PAPER FINALISTS

TH-ALL-D

ROOM: GALLERY OVERLOOK D HIGH POWER ELECTROMAGNETICS, ESD AND TRANSIENTS, EMP, IEMI AND LIGHTNING, GEOMAGNETIC STORM EMC

10:30am

Reconstruction of Sound Information Leakage Signals Obtained from Multiple Demodulation Methods Taiki Kitazawa, Seiya Takano, Yuichi Hayashi

Nara Institute of Science and Technology (NAIST), Japan

TU-ALL-F

ROOM: GALLERY OVERLOOK F EMC WIRELESS TECHNOLOGIES, EMC PLANNING/TESTING/ SPECIFICATIONS, WIRELESS COEXISTENCE

3:00pm

Oxidation Layer Formation on Aluminum Substrates with Surface Defects Using Molecular Dynamics Simulation

Emmanuel Olugbade¹, Hiep Pham¹, Yuchu He², Haicheng Zhou², Chulsoon Hwang¹, Jonghyun Park¹ ¹Missouri University of Science and Technology, USA; ²Google LLC, USA

BEST SIPI STUDENT PAPER FINALISTS

TU-ALL-H ROOM: GALLERY OVERLOOK H SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE

11:30am

On Finding an Equivalent Force to Mimic the Multilayer Ceramic Capacitor Vibration

Yifan Ding¹, Jianmin Zhang², Mingfeng Xue², Shenyin Ding², Benjamin Leung², Eric A. MacIntosh², Chulsoon Hwang¹ ¹Missouri University of Science and Technology, USA; ²Google LLC, USA

4:00pm

Design and Analysis of Double-Side Characteristic Impedance Compensation Structure in 2.5D / 3D Package for High-Speed Serial Link

Seonghi Lee¹, Hyunwoong Kim¹, Jiyoung Park², Yongho Lee², Sungwook Moon², Seungyoung Ahn¹ ¹Korea Advanced Institute of Science and Technology, Korea; ²Samsung Electronics Co., Ltd., Korea

WE-ALL-H

ROOM: GALLERY OVERLOOK H SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE

9:00am

Die Capacitance and Power Distribution Network Modeling Method through Measurement of Resonant Frequency

Marie Peyrard^{1,2}, Gilles Jacquemod¹, Nicolas Froidevaux², Mélanie Moign²

¹Universite Cote d'Azur Institut Universitaire de Technologie, France; ²STMicroelectronics, France

TH-ALL-H

ROOM: GALLERY OVERLOOK H SIGNAL AND POWER INTEGRITY, INTERCONNECTS, MODELING AND CHARACTERIZATION, CROSSTALK, JITTER, NOISE 11:00am

A Thermal-Aware DC-IR Drop Analysis for 2.5D IC Shengxuan Xia¹, Baris M. Dogruoz², Yansheng Wang², Songping Wu², Siqi Bai², Chulsoon Hwang¹, Zhonghua Wu² ¹Missouri University of Science and Technology, USA; ²Rivos Inc., USA



STANDARDS WEEK

STANDARDS ACTIVITIES PLANNED FOR THE 2023 IEEE EMC+SIPI SYMPOSIUM

By Karen Burnham and Ross Carlton, Standards Week Co-Chairs

This year's Standards Week program continues to offer many opportunities to learn about or engage in Standards activities of the IEEE EMC Society. Standards Week will offer a wide range of technical papers, tutorials, workshops, and meetings that are related to or focused on standards. While attending papers, tutorials, and workshops requires a Symposium registration, please note that all Standards meetings are open to all who would like to attend. Standards meetings include the SACCom, SDECom, Working Group, Continuity Group, and standards Updates. No registration fee or membership is required to attend, only your interest in Standards. Please drop by the registration desk for a free pass and join us.

Standards impact much of what we do in the EMC world. Whether designing for EMC, testing for EMC, operating an accredited EMC laboratory, making EMC-related measurements, manufacturing EMC components, documenting EMC performance, developing EMC simulation models, creating simulation tools, or most anything else, standards are there to promote consistency and document best practice. No matter if you are interested in education, developing a new standard, or changing an existing standard, we invite you to enjoy the program and engage with us.

To that end - while at the Symposium, be on the lookout for attendees with a "Standards" ribbon on their badge. These are people already involved in Standards activities and probably a member of one of one of our major Committees – SACCom and SDECom. Be sure to strike up a conversation with one of these new or old hands at Standards and see what Standards development and education has to offer you.

You will also find the IEEE EMC Society and others, such as the ASC C63 EMC committee and various accrediting organizations, staffing booths in the exhibit hall, ready to meet you, answer questions you may have, and to talk about Standards and their impact.

Standards Week kicks off on Monday morning, bright and early. First up is the meeting of the Standards Advisory and Coordination Committee (SACCom), which establishes and maintains representatives to various non-IEEE Standards Development Organizations (SDOs) that provide the EMC Society with up-to-the-minute information on standardization work you may not hear about elsewhere. SACCom is also a gathering place where the representatives get an opportunity to meet with each other and talk about standards with their peers in other SDOs. After the morning break, we will continue with the meeting of the Standards Development and Education Committee (SDECom), which sponsors EMC Society standards. SDECom reviews the standards under development, monitors progress, and discusses what new standardization work may be needed. SDECom meets again on Thursday to review progress made at the Symposium.

Throughout the week you will also find many other opportunities for standards-related learning and participation. Many workshops and tutorials on Monday and Friday offer unique and focused topics that are driven by Standards. Wednesday through Thursday you will find various Standards meetings including Working Groups, Continuity Groups and Updates. Working Group meetings can range from individuals doing actual work on standards to mini-tutorials on what the IEEE EMC standard contains. Standards Continuity Group meetings are our mechanism to preserve knowledge between standards development activities and provide a forum for reviewing and proposing new work. Updates will provide you with the latest on the topic Standard.





STANDARDS WEEK

A summary of the planned Standards Week activities is provided in the following table. Additional Working Group or Continuity Group meetings may be scheduled.

DAY	TIME (CDT)	MEETING TITLE
MON, JUL 31	12:00 PM - 1:30 PM	Strategic Standards for Education Round Table
	8:30 AM - 10:00 AM	SACCom Meeting
TUE, AUG 1	12:00 PM - 1:00 PM	IEEE 473 Working Group
	3:30 PM - 5:30 PM	P2710 Update
	8:00 AM - 9:00 AM	Shielding Standard Continuity Group
	8:30 AM - 10:30 AM	IEEE 1848 Working Group
WED, AUG 2	9:00 AM - 10:00 AM	IEEE 299 & 299.1 Working Group
	12:00 PM - 2:00 PM	P2855 Working Group
	2:00 PM - 4:00 PM	Computational EM Standards Continuity Group
	7:00 AM - 10:00 AM	P2838 Working Group
THU, AUG 3	8:30 AM - 12:00 PM	IEEE 1848 MSSV (Machinery) Study Group
	2:00 PM - 4:00 PM	SDECom Meeting (WG & CG Reports)
FRI, AUG 4	8:00 AM - 12:00 PM	I/O Buffer Info Specification (IBIS) Summit

The project descriptions for Working Groups planning to meet at the Symposium are noted below. Additional information on these projects can be found at the website of the IEEE Standards Association (IEEE-SA) located at <u>https://standards.ieee.org/standard/</u>. The Project Authorization Request (PAR) Approval link on each project page will take you to the project's PAR, which provides the project's purpose, leadership, and other useful information.

PROJECT	DESCRIPTION
IEEE 299	Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures
IEEE 299.1	Standard Method for Measuring the Shielding Effectiveness of Enclosures and Boxes Having all Dimensions between 0.1m and 2m
IEEE 473	Recommended Prectice for an Electromagnetic Site Survey (10kHz - 10 GHz)
IEEE 1848	Standard for Techniques and Measures to Manage Functional Safety and Other Risks with Regard to Electromagnetic Disturbances
P2710	Recommended Practice for Techniques to Evaluate the Performance of Enclosures and Other Methods for Electromagnetically Shielding Portable Electronic Devices
P2838	Standard for Aircraft Component Lightning Strike Direct Effects Qualification
P2855	Recommended Practice for the Electromagnetic Characterization of Cable/Connector Assembly Shielding Effectiveness (DC to 40 GHz)

And last but certainly not least, you may not be familiar with the **I/O Buffer Info Specification (IBIS) Summit** planned for Friday morning. The **IBIS Summit** is a meeting of the IBIS Open Form, which develops and maintains standards for electronic behavioral specifications of integrated circuit input/output analog characteristics including IBIS, IBIS-AMI, IBIS-ISS, ICM, and Touchstone. These standards enable a method for sharing integrated circuit I/O models between silicon vendors, simulation software vendors, and end customers. These models are key for efficient and accurate modeling of EMI and SIPI performance. While attending the IBIS Summit is free of charge, pre-registration is required. For the registration contact, please refer to the IBIS Summit details in this program or the IBIS events page at <u>https://ibis.org/events/</u>.



TECHNICAL COMMITTEES

EMC SOCIETY TECHNICAL COMMITTEES -BUILD YOUR EXPERTISE AND YOUR CAREER

No matter where you are in the industry, at some point you will deal with an EMC issue. Maybe a device is causing interference or maybe it's vulnerable to radio-frequency fields. Maybe a device crashes or resets after an electrostatic discharge. Maybe you've been looking for help explaining an EMC problem to your customer or your boss. All of these things happen. **Become part of the solution.**

The **IEEE EMC Society's Technical Committees (TCs)** convene to set EMC standards & practices and develop tools for success. Covering topics ranging from professional development to nanotechnology, the TCs are volunteer consensus groups that build our industry's foundations. Join remotely or in-person and help form important technical practices.

Find your place among these forward-looking committees. Join a TC today and set standards, explore emerging technology and help develop programs and create the tools that you and your industry need.

If you are interested in joining a committee, please complete the TC/SC Interest form. <u>https://www.emcs.org/committees/technical-committees/tc-sc-interest-form/</u>

WORKING GROUPS AND TECHNICAL COMMITTEE MEETINGS

The EMC Society has many working groups and committees that are tackling the wide range of functions of the society's mission. The working groups primarily come out of the EMC Society Standards activities developing new EMC Standards and revising existing standards. Standing and special committees are formed to address a broad range of needs, ranging from interfacing with other industry organizations to dealing with the administration of the society. All of these meetings are open to everyone (unless listed otherwise). Join them for breakfast, breaks, lunch or dinner. Learn what other EMC members are working on and influence how the society operates.

COLLATERAL MEETINGS

With so many people attending this pinnacle event from across the globe, it's a perfect opportunity for groups other than the EMC Society to hold meetings in parallel to the Symposium. Be sure to check out the schedule to find out about the numerous collateral meetings and who can participate. The EMC Society is neither responsible for nor endorses any of these collateral meetings and discourages any meetings from conflicting with the technical and networking programs of the Symposium.





TECHNICAL COMMITTEES

TC 1 EMC Management	This committee is concerned with the development and dissemination of Best Practices and Methodologies for the successful leadership, supervision and guidance of EMC related activities. These Best Practices and Methodologies shall be structured so as to provide assistance to all managers, and engineers. Appropriate and convenient tools shall serve as a foundation to these Best Practices and Methodologies.
TC 2 EMC Measurements	The committee reviews the adequacy of measurement procedures and measurement instrumentation specifications for radiated and conducted emission and immunity tests. Also discussed is the rationale for product emission limits and immunity test levels including performance requirements. The committee also supports EMC standards and procedures that deal with measurements and their uncertainty and how they are interpreted and applied.
TC 3 Electromagnetic Environment	 The charter of TC3, the Technical Committee on Electromagnetic Environment is to encourage research on the: electromagnetic environment (EME) development of standards for EME measurement and characterization natural and man-made sources of electromagnetic environment that comprise this environment effects of noise (unwanted portions of EME) on systems performance effects of international civil and military standards intended to control manmade intentional and unintentional emissions of electromagnetic energy.
TC 4 Electromagnetic Interference Control	This committee is concerned with design, analysis, and modeling techniques useful in suppressing interference or eliminating it at its source. Bonding, grounding, shielding, and filtering are within the jurisdiction of this committee. These activities span efforts at the system, subsystem, and unit levels
TC 5 High Power Electromagnetics	This committee is concerned with the effects and protection methods for electronic equipment and systems for all types of high power and other electromagnetic threat environments. These environments include electromagnetic pulse (EMP), intentional EMI environments (i.e., narrowband and wideband), lightning electromagnetic currents and fields, electrostatic discharge and geomagnetic storms. In addition this committee deals with the commercial data security issue through electromagnetic information leakage activities. Interactions with subsystems, systems and platforms are included.
TC 6 Spectrum Engineering	This committee is concerned with the analysis, design, and measurement techniques for intentional RF transmitting and receiving equipment to prevent interference and promote efficient spectrum use through technology and operational based approaches, such as software design, dynamic spectral allocation, waveform control, as well as frequency coordination and management procedures.
TC 7 Low Frequency EMC	This technical committee is concerned with low-frequency EMC including Power Quality in electric power systems. The committee is focusing on application of fundamental EMC concepts also to low frequency conducted disturbances. EMC in power systems is expected to be increasingly important. This is due to increased use of electronics in renewables, electric vehicles, energy efficient technologies and Smart Grid applications



TECHNICAL COMMITTEES

TC 8 Aeronautics and Space EMC	This committee is concerned with EMI/EMC issues in aircraft, spacecraft & space launch vehicles, robotic and crewed. The space environment provides unique challenges in the design, development, test and operation of space systems to avoid EMI and achieve EMC. Aeronautics & space EMC covers a wide range of topics on the part, board, box, system, multi-system, planetary and interplanetary levels. The harshness of the atmospheric, launch and space environments necessitates a broader view of EMC issues than traditional terrestrial projects, often leading to creative methods and solutions that can benefit our society's efforts elsewhere on Earth.
TC 9 Computational Electromagnetics	This committee is concerned with broad aspects of Applied Computational Electromagnetic techniques which can be used to model electromagnetic interaction phenomena in circuits, devices, and systems. The primary focus is with the identification of the modeling methods that can be applied to interference (EMC) phenomena, their validation and delineating the practical limits of their applicability. Included are low and high frequency spectral- domain techniques and time-domain methods.
TC 10 Signal and Power Integrity	This committee is concerned with the design, analysis, simulation, modeling and measurement techniques useful in maintaining the quality of electrical signals and power distribution network in printed circuit boards, ICs and within systems. These activities encompass all aspects of signal and power integrity from the integrated circuit level to the system level.
TC 11 Nanotechnology and Advanced Materials	Concerned with modelling, simulation and experimental characterization of nanomaterials and nanodevices for EMC applications. Nanotechnology is the understanding and controlling of matter at atomic and molecular scale. Nanotechnology has already found its way into various EMC applications. New materials such as single- and multi-phase composites filled with nanoparticles, nanotube and/or nanofibres have been designed and tested for gaskets and absorbing screens with outstanding performance and capabilities. Innovative nanostructured shields have shown multifunctional properties and higher efficiency than commonly used materials. Nanowires for high speed interconnects and high density integrated systems, could replace copper in the near future, but require adequate modelling and simulation approaches for signal integrity and also to avoid electromagnetic interference problems.
TC 12 EMC for Emerging Wireless Technologies	 This committee is concerned with the EMC design, analysis, modeling, measurement, and testing aspects of emerging wireless products, such as Internet of Things and 5th Generation of Wireless Communication. The committee encourages research including but not limited to the following areas: Innovative Wireless Component Design for System Integration: wireless component design with integrated EMC functions and/or meeting certain EMC specifications Radio-Frequency Interference and De-sense: characterization and mitigation of interference from digital circuits to wireless antennas EMC and OTA Measurement & Testing of Wireless Systems: development of methods and standards for wireless performance and compliance testing Wireless radios, as well as related testing methods and standard development Wireless Product or Subsystem EMC: wireless-specific EMC design for Autonomous cars, Phased Array, and others.



TECHNICAL COMMITTEES

SC 1 Smart Grid	This special committee is concerned with coordinating the EMC Society activity on providing EMC principles for those organizations and associated documentation and specifications that address the efficient use of the AC power grid including the control of power entering a house or building. Such control may be from a meter at the point of power entry into these facilities to control incorporated into appliances and other electronic devices in these facilities. Such controllers may be sources of undesirable RF emissions and at the same time vulnerable to the RF environment which speaks to the need for EMC. It is expected that the coordination aspect of this special committee will involve several EMCS Technical Committees.
SC 3 Machine Learning and Artificial Intelligence in EMC and SIPI	This Special Committee is concerned with all aspects of machine learning, artificial intelligence and deep learning as it applies to all aspects of Electromagnetic Compatibility, Signal Integrity and Power Integrity.
SC 5 Power Electronics EMC	This special committee is concerned with power electronics converters EMI/ EMC issues. These are mainly, converters that use switching frequency schemes to control the output parameters, such as voltage and current. These converters, including inverters, can be found as interface between the raw power and the electrical grid to provide the end-user with the desired operating power. Applications can range from grid-connected PV systems, wind farms, automotive, aerospace, and communication systems.
Standards Advisory and Coordination Committee (SACCom)	 The IEEE EMC Society Standards Advisory and Coordination Committee is responsible for providing technical liaison between the IEEE EMC Society Standards Development Committee and various non-IEEE entities involved with EMC standards activities. In particular, the SACCom will include the following: Propose to the EMCS board of directors (BOD), the appointment of representatives to various non-IEEE standards developing entities. To monitor the activities of various non-IEEE standards developing organizations with a view toward making recommendations to the EMCS board of directors on any required coordination of those activities within the society. To communicate and coordinate with non-IEEE standards developing activities and the EMCS Standards Development Committee on matters relating to the development of EMC related standards.
Standards Development and Education Committee (SDECom)	The IEEE EMC Society Standards Development and Education Committee is responsible for guiding the development of IEEE EMC Standards, the training of those involved in the standards making process and the education of the EMC Society community on all aspects of EMC Standards. The IEEE EMC Society is the primary international developer of fundamental test, measurement and verification standards for EMC.
Education Committee (EdCom)	This committee's mission is to promote EMC education related activities of the IEEE EMC Society. Our vision is to provide opportunities for individuals and organizations involved with electrotechnology and products to become aware of EMC at levels consistent with their needs, and our goals are to establish an awareness of EMC fundamentals throughout industry and academia as well as to enhance EMC education through the development of improved education techniques, materials, opportunities, and communications.

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COLLATERAL MEETING SCHEDULE

WORKING GROUPS, COLLATERAL MEETINGS & SOCIAL EVENTS

Technical Committee, Standards and EdCom Meetings -All meetings will be held via Webex for those unable to attend in person.

Meeting URL: <u>https://ieee.webex.com/ieee</u> Password: Virtual2023

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MEETING	TIME	LOCATION	SESSION TYPE	ATTENDEES	WEBEX #
EMC Society Board of Directors Meeting	9:00 AM - 5:00 PM	Gerald Ford Ballroom (Amway Grand)	Other	Pre-Registration	
MONDAY, JULY 31					
MEETING	TIME	LOCATION	SESSION TYPE	ATTENDEES	WEBEX #
Speaker Breakfast	7:00 AM - 8:00 AM	Grand Gallery DEF	Other	Speakers Only*	
Technical Advisory Committee (TAC) Meeting #1	7:00 AM - 9:00 AM	Riverview Overlook E/F	Technical Committee		2634 320 3009
EMC Society Chapter Chairs Meeting	12:00 PM - 1:30 PM	Riverview Overlook E/F	Social Event		2630 636 6483
Strategic Standards for Education Round Table	12:00 PM - 1:30 PM	Riverview Overlook A	Standards Meetings		2632 436 6303
SC-1 Smart Grid and EMC Issues Committee Meeting	5:30 PM - 6:30 PM	Riverview Overlook A	Technical Committee		2631 098 1843
Young Professionals - Speed Networking with EMC	6:00 PM - 10:00 PM	Founders Brewing Co. Centennial Room	Social Event	Pre-Registration	

TUESDAY, AUGUST 1

MEETING	TIME	LOCATION	SESSION TYPE	ATTENDEES	WEBEX #
Speaker Breakfast	7:00 AM - 8:00 AM	Grand Gallery DEF	Other	Speakers Only*	
IEEE EMC Society Education Committee Meeting	7:00 AM - 9:00 AM	Riverview Overlook E/F	Technical Committee		2632 650 7747
TC-2 EMC Measurements Committee Meeting	7:30 AM - 9:00 AM	Riverview Overlook B	Technical Committee		2630 930 0076
Machinery Sector Version of IEEE 1848 on EM Resilience - Working Group	8:00 AM - 9:00 AM	Riverview Overlook D	Standards Meetings		2633 654 0937
T-EMC Associate Editor Meeting	8:00 AM - 10:00 AM	Riverview Overlook C	Communication Services		2632 080 2622
Standards Advisory & Coordination Committee (SACCom) Meeting	8:30 AM - 10:00 AM	Riverview Overlook A	Standards Meetings		2633 709 2369
TC-8 Aeronautics and Space EMC Committee Meeting	12:00 PM - 1:00 PM	Riverview Overlook E/F	Technical Committee		2634 906 4996
TC-9 Computational Electromagnetics Committee Meeting	12:00 PM - 1:00 PM	Riverview Overlook D	Technical Committee		2634 557 1323
SC-5 Power Electronics EMI/EMC Committee Meeting	12:00 PM - 1:00 PM	Riverview Overlook C	Technical Committee		2632 519 5282
IEEE 473 Recommended Practice for Site Surveys	12:00 PM - 1:00 PM	Riverview Overlook A	Standards Meetings		2634 716 4060
Update on P2710 "Recommended Practice for Techniques to Evaluate the Performance of Enclosures and Other Methods for Electromagnetically Shielding Portable Electronic Devices	2:00 PM-4:00 PM	Riverview Overlook A	Standards Meetings		2633 052 3060
EMC+SIPI 2023 Welcome Reception	6:00 PM-8:00 PM	Exhibit Hall	Social Event	Pre-Registration	
Young Professionals - After the Welcome Reception Social	8:00 PM - 11:00 PM	Grand Rapids Brewing Co.	Social Event	Pre-Registration	

COLLATERAL MEETING SCHEDULE

WEDNESDAY, AUGUST 2

MEETING	TIME	LOCATION	SESSION TYPE	ATTENDEES	WEBEX #
Speaker Breakfast	7:00 AM - 8:00 AM	Grand Gallery DEF	Other	Speakers Only*	
TC-1 EMC Management Committee Meeting	7:30 AM - 9:00 AM	Riverview Overlook A	Technical Committee		2632 664 3478
L-EMCPA Associate Editor Meeting	8:00 AM - 9:00 AM	Riverview Overlook D	Communication Services		2633 032 3157
Shielding Standards Continuity Working Group	8:00 AM - 9:00 AM	Riverview Overlook E/F	Standards Meetings		2633 145 5223
TC-11 Nanotechnology and Advanced Materials Committee Meeting	8:00 AM - 9:00 AM	Riverview Overlook C	Technical Committee		2633 404 4296
TC-12 EMC for Emerging Wireless Technologies Executive Committee	8:00 AM - 9:00 AM	Riverview Overlook B	Technical Committee		2634 194 3056
IEEE 299 and 299.1 Working Group Meeting	9:00 AM - 10:00 AM	Riverview Overlook A	Standards Meetings		2630 793 8319
Managing Functional Safety Risks Caused by EMI - IEEE 1848-2020 Continuity Working Group	9:00 AM - 11:00 AM	Riverview Overlook C	Standards Meetings		2631 333 0263
TC-10 Signal and Power Integrity Committee Meeting	12:00 PM - 1:00 PM	Riverview Overlook E/F	Technical Committee		2630 264 7819
Past Presidents Luncheon	12:00 PM - 1:30 PM	Grand Gallery D	Social Event	Invitation Only	
TC-7 Low Frequency EMC Committee Meeting	12:00 PM - 1:30 PM	Riverview Overlook B	Technical Committee		2632 423 2421
TC-5 High Power Electromagnetics (HPEM) Committee Meeting	12:00 PM - 1:30 PM	Riverview Overlook D	Technical Committee		2633 680 1521
IEEE Standard Project P2855 Working Group Meeting	12:00 PM - 2:00 PM	Riverview Overlook A	Standards Meetings		2631 851 6618
TC-4 Electromagnetic Interference Control Committee Meeting	12:00 PM - 2:00 PM	Riverview Overlook C	Technical Committee		2634 894 8889
EMC+SIPI 2023 Youth Technical Program	1:00 PM - 3:30 PM	Paintland Ballroom (Amway Grand)	Social Event	Pre-Registration	
CEM and Validation	2:00 PM - 4:00 PM	Riverview Overlook D	Standards Meetings		2632 632 5589
Women in Engineering Event (WIE)	3:00 PM - 5:00 PM	Grand Gallery Overlook A	Social Event		
EMC+SIPI 2023 Gala Dinner	7:00 PM - 10:00 PM	Steelcase Ballroom C/D	Social Event	Pre-Registration	

THURSDAY, AUGUST 3

MEETING	TIME	LOCATION	SESSION TYPE	ATTENDEES	WEBEX #
Speaker Breakfast	7:00 AM - 8:00 AM	Grand Gallery DEF	Other	Speakers Only*	
TC-6 Spectrum Engineering Committee Meeting	7:00 AM - 8:30 AM	Riverview Overlook B	Technical Committee		2634 029 6225
IEEE 1848 MSSV (Machinery) Study Group	8:30 AM - 12:00 PM	Riverview Overlook C	Standards Meetings		2633 653 9370
TC-3 Electromagnetic Environment Committee Meeting	9:00 AM - 10:00 AM	Riverview Overlook B	Technical Committee		2632 042 7437
P2838 WG Lightning Qualification Standard	9:00 AM - 12:00 PM	Riverview Overlook A	Standards Meetings		2633 557 9852
EMC+SIPI 2023 Awards Luncheon	12:30 PM - 2:00 PM	Steelcase Ballroom C/D	Social Event	Pre-Registration	
EMC-S PerCom Meeting	2:00 PM - 3:00 PM	Riverview Overlook C	Communication Services		2633 270 3997
Standards Development & Education Committee (SDECom) Meeting	2:00 PM - 4:00 PM	Riverview Overlook A	Standards Meetings		2633 900 4479
SC-3 Special Committee on Machine Learning and Al in EMC and SIPI - Inaugural Meeting	2:00 PM - 4:00 PM	Riverview Overlook B	Technical Committee		2630 190 8062
Discussion: Is There a Role for Open Software in EMC + SIPI	2:00 PM - 4:00 PM	Riverview Overlook E/F	Technical Committee		2631 528 4919
EMC Society Board of Directors Meeting	6:00 PM - 8:00 PM	Riverview Overlook E/F	Other	Pre-Registration	

FRIDAY, AUGUST 4					
MEETING	TIME	LOCATION	SESSION TYPE	ATTENDEES	WEBEX #
Speaker Breakfast	7:00 AM - 8:00 AM	Grand Gallery DEF	Other	Speakers Only*	
Technical Advisory Committee (TAC) Meeting #2	7:00 AM - 9:00 AM	Riverview Overlook E/F	Technical Committee		2631 368 6365
IBIS Summit	8:00 AM - 12:00 PM	Grand Gallery Overlook A	Standards Meetings	Pre-Registration	2632 627 1828

EMC+SIPI



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ANSI 63

EMISSION MEASUREMENTS OF ANSI C63.4 AND TIME DOMAIN APPLICATIONS (ANSI C63.25 SERIES) (Visit www.c63.org for more information)

This workshop will share the activity currently underway in the ANSC C63[®] committee for C63.4 and C63.25 series. Among the many updates, EMC Site Validation requirements are migrating from C63.4 to the C63.25 standards series: ANSC C63 - C63.25.1, C63.25.2, and C63.25.3. Topics covered include: (1) Review of the latest draft edition of ANSI C63.4:20xx and (2) Application of Time Domain (TD) SVSWR in C63.25.1 (1 GHz – 18 GHz) (3) Newly streamlined procedures for site validation measurements in C63.25.2 (30 MHz – 1 GHz) (4) Latest development for site validations using Cylindrical Mode Filtered SVSWR (CMF SVSWR) measurements for test site validation and antenna calibration (18 GHz – 40 GHz) to be included in C63.25.3.

This workshop is designed to increase your understanding of the C63.4 standard and the expected changes in the next revision, and what to anticipate in the new C63.25 series on EMC site validation methods.

For the C63.4 discussions, there will be an analyses and changes in the requirements for the above 1 GHz test method, use of the 2 dB rule, compliance files, test setup changes and many other aspects.

For the C63.25 discussion, application of time domain and mode filter methods for validating EMC test sites will also be presented along with a live demonstration on its usage. As time permits, attendees will get a chance to apply what they learned via problem solving.

In the C63.4 workshop, you will learn:

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

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

State

Fax

Zip

- Application for site validation
- Application for antenna calibration

Support material provided

Daytime Phone

and an invoice will be emailed to you.

Check or Credit Card Number must accompany registration.

To pay by credit card, please so indicate when you submit your registration form

Ms./Mr.____ Company____ Address

Citv

Email

Signature:

- A complete lecture flash drive
- FCC handouts and references

WHO SHOULD ATTEND

Those responsible for determining compliance with FCC Rules and Regulations (and CISPR 22), including:

- Product managers and developers
- EMC engineers and test technicians
- Regulatory compliance managers
- Test instrumentation developers
- Those using and calibrating antennas in making radiated emission compliance measurements
- Calibration technicians
- Calibration and measurement accreditation bodies
- Lab quality assessors
- Test instrumentation and chamber manufacturers

EXPERT INSTRUCTORS

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

DATES AND LOCATION • JULY 28-29, 2023

Grand Valley State University/E3 Compliance in Grand Rapids, MI. See www.emc2023.org for symposium hotel info and to reserve your hotel room.

FEE INCLUDES

Complete lecture flash drive, continental breakfast, lunch, breaks, and completion certificate. Fee does NOT include copies of the draft or published standards. Fee does NOT include hotel accommodations.

AGENDA

Friday, July 28

Saturday, July 29

8:30 am: Continental Breakfast 9:00 am to 12:00 pm: Workshop Lectures and Live Demonstrations

EMC+SIP

REGISTRATION FORM Contact: Janet O'Neil • Telephone: 425-443-8106 • j.n.oneil@ieee.org

8:30 am: Registration and Continental Breakfast

9:00 am to 5:00 pm: Workshop Lectures

Workshop Fee – All Day July 28 and Morning Only July 29

By June 15*:	\$1,100 USD
C63 [®] & S/C Members (by June 15)	\$975 USD
Add \$200 if after June 15 or at the door**	\$200 USD
M H H H H H H H H H H	Total USD \$

Make check payable to:

U.S. EMC Standards Corporation in U.S. dollars drawn on a U.S. bank.

Mail to:* Janet O'Neil

ETS-Lindgren 8422 NE Meadowmeer Drive

Bainbridge Island, WA 98110

NOTE: You are not registered until you receive confirmation.

*Please do not mail after July 10. **With prior telephone or email registration only.

The organizing committee reserves the right to substitute speakers, modify the program (or lecture notes), restrict attendance or to cancel the workshop(s). In the event the workshop is canceled, registration fees will be refunded. No refunds will be made to individuals who cancel after July 10. Substitutions are allowed. <u>Workshops without a minimum of 12 attendees registered by 1 July 2023 will be cancelled and registration fees</u> returned. It is suggested that you book refundable travel arrangements as appropriate if workshop is cancelled.

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CLAYTON R. PAUL GLOBAL UNIVERSITY

EDUCATION

ADVANCE YOUR EMC KNOWLEDGE AND CAREER WITH 20 HOURS OF IN-DEPTH CLASSES ON EMC AT THE IEEE EMC SOCIETY'S PREMIER EDUCATIONAL EVENT.

Chair: Arturo Mediano, Professor, I3A, University of Zaragoza

The first Global University took place at the 2007 International Symposium on EMC in Honolulu, Hawaii. Janet O'Neil, the symposium chair, was looking for events to help encourage people relatively new to EMC to come to the symposium. Dr. Clayton Paul proposed a series of courses taught by internationally recognized EMC instructors from around the world. Together, they organized an event they named "Global University" consisting of ten, two-hour courses that ran throughout the symposium week. The event proved to be very popular and has been a fixture at every EMC symposium since then.

In the early years, the name of the event changed from Global University to Global EMC University to Global EMC & SI University, as the topics and the nature of instruction evolved. However, in 2013 the IEEE EMC Society Education Committee determined that the membership was best served by Global University as it was originally envisioned and organized by Dr. Paul. The committee established strict standards for both the topics and instructors to ensure a high-quality educational experience. They also renamed the event "Clayton R. Paul Global University."

The topics for this year's Global University are those that have been proven to be valuable to participants in previous symposia. The event for this year will provide the attendees with a great learning experience, due to the ability for interaction between instructors and attendees, as well as providing networking among attendees.

This year's Global University will truly be an event that honors Dr. Paul's efforts and dedication to the EMC Society as well as maintains his high standards in providing EMC educational opportunities!

PLEASE NOTE: The Clayton R. Paul Global University course content is intended for engineers who have been working in EMC and/or SIPI for several years and wish to be able to deepen their understanding. It is suggested that those who would like to attend will have already participated in the "Fundamentals Tutorial" held on Monday during the annual IEEE EMC Society Symposium week.

RATE:

Price: \$400 *Full Registration Required



VISIT <u>www.emc2023.org/clayton-r-paul-global-university.html</u> to learn more and read the full instructor bios.
EDUCATION

SPEAKERS AND TOPICS

Global University will begin with a short introduction followed by eight presentations that will be designed to encourage attendees' questions and will allow the attendees to have opportunities for discussions with the speakers after the tutorial.



SIGNAL SPECTRA Dr. Flavia Grassi Professor, Politecnico Milano IEEE EMC-S TAC Vice-Chair, IEEE EMC-S TC-7 Chair



NON-IDEAL BEHAVIOR OF COMPONENTS Dr. Anne Roc'h Assistant Professor, Eindhoven University of Technology



RADIATED EMISSIONS Mr. Lee Hill

MSEE, Missouri University of Science & Technology Founding Partner, SILENT Solutions LLC & GmbH Adjunct Faculty, Worcester Polytechnic Institute (WPI) Associate Tutor, University of Oxford



CONDUCTED EMISSIONS **Dr. Arturo Mediano**

Professor, I3A, University of Zaragoza Founder The HF Magic Lab IEEE Senior Member. Chair EMC-S Spain Chapter. Past Chair MTT-S MTT-17 Committee.



PCB DESIGN FOR EMC **Dr. Bruce Archambeault** Adjunct Professor, Missouri University of Science & Technology

IBM Distinguished Engineer Emeritus Principal, Archambeault EMI/EMC Enterprises IEEE Fellow. Past President, IEEE EMC Society



SHIELDING Dr. Frank Leferink Professor, University of Twente Technical Authority, THALES Nederland



SIGNAL INTEGRITY Dr. Eric Bogatín Professor, University of Colorado, Boulder Fellow, Teledyne LeCrov Technical Editor, Signal Integrity Journal



CROSSTALK Dr. Darvl G. Beetner

IEEE Fellow

Professor, Missouri University of Science & Technology Director, Missouri S&T Electromagnetic Compatibility Laboratory Director, NSF Center for Electromagnetic Compatibility



ELECTROSTATIC DISCHARGE (ESD) **Dr. Todd Hubing** Professor Emeritus, Clemson University IEEE Fellow, ACES Fellow Past President, IEEE EMC Society



POWER INTEGRITY Mr. James Herrmann, MSEE General Manager and Principal Engineer, Re:Build AppliedLogix, LLC. IEEE Member

TUESDAY, AUGUST 1 - GALLERY OVERLOOK C

TIME (ET)	TITLE	LECTURER
8:00 AM - 10:00 AM	Signal Spectra	Dr. Flavia Grassi
10:30 AM - 12:30 PM	Non-Ideal Behavior of Components	Dr. Anne Roc'h
1:00 PM - 3:00 PM	Radiated Emissions	Mr. Lee Hill
3:30 PM - 5:30 PM	Conducted Emissions	Dr. Arturo Mediano

WEDNESDAT, AUGUST 2 - GALLERT OVERLOOK C						
TIME (ET)	TITLE	LECTURER				
8:00 AM - 10:00 AM	Electrostatic Discharge	Dr. Todd Hubing				
10:30 AM - 12:30 PM	PCB Design for EMC	Dr. Bruce Archambeault				
1:00 PM - 3:00 PM	Shielding	Dr. Frank Leferink				
3:30 PM - 5:30 PM	Signal Integrity	Dr. Eric Bogatín				
THURSDAY, AUGUST 3 - GALLERY OVERLOOK C						
TIME (ET)	TITLE	LECTURER				

Crosstalk 8:00 AM - 10:00 AM Dr. Daryl G. Beetner 10:30 AM - 12:30 PM **Power Integrity** Mr. James Herrmann

*Attendees participating in Clayton R. Paul Global University must attend all 20 hours of the instruction to receive a participation certificate. Other Symposium sessions and activities can be attended outside of these hours.





MEET AND NETWORK WITH Network with your peers and other top industry profession

TUESDAY, AUGUST 1, 2023 • 6:00 - 8:00 PM WELCOME RECEPTION

The EMC+SIPI 2023 Welcome Reception will be held in the Exhibit Hall at the DeVos Place on Tuesday.

One ticket to this event is included in all 5-Day technical registrations and the Companion Program registration. All others may purchase a ticket to the Welcome Reception as an add-on to your registration.

Location: Exhibit Hall B&C- DeVos Place

SPONSORED BY





PRICE:

\$100 age 18+

\$65 age 8-17

EMC+SIPI

LIKE-MINDED INDIVIDUA als throughout the week during numerous planned events!

WEDNESDAY, AUGUST 2, 2023 • 7:00 - 10:00 PM **EVENING GALA EVENT**

The Gala is our symposium celebration that is traditionally a sit-down dinner event with entertainment.

One ticket to this event is included in all 5-Day technical registrations EXCEPT student registrations. This is a change from previous years, made to keep student registration costs down. Extra tickets to the Gala may be purchased as an add-on to your registration.

Location: Steelcase Ballroom CD - DeVos Place

THURSDAY, AUGUST 3, 2023 • 12:30 - 2:00 PM AWARDS LUNCHEON

The Awards Luncheon is a wonderful opportunity to recognize achievements and network with families and EMC professionals from academia, industry, government, military, and retired sectors. The event will start off with a catered sit-down meal. Afterwards, the EMC Society will take time to recognize members and non-members for their contribution to the Society and for professional excellence.

Location: Steelcase Ballroom CD - DeVos Place



PRICE:

\$120 age 18+

\$80 age 8-17

PRICE:

\$70 age 18+

\$45 age 8-17

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WEDNESDAY, AUGUST 2, 2023 • 12:00 - 1:30 PM PAST-PRESIDENTS LUNCHEON

The Luncheon is open to Past-Presidents of the EMC Society, and current members of the Board of Directors. The luncheon is a chance for the old and the new to mix, exchanging experiences of the past and challenges of the future relative to the EMC profession. A sit down lunch is provided. Past-Presidents should inform the Chair of the History Committee (danhoolihanemc@aol. com) of their interest in attending so there will be seating and food available for all.

Location: Grand Gallery D

PRE-REGISTRATION REQUIRED



Photo by Richard Georger

WEDNESDAY, AUGUST 2, 2023 • 3:00 - 5:00 PM WOMEN IN ENGINEERING

PARTICIPATION IS FREE!

IEEE Women in Engineering (WIE) is a global network of IEEE members and volunteers dedicated to promoting women engineers and scientists, and inspiring girls around the world to follow their academic interests in a career in engineering and science. Our goal is to facilitate the recruitment and retention of women in technical disciplines globally. We envision a vibrant community of IEEE women and men collectively using their diverse talents to innovate for the benefit of humanity.



Let's meet for a networking and enrichment event during the Grand Rapids Symposium and share experiences. We, the IEEE WIE and the IEEE EMC Society, invite you to attend this free event. Join us for a special celebration at the end of the presentations.

Everyone is welcome - men and women - to attend the special presentations!

Location: Grand Gallery Overlook A

Chair: Tara Kellogg, *ETS-Lindgren* Business Development Director; IEEE EMC Society WIE Americas Chair; IEEE EMC Society Central Texas Chapter Chair



See the full agenda in the app and on the Symposium website:

www.emc2023.org/womenin-engineering.html

YOUNG PROFESSIONALS

MONDAY, JULY 31, 2023 • 6:00 - 10:00 PM "SPEED NETWORKING" WITH EMC EXPERTS

Get to know the other young members of EMC Society and comingle with seasoned experts as well! All YPs (BS within 15 years) and Undergraduates are invited for dinner and socializing at our "Speed Networking" event at the Centennial Room of Founders Brewing Company. We'll have eight to ten seasoned EMC Experts for the YPs to network with in three-minute sessions. We will also highlight the Best Student Paper Candidates at this event!

Location: Founders Brewing Co.: Centennial Room

PRICE: \$30 \$40 after July 26, 2023 (Limited Space Available)

(Limited Space Available) Includes: Dinner and 1 Drink



PRICE: \$20 Includes: 2 drinks and

1 appetizer

Photo by Karthik Vepuri

TUESDAY, AUGUST 1, 2023 • 8:00 - 11:00 PM "AFTER THE WELCOME RECEPTION" SOCIAL

Come enjoy The Barn Room at GRBC where we'll have access to a full game room. This is a great opportunity to continue the conversations and fun from the Welcome Reception into the rest of the evening. Relationships formed in the EMC Society can lead to future collaborations and will provide valuable contacts when you need a friend to bounce ideas off!

Location: Grand Rapids Brewing Company: The Barn Room w/Game Room





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COMPANION CLUB



The Companion Club is your chance to meet new people and catch up with old friends. You may register for the Companion Club as a part of the technical attendee's registration or separately.

Paid Companion Club members are welcome to visit the beautiful Companion Suite where a delicious breakfast will be served Monday to Thursday, from 7:00 to 10:00 am. There will also be daily raffles! This year, the EMC+SIPI Symposium offers four attractive group Companion Tours. However, you don't have to be registered for the Companion Club to participate in a tour.

If you register for the Companion Club, you may sign up for the tours with your own registration. Otherwise, you may purchase tours through the technical attendee's registration; there will be a drop down space to add your name.

Join your technical attendee at any of our Social Events for more fun and to meet more people. We have special prices for companions under the age of 18. Tickets to the Welcome Reception, a great networking time for all, are included in all Companion Club registrations. The Evening Gala is also a fun event, and companions are invited to register for this event separately in their Companion Club or technical attendee's registration.

For the younger crowd, our ever popular **Youth Technical Program** is back once again to amaze all companions and guests aged 8 to 17. This program will again be free of charge, but please register early to be assured a project kit. Registration for each young person can be made either through your own Companion Club registration or the technical attendee's registration. Your children don't have to be registered in the Companion Club to sign up for the Youth Technical Program, but an adult must accompany them to the session since this is a hands-on project.

COMPANION CLUB RATES: Adult. age 18+: \$130 Junior, age 8-17: \$85 Children under 8: No charge

VISIT OUR SYMPOSIUM COMPANION **GROUP FACEBOOK PAGE**

JOIN THE BREAKFAST CLUB

Would you like to invite your technical attendee to join you for breakfast in the Companion Suite? "Breakfast Club" tickets may be purchased by the technical attendee as an option for each day breakfast is desired. Tickets must be purchased at a minimum 24 hours in advance to ensure adequate seating and catering.

Join fellow companions at the symposium by registering for the Companion Club. This is an excellent opportunity to meet new people and reconnect with old friends! Adult or youth (ages 8 to 17) companions who are pre-registered may go directly to the registration desk located in the Convention Center to obtain a special Companion Registration Packet. This will include:

- Name badge that will allow you access to the Companion Suite and Exhibit Hall (during regular hours)
- Gift bag with goodies
- One ticket to the Tuesday evening Welcome Reception
- Any tour or social event tickets you may have purchased

Youths (ages 8-17) who are registered for the Junior Companion Club are welcome in the Companion Suite with an adult Companion Club member. Children under age 8 do not receive a gift bag, but will be admitted free if accompanied by a registered adult Companion Club member.

Your ticket to the Welcome Reception is an opportunity to enjoy another great event with your technical attendee where everyone can have more fun and meet new people. It is a great networking time for all. The Wednesday night Gala Banquet is also a fun event; however, companions must purchase tickets separately for that event. Discounted prices are available for youth under age 18, and children under age 8 will be admitted for free if accompanied by a registered adult.

COMPANION TOURS

MONDAY, JULY 31, 2023 • 9:00 AM - 11:00 AM GRAND RAPIDS CITY WALKING TOUR

Enjoy a mix of history, culture, and architecture as we walk the streets of Grand Rapids. Learn about what makes this city so unique, hear the stories from its past and present. See the iconic sights and learn about the famous figures that helped put this city on the map. Learn about the social groups and cultures that helped shape the city. Discover the history of Native Americans and European immigration. See the 1800s building that defined the "Furniture Capital Of The World"; visit President Gerald R. Ford's burial site, admire the iconic sculpture and a city park designed by famous artists, enjoy the river views and much more!

The tour will conclude at the steps of Grand Rapids Public Museum, an impressive history and science museum with exhibits on 3 floors, a 1928 carousel and a planetarium. Guests may choose to return to the hotel or stay and explore the museum on their own. General Admission tickets (not included in the tour) range from \$10-\$12 and can be purchased directly at the museum.

TUESDAY, AUGUST 1, 2023 • 9:00 AM - 12:00 PM GRAND LADY RIVERBOAT CRUISE

Take a 2-hour site-seeing cruise aboard the Grand Lady Riverboat, constructed in the style of steamboats that operated along the Grand River in the 1800s. Built and launched in 1990s, The Grand Lady has 2 covered decks and is powered by 2 stern paddle-wheels running on diesel engine. Board at Boyton's Landing, a historic stop for steamboats in 1830s through the end of the steamboat era around 1910. Enjoy peaceful river scenes and keep an eye out for wildlife as we cruise on the Grand River. Spot deer, bald eagles, herons, cranes, ospreys, and turtles.

Restrooms are available on the Lower Deck. Beverages (soft drinks, draft beer, and wine) and snacks (chips, nuts and candy) are available for purchase at the Lower Deck bar.

WEDNESDAY, AUGUST 2, 2023 • 9:00 AM - 12:00 PM FREDERIK MEIJER GARDENS AND SCULPTURE PARK TOUR

Take a tour of 158-acre botanical garden and outdoor sculpture park, and experience a unique blend of premier horticultural display and fine art. Admire a beautiful display of trees, plants, and flowers from regions around the world. Enjoy tranquility of the Japanese Garden, experience English Perennial Garden, visit Tropical Conservatory and Carnivorous Plant House, walk through Victorian Garden Parlor, Arid Garden and more! Explore the sculpture collection throughout the gardens, featuring more than 200 art pieces.

Guests will have a chance to experience the vast beauty of the outdoor Sculpture Park in comfort, during a narrated tram tour (weather dependent).

THURSDAY, AUGUST 3, 2023 • 9:00 AM - 11:00 AM AROMA LABS EXPERIENCE TOUR

Your signature scent is like a perfect accessory that expresses your personality and individual style. Discover your inner passion for fragrance and mixology during this unforgettable aromatic experience. Join us for this fun and unique activity, enjoy a personable atmosphere and create a unique fragrance to complement your personality! Guests will leave the tour with a uniquely blended perfume spray or rollerball dispenser.

Guests will also have a chance to purchase additional items with their uniquely blended sent if they choose.





PRICE: \$55 Includes: Includes Transportation and gratuities



PRICE: \$55 Includes: Includes Tram Ride, Transportation, and gratuities





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TECHNICAL TOURS

THURSDAY, AUGUST 3, 2023 • 5:50 - 8:00 PM GRAND VALLEY STATE UNIVERSITY & E3 COMPLIANCE

Just across the river from DeVos Place, venue for the IEEE EMC+SIPI Symposium, you will find the DTE EMC Center at Grand Valley State University. Located inside the Shape Corp Innovation Design Center, the DTE EMC Center houses numerous project and design labs. The 6,000 sq. ft. EMC Center is a one-of-a-kind facility that supports EMC education, research, and EMC pre-compliance testing for industry. The center employs co-op students through a unique industry collaboration with E3 Compliance - an onsite EMC, high-speed design consulting, pre-compliance, and diagnostics company.

At E3 Compliance, attendees will see what's inside the 6,000 sq. ft. EMC and highspeed engineering, pre-compliance, and diagnostics lab. Tour highlights include a new 3-meter automated EMC pre-compliance test chamber, a 25 ft. long GTEM cell, an automotive emissions chamber, as well as conducted and radiated reverberation immunity chambers. The lab is equipped with a custom-made near-field EMC scanner and high-speed measurement equipment for signal and power integrity. Visitors will also see electrical and Electro-Static Discharge (ESD) test capabilities, which are intended for various industries.

The tour begins with a delicious buffet dinner hosted by ETS-Lindgren and a welcome by GVSU and E3 Compliance representatives.

- Transportation will be provided upon request; the tour location is a 5-10 minute walk from DeVos Place.
- Dinner Buffet Sponsored by
 Set Solution

SOLD OUT!



GRANDVALLEY

STATE UNIVERSITY.

SCHOOL OF ENGINEERING

ON-SITE REQUIREMENTS: No photography is allowed during DTE EMC Center Lab tour.

FRIDAY, AUGUST 4, 2023 • 9:00AM - 12:00 PM INTERTEK

An ESCO Technologies Company

An ESCO Technologies Company

Board the motor coach from DeVos Place for a short 20-minute journey to Intertek, Grand Rapids. Intertek Grand Rapids is a state-of-the-art 120,000 sq. ft. lab offering a very diverse set of testing services for many industries including the automotive, aerospace, MIL-STD, industrial, medical, building products, furniture, and more. The Intertek Grand Rapids team has a varied background with many employees having worked in the industry for more than 30 years across multiple test disciplines such as electrical and mechanical engineering, EMC, chemistry, metallurgy, volatile organic compounds, and materials science.

The tour begins with an energizing continental breakfast buffet hosted by ETS-Lindgren and a welcome by Intertek's Michael Koffink, Global Technical Lead, EMC, who will provide an overview of the many interesting test capabilities attendees will see on the Intertek tour. Attendees will also learn more about and see Intertek's 10,000 sq. ft. EMC test laboratory that includes three Semi-Anechoic EMC Test Chambers, a Reverb Chamber, and a TEM, Stripline.

- Intertek is located just 3-5 minutes from the Gerald R. Ford International Airport (GRR). Tour attendees may bring their baggage on the bus to Intertek (or drive on their own) and from there easily travel to the airport (transportation from Intertek to the airport is not provided, but is readily available by taxi and ride-share apps such as Uber and Lyft).



SOLD OUT!

ON-SITE REQUIREMENTS: Safety Glasses (provided) and closed toe shoes. No photography is allowed, all tour guests must sign in on arrival.

YOUTH TECHNICAL PROGRAM

WEDNESDAY, AUGUST 2, 2023 • 1:00 - 3:30 PM ENGINEERING MEETS ART WITH E-TEXTILES

The 2023 Youth Technical Program will introduce participants to the basics of the Arduino through the creation of a hand-sewn, personalized, E-textile plush toy, enhanced with programmable LEDs.

The Arduino is an open-source, programmable circuit board that is used around the world by everyone from DIY hobbyists and college students, to modern engineering innovators. The LilyPad is a wearable, washable, E-textile circuit kit with specially-designed circuit components designed to be assembled with conductive thread. Coupled with the Arduino hardware and software platform, the Lilypad E-textile materials can be used to make projects with programmable lights, motors, buzzers, buttons, etc., depending on the needs of the project.

This year's project will provide each participant with a pre-programmed Arduino LilyPad and instructions for assembling the felt plush toy using E-textile components. Participants will also be provided with materials and instructions for modifying the Arduino program at home, should they wish to explore the possibilities of the platform. What may seem like a simple craft project on the surface is meant to serve as a gateway to the Arduino and E-Textile platforms, which will build skills in computer programming and foster creative applications of the technology. Join us and learn what Arduinos can do!



Open to Jr. companions and guests aged 8-19.

PRE-REGISTRATION REQUIRED





Location: Paintland Ballroom (Amway Grand)



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EXHIBIT HALL





ORE THE EXHIBIT HALL A LEARN ABOUT NEW TECHNOL INSTRUMENTATION AND SOLUTIONS THAT SERVICE THE INDUSTRY

WHAT'S HAPPENING IN THE **EXHIBIT HALL?**

- Explore and learn from over a hundred top suppliers
- Attend "Ask the Experts" panels and get your questions answered
- Enjoy Experiments, Demonstrations and **Poster Sessions**
- Visit exhibitor booths to participate in raffles and daily prizes

VISIT EXHIBIT HALL B&C

TUESDAY, AUGUST 1, 2023

Grand Opening Ribbon Cutting 9:20 AM Exhibits Open 9:30 AM - 4:00 PM Exhibits Closed 4:00 PM - 6:00 PM Welcome Reception 6:00 PM - 8:00 PM

WEDNESDAY, AUGUST 2, 2023

Exhibits Open 10:00 AM - 5:00 PM

THURSDAY, AUGUST 3, 2023

Exhibits Open 10:00 AM - 1:00 PM



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EXHIBIT HALL MAP

VIEW THE INTERACTIVE FLOORPLAN IN THE MOBILE APP!



EXHIBIT HALL MAP

EMC+SIPI



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412 TW BENEFIELD ANECHOIC FACILITY

https://www.edwards.af.mil/Units/772nd-Test-Squadron/ The BAF provides a robust and scalable RF T&E infrastructure to ensure weapons system survivability and mission effectiveness for the DoD, industry and our allies. The largest anechoic test facility provides a secure "virtual open-air RF range (OAR) within four walls and ceiling" —a valuable tool providing systems and test engineering applied to the development and the T&E of RF systems. We conduct Antenna Pattern, EW/IO, Electromagnetic Compatibility and Electromagnetic Environmental Effects (E3) tests.



A2LA - AMERICAN ASSOCIATION FOR LABORATORY ACCREDITATION Booth 520

http://www.A2LA.org

American Association for Laboratory Accreditation (A2LA) is among the largest accreditation bodies in the world and the only independent, 501(c)3, non-profit, internationally recognized accreditation body in the United States that offers a full range of comprehensive conformity assessment accreditation services.

A2LA is dedicated to the formal recognition of competent testing in calibration laboratories (including medical laboratories), biobanking facilities, inspection bodies, product certification bodies, proficiency testing providers, and reference material producers. A2LA has over 4,000 ac



ABSOLUTE EMC LLC Booth 418

http://absolute-emc.com

Absolute EMC LIC. is a North American company specializing in EMC testing equipment and knowledge. We offer consulting services for the use of all EMC & RF test equipment. We focus on EMC and offer only high-quality rugged equipment. our strategic partners are: HILO/TEST, Schwarzbeck, Schloder EMV, BOLAB Systems, mk-Messtechnik, EMC Instruments, GTEMCell.com, Steppir Comnications, Seiberdorf Labs, The Conformity Assessment Business, and TekBox. we cover all aspects of EMC testing with a strong product knowledge and support network we exceed where others fail.



ADVANCED TEST EQUIPMENT CORPORATION Booth 309

http://www.atecorp.com

Advanced Test Equipment Corp. (ATEC) is a leading provider of test & measurement equipment rentals, sales, calibration, and service. Since 1981, test engineers, government agencies, and Fortune 500 companies have relied on ATEC to guide them to the right equipment, ship it quickly, and offer them the industry's best technical expertise and customer care. ATEC's broad inventory includes EMC, Power Supplies & Loads, RF Safety, Electrical, NDT, Environmental, Communications, and General Purpose test equipment. Explore the ATEC inventory at www.atecorp.com.



http://www.aetechron.com

AE Techron is a leading producer of audio bandwidth amplifiers and test systems for the EMC industry. We provide comprehensive solutions for power quality, conducted immunity, and induced susceptibility testing for Automotive, Aviation, and Telecom. With a focus on modular testing systems and configurable amplifier solutions for difficult requirements, we consistently meet the challenges of the EMC industry with innovative design and exacting performance.

$A - I N F \Box$ A-INFO INC.

A-INFU INC. Booth 304

http://ainfoinc.com

Established in 2001, A-INFO has developed into a global leading manufacturer of Antennas, Waveguide, Microwave and RF Components with branches in Beijing, Chengdu, and California. Thanks to the support and collaboration with top Universities and Research Institutions from around the world, A-INFO has been developing thousands of products including Antennas, Waveguide Components, MW/RF Components and related systems, offering some of the most reliable and valuable innovative products to the international Radio Frequency and Microwave Technologies community.

Currently, A-INFO has over 100 patents and over 10 software copyrights. With a strict quality control system, A-INFO has passed the ISO 9001: 2015 Quality System Authentications. A-INFO's products can cover frequencies from 30MHz to 500GHz. With our manufacturing process, we ensure that all products are well designed and have a high accuracy machine finishing. Our products have been widely used in more than 100 Countries for dozens of industries such as aerospace, defense, accuracy test and measurement, radar systems, weather systems, EMC/EMI testing, healthcare, communication, automobile, material analyzing, sensors, etc.

EXHIBITS EXHIBITOR PROFILES



A-jin electron

A-JIN ELECTRON Booth 210

http://www.ajinelectron.co.kr

Conductive fabric, Conductive foam, Conductive tape, SMT gasket, Absorber

In order to shield harmful electromagnetic waves, issuing from the rapid-changing information communication technology and electronic equipment, our company has been manufacturing conductive fabric for anticipating into creation of "Electromagnetic radiation free zone" since its foundation in 1991 with continuous challenging and creating through intensive technical innovations. As a leading company which have developed a conductive fabric market in domestic, A-Jin has been grown up in every single year with developing its technologies and materials. With best quality, long term experienced know-how, and cost reduction, A-Jin provides better competitive power for our customers. To meet customers' satisfaction, A-Jin always tries to do our best.



http://www.altair.com

Altair is a global leader in computational science and artificial intelligence (AI) that provides software and cloud solutions in simulation, high-performance computing (HPC), data analytics, and AI. Altair enables organizations across all industries to compete more effectively and drive smarter decisions in an increasingly connected world - all while creating a greener, more sustainable future. For more information, visit https:// www.altair.com/.



AMBER PRECISION INSTRUMENTS Booth 612

http://www.amberpi.com

Amber Precision Instruments is a research-oriented EMC solution provider and EMC scanner manufacturer providing measurement technologies to resolve urgent and long-soughtafter industry problems.



Booth 701

http://ametek-cts.com

Ametek Compliance Test Systems, featuring the Teseq, EM Test & Milmega brands - specializing in Conducted Transient, Conducted RF & Radiated RF Immunity equipment.

AmphenolCANADA AMPHENOL CANADA CORP Booth 519

http://www.amphenolcanada.com

Amphenol Canada (ACC) has pioneered many unique technologies to address the interconnect needs of increasingly demanding applications, including Filtered Connectors and Interconnect devices for EMI and EMP protection, Ruggedized connectors for Harsh Environments, industry-leading High-Speed signal connectors for use in the rapidly growing In-flight Entertainment industry of Commercial Aviation.

ANSI-ASC C63 COMMITTEE ON EMC Booth 812

http://www.c63.org/

The "ANSI C63" Committee is an 80-year old committee specializing in, originally, Radio Frequency Interference, and, now, Electromagnetic Compatibility. It is a Standards Development Organization whose published standards are coapproved by both the American National Standards Institute (ANSI) and the IEEE. Some of the Committee's standards are "incorporated by reference" into US law; for example, the Federal Communication Commission (FCC) Rules. The Main Committee meets twice a year. Some key standards include: C63.2, C63.4, C63.5,C63.10, C63.14, C63.17, C63.19, and C63.26.



http://www.anab.org

The ANSI National Accreditation Board (ANAB) is the largest multi-disciplinary accreditation body in the western hemisphere, with more than 2,500 organizations accredited in approximately 80 countries. ANAB's accreditation portfolio includes ISO/IEC 17025 calibration and testing laboratories, ISO/IEC 17065 product certification bodies, ISO/IEC 17020 inspection bodies and ISO/IEC 17043 proficiency test providers.

NNSYS®

ANSYS, INC. Booth 801

http://www.ansys.com

Ansys is the global leader in engineering simulation. Through the broadest portfolio of fast, accurate and reliable simulation tools, Ansys brings clarity and insight to our customer's most complex design challenges. Ansys technology enables organizations in all industries to imagine high-quality, innovative and sustainable product designs that have an accelerated time to market.

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□ → □ AP Americas

AP AMERICAS Booth 808

http://www.apamericas.com

AP Americas Inc. is one of the leading global manufacturers of anechoic chambers and shielded rooms for various applications in EMC, antenna testing, 5G, wireless and high-frequency technology. Our successful solutions are based on the vast technical knowledge and expertise of our team, from sales to execution.

rf/microwove instrumentation

AR RF / MICROWAVE INSTRUMENTATION Booth 500

http://www.arworld.us

AR RF/Microwave Instrumentation provides Total RF Test Solutions, by offering customers RF test instrumentation, RF test systems, EMC test software, and chambers. More specifically, we manufacture and distribute: RF & Microwave Solid State Amplifiers ranging from: 1-50,000 watts, 10 Hz to 50 GHz, Antennas to 15,000 watts input power, 10 kHz to 50 GHz, EMC and Wireless Test Systems, Multi-tone test systems, Field measuring equipment, EMC test software, EMC & RF test accessories, Positioning equipment, and Chambers and accessories.

AR RF/Microwave Instrumentation as part of the AR family, which also includes AR Modular RF, SunAR RF Motion, and AR Europe, is recognized around the globe for products that deliver both outstanding quality and exceptional value.



TEST WITH CONFIDENCE®

AVALON TEST EQUIPMENT CORP. Booth 705

http://avalontest.com

Avalon Test Equipment aspires to be the nationally preferred test equipment rental company through both legendary customer service and exceptional product quality. The rental business will be the foundation upon which we build our sales and service departments. Avalon's vision and commitment to being legendary will bring true value to our clients as a full-service test and measurement solutions provider, so that they can Test With Confidence®.



BUREAU VERITAS CONSUMER PRODUCTS SERVICES

Booth 313

http://www.cps.bureauveritas.com

Suppliers and manufacturers of components intended for the automotive industry need to be confident that their products meet customer expectations along with the required safety, regulatory and industry standards. The need to meet these objectives is crucial to ensure the brand image is protected and due diligence to APQP processes is being demonstrated. With six automotive testing labs in the Americas Bureau Veritas services include but are not limited to: EMC Testing, Certification, Environmental Testing, Material Testing, Performance Testing, and Chemical / Analytical Testing.



CHANGZHOU PIONEER ELECTRONIC CO., LTD. Booth 709

http://www.emc-emi.com

EMCPIONEER is one of the leading manufacturer and supplier focus on the EMC/EMI market in China. EMCPIONEER designs, manufactures and installs the RF Shielded Enclosures, Anechoic Chambers and MRI Cages for military, commercial and medical facilities.We manufactures a wide range of RF shielding products, as RF Shielding Door, Honeycomb Vent, Power Filter, Signal Filter, RF Window, BeCu Finger Gasket, Wire Mesh, also supply Foam Absorber, Ferrite Tile and other shielding components.



satcom 🌖 products

COMMUNICATIONS & POWER INDUSTRIES (CPI) Booth 414

https://www.cpii.com/product.cfm/4/11 High-Powered CW and Pulsed TWT Amplifiers

COM-POWER CORPORATION COM-POWER CORPORATION Booth 609

http://www.com-power.com Com-Power is a leading supplier of EMC test instrumentation. We offer a wide selection of products and unique solutions. Our products are suitable for compliance or pre-compliance EMC testing. All our products are calibrated and conform to the latest test standards and are usually available from stock. Products can be ordered directly from Com-Power or from distributors listed on our website.



EXHIBITOR PROFILES



DASSAULT SYSTÈMES SIMULIA Booth 724

http://www.3ds.com/products-services/simulia/products/cststudio-suite/

Dassault Systèmes SIMULIA reveals the world we live in through realistic simulation of product, nature & life. We provide high-value end-to-end industry processes for digital engineering that employ state-of-the-art connected multidisciplinary-multiscale simulation applications. With SIMULIA, customers can reduce testing, increase confidence & quality, and get to market faster using always-available virtual worlds for discovery and testing. www.3ds.com/simulia



http://www.detectus.com

Now you can SEE high frequency electromagnetic fields. Detectus has developed an automated EMC measuring system with which the designers can determine the intensity and the location of a radiation source at a component level, board level, or even from a fully assembled device. The results are shown as two- or three-dimensional colored contour maps. These multiaxis scanners allow for movement around the DUT. EMC Tools: Near Field Probes (E & H field), Preamplifiers, Development System Disturbance Emissions, Set HF-Transformer. Pre-compliance EMC test and measuring devices; Measure Disturbance Immunity: Development System Disturbance Immunity, Magnetic Field Probes, MINI-Burst generators, Field Source Sets, Burst Transformer, Optical Signal Acquisition (1/2/4 channels), Optical Fibre Probe analog, Burst Detectors. Measurement Radiated Emissions.



D.L.S. ELECTRONIC SYSTEMS, INC Booth 614

http://www.dlsemc.com

DLS provides global EMI and EMC,, Environmental, Product Safety compliance testing & consulting services for commercial, industrial, wireless, military & avionics industries. DLS is NVLAP & ANAB certified & supports MIL STD, RTCA DO 160, FCC, EU, CE, VCCI, IC, BSMI, RED & other worldwide EMC specifications. DLS also performs Environmental testing to MIL-STD, RTCA, NEMA, IEC/EN, ISO, ANSI, SAE & other standards. DLS offers safety testing, including to CE, LVD, MDD, IEC/EN, CCC & other specifications.



E3 COMPLIANCE Booth 423

https://www.e3compliance.com/

E3 Compliance is an ITAR Registered independent engineering consulting company located in downtown Grand Rapids, Michigan. Here at E3, we specialize in EMC and High-speed design, analysis and perform pre-compliance and diagnostic testing in our ~6000 sq ft EMC lab. We help our customers upfront in the product development process so they can pass compliance testing with confidence and get to market on time. We support product launches at any phase of development in automotive, aerospace, consumer, medical, office, industrial and other industries.



ELECTRO MAGNETIC APPLICATIONS Booth 803

https://www.ema3d.com/

EMA is a leading developer of technologies for engineering simulation. EMA's engineering specialty is in applied electromagnetics. In this domain, EMA provides software and services to promote the design, certification, and performance of our customers' products. The company has been in business for over 40 years and is one of the pioneers in using electromagnetic simulation to solve challenging electromagnetic problems on complex platforms.



ELITE ELECTRONIC ENGINEERING, INC. Booth 804

https://www.elitetest.com

Founded in 1954, Elite Electronic Engineering, Inc. is a fullservice electromagnetic compatibility/interference (EMC/EMI), environmental stress, and photometric testing laboratory. We are the premier test provider for the aerospace, military, automotive, heavy equipment, electronics, and telecommunications industries. Elite is recognized worldwide as a leader in product qualification, compliance testing, and consulting services. Few laboratories offer our combination of expert engineers, state-of-the-art equipment, and cutting-edge test facilities all in one location.



EXHIBITOR PROFILES



EMC JAPAN/APEMC OKINAWA Booth 621

https://www.ieice.org/~emc/2024/ 2024 IEEE Joint International Symposium on Electromagnetic Compatibility, Signal & Power Integrity: EMC Japan / Asia-Pacific International Symposium on Electromagnetic Compatibility (EMC Japan/APEMC Okinawa) is the 9th "International Symposium on Electromagnetic Compatibility" organized by Institute of Electronics, Electronics, Information and Communication Engineers - Communication Society (IEICE-CS), and the joint symposium under technical co-sponsorship by IEEE EMC+SIPI and Asia-Pacific EMC (APEMC). We would like to invite all engaged in research and development in the various fields of electromagnetic compatibility to participate in this Symposium. This EMC Symposium series has a long history, and it has been held every 5 years in Japan. The first of its series was held in Tokyo in 1984, which was the first IEEE EMC Symposium held outside USA sharing sponsorship with IECE (current IEICE). Ever since the second in 1989, this symposium series has been sponsored by IEICE.



EMCOS LLC Booth 708

http://www.emcos.com

EMCoS focuses on problems related to electromagnetic fields, data visualization and generation of special simulation software. Driven by the forefront scientific and modern industrial problems we provide powerful methods and solutions with comprehensive interfaces and flexible result processing.



EMP SHIELD, INC.

Booth 521 http://www.empshield.com Ultra High Seed Surge Protection for HEMP/EMP/Lighting

emv

International Exhibition and Conference on Electromagnetic Compatibility (EMC) Cologne, 17 – 19 March 2020

EMV - INTERNATIONAL EXHIBITION AND CONFERENCE ON ELECTROMAGNETIC COMPATIBILITY

Booth 625

http://mesago.de

The EMC event in Europe From 12 - 14 March 2024, the trade fair EMV with conference on the subject of electromagnetic compatibility, will take place in Cologne again! Since the end of the 80s, the international EMV trade fair with conference and practice-oriented workshops has developed into one of the most important platforms for the EMC-community. Under the headline ""Creating a compatible future"", the event offers a comprehensive overview of the latest products and developments in the industry and is held alternately in Cologne or Stuttgart.

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Since the end of the 80s, the international EMV trade fair with conference and practice-oriented workshops has developed into one of the most important platforms for the EMC-community. Under the headline ""Creating a compatible future"", the event offers a comprehensive overview of the latest products and developments in the industry and is held alternately in Cologne or Stuttgart.

ESDEMC EXPERT ESD/EMC SOLUTIONS

ESDEMC TECHNOLOGY, LLC Booth 200

http://www.esdemc.com

ESDEMC develops ESD and EMC solutions. We are devoted to delivering creative, advanced, high-quality, and cost-effective solutions as well as general consulting, test services, and customized projects.



ETS-LINDGREN Booth 301

http://www.ets-lindgren.com

ETS-Lindgren designs, manufactures and installs EMC/EMI, RF/ Microwave, MIMO/OTA, and Acoustic test and measurement systems and components. Our patented technology has resulted in many milestones: the world's first CTIA Authorized Test Lab and the first oversize RF shielded sliding door for full vehicle test chambers. Our full line of EMP/IEMI products is the first to be independently tested and certified. Services include calibration at our A2LA accredited calibration lab. For more information, visit us at www.ets-lindgren.com.

EXHIBITS EXHIBITOR PROFILES





FAIR-RITE PRODUCTS CORP.

http://www.fair-rite.com

For close to 70 years Fair-Rite Products Corp. has been Your Signal Solution, offering a comprehensive line of ferrite products for EMI suppression, power applications, and RFID antennas. EMI suppression components range includes split round and flat cable snap-on suppression cores, surface mount beads, and PC board suppressor cores. Designing solutions for markets and applications such as; Automotive, Mil/Aero, Energy, Medical, RFID, Power Supplies and more. Fair-Rite is ISO 9001 and IATF 16949 certified, as well as ITAR compliant. Custom manufacturing, prototype development, and engineering.



FARADAY DEFENSE CORPORATION Booth 610

https://shop.faradaydefense.com/

Faraday Defense Corporation is a U.S-based, SAM-certified company specializing in the design, production, and distribution of conductive textile products. They provide solutions for the isolation and protection of equipment and personnel from EMF, EMI, RFI, and static discharge.



http://www.fischercc.com

Since 1971, Fischer Custom Communications, Inc., has pioneered the development of state of the art EMC test and measurement equipment.



GAUSS INSTRUMENTS INTERNATIONAL GMBH Booth 202

http://www.gauss-instruments.com

GAUSS INSTRUMENTS manufactures highest performance EMC test equipment and provides advanced EMI test solutions and instrumentation pushing your product development and testing capabilities ahead, and speeding up your time to market cycles. GAUSS offers a wide range of solutions from DC to 50GHz, or even up to the THz range, for all kind of test requirements – full-compliance as well as pre-certification or even customized solutions perfectly fitting to your specific requirements pushing your testing capabilities ahead. Driven by our ultimate mission: Smarter testing for smarter products.

GLOBAL SEALING SYSTEMS, INC Booth 800

http://www.global-sealing.kr/main/main.php GSS manufactures knitted wire mesh, which can be used as economical gaskets for EMI/RFI shielding. It reduces electronic malfunction by blocking unintended external electromagnetic waves or preventing internal electromagnetic waves. GSS provides guaranteed EMI/RFI shielding solutions for various types of industrial application.



GRAND VALLEY STATE UNIVERSITY Booth 425

http://www.gvsu.edu

The 6,000 sq ft EMC Center at Grand Valley State University is a one-of-a-kind facility that supports EMC education, research, and EMC pre-compliance testing for industry.



Booth 408 http://www.hvtechnologies.com

HV TECHNOLOGIES, Inc. is a prominent supplier of High Voltage and EMC test equipment. We have a century of experience and dedication in serving the testing equipment needs for the power utility, power apparatus, and electronic equipment industries.



IEEE 2024 INTERNATIONAL SYMPOSIUM ON EMC AND SIPI Booth 717

www.emc2024.org

EMC+SIPI 2024 leads the industry in providing state-ofthe-art education on EMC and Signal Integrity and Power Integrity techniques. The IEEE EMC Society is seeking original, unpublished papers covering all technologies that are affected by EMC, Signal & Power Integrity. Join us in Phoenix, Arizona. Share your insight, ask questions, learn from the experts/ innovators and see new products at the 2024 IEEE International Symposium on Electromagnetic Compatibility, Signal & Power Integrity. Your published paper will be seen by thousands in the EMC community and across the wide array of disciplines that look to the IEEE EMC Society for technical guidance. In addition, it will be uploaded to IEEE Xplore® with the exposure and recognition that brings.

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IEEE Antennas and Propagation Society

IEEE ANTENNAS AND PROPAGATION SOCIETY Booth 725

http://aps.ieee.org

The field of interest of the AP-S includes: antennas, including analysis, design, development, measurement, standards and testing; radiation, propagation, and the interaction of electromagnetic waves with discrete and continuous media; and applications and systems pertinent to antennas, propagation, and sensing, such as applied optics, millimeterand submillimeter-wave techniques, antenna signal processing and control, radio astronomy, bioelectromagnetics, and propagation and radiation aspects of terrestrial and spacebased communication, including wireless, mobile, satellite, and others.

SOCIETY® IEEE EMC SOCIETY Booth 717

www.emcs.org

The IEEE Electromagnetic Compatibility Society is the world's largest organization dedicated to the development and distribution of information, tools and techniques for taming electromagnetic interference beasts. The society's field of interest includes standards, measurement techniques and test procedures, instrumentation, equipment and systems characteristics, interference control techniques and components, education, computational analysis, and spectrum management, along with scientific, technical, industrial, professional or other activities that contribute to this field. Explore the many benefits of EMC Society membership, from being part of the Young Professionals, the many Standards resources, Distinguished Lecturer and engagement at the local Chapter level. Join today and give your career a much-need zap!

IEEE EMC SOCIETY HISTORY COMMITTEE Booth 717

www.emcs.org

The EMC Society is responsible for recording and maintaining the historical records of the EMC Society. That includes photos and papers as well as equipment artifacts. The Committee has digitized old EMC Symposium records and has distributed them via USB memory sticks and CDs.

IEEE EMC SOCIETY STANDARDS

Booth 717

The IEEE EMC Society Standards Advisory and Coordination Committee is responsible for providing technical liaison between the IEEE EMC Society Standards Development Committee and various non-IEEE entities involved with EMC standards activities.

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The purpose of the EMC-S SACCom committee is:

- To propose to the EMC-S Board of Directors (BoD) the appointment of representatives to various non-IEEE standards development entities
- To monitor the activities of various non-IEEE standards developing organizations with the view towards making recommendations to the EMC-S BoD on any required coordination of those activities within the society
- To communicate and coordinate with non IEEE standards developing activities and the EMC-S SDCom on matters relating to the development of EMC related standards



IEEE MICROWAVE THEORY AND TECHNOLOGY SOCIETY Booths 308

http://www.mtt.org

The IEEE Microwave Theory and Technology Society (formerly the IEEE Microwave Theory and Techniques Society) (MTT-S) is a transnational society with more than 11,000 members and 190 chapters worldwide. Our society promotes the advancement of microwave theory and its applications, including RF, microwave, millimeter-wave, and terahertz technologies. Established in 1952, for more than 70 years, the MTT-S has worked to advance the professional standing of its members and enhance the quality of life for all people through the development and application of microwave technology. As we enter into an exciting future, our mission is to continue to understand and influence microwave technology and to provide a forum for all microwave engineers. The MTT-S will continue to be the global focus for the promotion of the RF and microwave engineering profession, by advancing and distributing knowledge and supporting professional development.



IEEE PRODUCT SAFETY ENGINEERING SOCIETY (PSES) Booths 622

http://ewh.ieee.org/soc/pses/

The IEEE Product Safety Engineering Society focuses on the theory, design, development and practical implementation of product safety engineering methodologies and techniques for equipment and devices. This includes the study and application of analysis, techniques, construction topologies, testing methodologies, conformity assessments and hazard evaluations. The Society provides a focus for cooperative activities, including the promotion of product safety engineering for the benefit of humanity.



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COMPLIANCE IN COMPLIANCE MAGAZINE

http://www.incompliancemag.com

In Compliance Magazine features in-depth coverage of worldwide regulatory compliance issues for the electronics industry. Each month you'll find technical articles from industry-leading authors on topics related to testing and design, standards updates and changes, products, services, and more!

Available in print or digitally, we offer a variety of informational resources for electrical engineering professionals. Visit our website, activate your free subscription, and join one of our many eNewsletters for regular updates.



Total Quality. Assured.

INTERTEK Booth 824

http://www.intertek.com/

For more than 130 years, companies around the world have depended on Intertek to help ensure the quality and safety of their products, processes and systems.

We go beyond testing, inspecting and certifying products; we are a Total Quality Assurance provider to industries worldwide. Through our global network of state-of-the-art facilities and industry-leading technical expertise we provide innovative and bespoke Assurance, Testing, Inspection and Certification services to customers. We provide a systemic approach to supporting our customers' Quality Assurance efforts in each of the areas of their operations including R&D, raw materials sourcing, components suppliers, manufacturing, transportation, distribution and retail channels, and consumer management.

JIANGSU WEMC ELECTRONIC TECHNOLOGY CO., LTD Booth 201

http://www.wemctech.com/

Jiangsu WEMC Electronic Technology Co., Ltd. is a leading filter specialist in China. Our commitment to RFI/EMC/TEMPEST/EMP/ HEMP industry has resulted in a sound comprehensive range of filter products available from us. All our manufacturing is done on site and most of products are in compliance with IEC-60939, UL-1283, CISPR17, IEEE-299.... We have:

EMC/EMI Filters Power Line Filters Signal Line Filters TEMPEST Filters Filters for Shielded Room Filters for Anechoic Chamber Customzied Filters EMP Filters High Voltage Filters Filters for Medical (devices) Filters for EV

KEYSIGHT KEYSIGHT TECHNOLOGIES Booth 310

http://www.keysight.com

At Keysight (NYSE: KEYS), we inspire and empower innovators to bring world-changing technologies to life. As an S&P 500 company, we're delivering market-leading design, emulation, and test solutions to help engineers develop and deploy faster, with less risk, throughout the entire product lifecycle. We're a global innovation partner enabling customers in communications, industrial automation, aerospace and defense, automotive, semiconductor, and general electronics markets to accelerate innovation to connect and secure the world. Learn more at www.keysight.com.



KGS AMERICA (KITAGAWA INDUSTRIES AMERICA, INC.) Booth 208

https://www.kgs-ind.com/

KITAGAWA INDUSTRIES (KGS) manufactures solution materials to solve electrical, mechanical, and design engineering needs for electromagnetic compatibility (EMC), heat dissipation, vibration damping & shock absorption, cable management, and PCB spacing. KGS solution materials include EMI absorbers, ferrites, shields, grounding components, as well as a wide variety of thermal interface materials, vibration dampers, and plastic straps/ clamps/spacers. KGS products are designed and engineered for current and future requirements surrounding research and development, business and consumer trends.



LANGER EMV-TECHNIK GMBH

Booth 618

https://www.langer-emv.de

Langer EMV-Technik is in the forefront of research, development, and production in the field of EMC. Through EMC experimental seminars and EMC workshops we offer our comprehensive knowledge to our customers. Our interference emission and interference immunity EMC measurement technology as well as the IC test system are used mainly in the development stage and are in worldwide demand. Developers and designers gain new perspectives and more efficient working strategies for module- and IC developments with the EMC know how and measurement technology of



Langer EMV-Technik GmbH.

LIGHTNING EMC Booth 312 www.lightningemc.com US Distributor for Haefely AG EMC products.

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LITTLE MOUNTAIN TEST FACILITY -THE BOEING COMPANY Booth 525

http://www.boeing.com

LMTF is a state-of-the-art laboratory dedicated to simulation testing of radiation, shock and vibration, and electromagnetic effects for defense and commercial systems.



http://lumiloop.de/

Lumiloop GmbH is a German manufacturer of high performance optically powered electronic measurement devices. These are applied in the field of Electromagnetic Compatibility (EMC) as well as other RF applications. LUMILOOP's key competence is the optical supply of sensor systems using lasers in combination with a proprietary packaging technology and power regulation method. LUMILOOP combines this power-over-fiber (PoF) technology with state-of-the-art low power electronics design.



M PRECISION LABORATORIES Booth 718

http://www.mprecisionlabs.com

M Precision Laboratories, INC is a global supplier of Electromagnetic Compatibility (EMC) and Electrostatic discharge (ESD) systems and solutions (high voltage test devices). Along with manufacturing our own line of products, we are also A2LA accredited calibration laboratory for multiple types of test equipment.



MVG (MICROWAVE VISION GROUP) Booth 513

http://www.mvg-world.com

The Microwave Vision Group offers cutting-edge technologies for the visualisation of electromagnetic waves. Enhancing the speed and accuracy of wireless connectivity testing, as well as the performance and reliability of anechoic and EMC technologies, our systems are integral to meeting the testing challenges of a fully connected world.



NATIONAL VOLUNTARY LABORATORY ACCREDITATION PROGRAM (NVLAP) Booth 713

http://www.nist.gov/nvlap

NVLAP provides unbiased third party accreditation services through various laboratory accreditation programs for testing and calibration activities. NVLAP accreditation signifies that a laboratory has demonstrated that it operates in accordance with ISO/IEC 17025. NVLAP operates an accreditation system that is compliant with ISO/IEC 17011 and is a recognized signatory for testing and calibration under the ILAC, APLAC, and IAAC mutual recognition arrangements (MRA).



NAYAK CORPORATION, INC. Booth 613

http://www.nayakcorp.com

Nayak Corporation has unique combination of power system simulator knowhow and industry application experience. We are the sole representatives for RTDS, PSCAD and SPS amplifiers in the US. Our expertise is in power system modeling, simulation and studies which covers a wide range of power engineering disciplines - power system protection, HVDC, FACTS, distributed and renewable energy resources, microgrid, etc. We provide studies and testing services in addition to sales, technical support and training for power system simulators.



http://www.nemko.com

Nemko is your complete source for compliance testing, certification and global market access. Nemko provides one local point of contact for all major market certifications using our Nemko Direct network. Nemko offers EMC, Wireless, Electrical Safety, Field Evaluation/Special Inspection and Environmental testing and certification services, to meet the most complex compliance needs. With 24 locations worldwide, experienced staff, and personalized service, Nemko is strategically positioned to provide on time testing, inspection and certification support. Visit our website at nemko.com

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EMC+SIPI

NEXIO TECHNOLOGIES Booth 209

http://www.nexiogroup.com

NEXIO, founded in 2003, offers the market's widest range of electromagnetic automation test software through a global network of support staff and sales representatives. NEXIO develops the software range called BAT, which stands for "Benchtop Automated Testing". BAT is a package of highperformance automation test software for a variety of lectromagnetic compliance and RF testing requirements for all industries. Our star product, BAT-EMC, is a world leader in automated test software. The world's top accredited labs and top industries leaders are equipped with BAT-EMC. BAT-EMC is used in more than 20 countries worldwide (Germany, USA, China, Japan, Canada, Mexico...). Other star products are BAT-SCANNER (near field measurements), and BAT-ELEC (for burst, surge, transients, etc.).

Our key points are:

- -Hardware independant & free drivers
- -25 years experience
- -support and maintenance
- -flexibility and evolution
- -Monitoring functions
- -Automatic report



NEXPERIA SEMICONDUCTOR Booth 723

http://www.nexperia.com

Nexperia is a leading expert in high-volume essential semiconductors, that are required in every electronic design. The company's extensive portfolio includes diodes, bipolar transistors, ESD protection, MOSFETs, GaN FETs and analog & logic ICs. Headquartered in the Netherlands, Nexperia ships +100 billion products annually, meeting automotive standards. Our industry-leading packages are recognized as benchmarks in efficiency – in size, power and performance. Nexperia has +12,000 global employees.



OHTAMA CO., LTD. Booth 518

http://www.ohtama.co.jp/

Ohtama is the specialist of Magnetics technology and EMC Test. Now Ohtama is promoting EMC Test System "e-MotorChamber". e-MotorChamber has very special and unique LONG SINGLE SHAFT SYSTEM which is developed to meet CISPR25 Annex I. This shaft can handle 20,000RPM without any gear on. For more detail, please visit tabletop T6.



OMNI-THREAT STRUCTURES Booth 424

http://www.omni-threat.com Omni-Threat Structures (OTS) is an electromagnetic shielding company that uses our in-house, patented, conductive concrete & embedded mesh system to protect against threats, both man-made and environmental. OTS patented proprietary EM shielded construction process allows precast and tiltwall panels as well as cast-in-place erection for multi-threat hardened structures. OTS applications include MIL-STD-188-125 HEMP shielding, ICD-705 SCIF, TEMPEST, and Anechoic Chambers.

OnRule

ONRULE, INC. Booth 620

http://www.onrule.com/

OnRule is a world-leading cloud-based software platform to manage the product regulatory compliance. OnRule enables enterprises to rapidly launch new products in the global marketplace by accelerating the product certification process. streamlining collaboration, and delivering up-to-date global regulatory intelligence. OnRule organizes the compliance records by products, markets, record types, and record disciplines. It creates SmartCerts™ enabling a quick search and secured sharing; the view-only privileges allow the internal and external stakeholders to have visibility on the compliance status and records. The notifications of upcoming expirations alert the compliance team, prevent stop ship and ship hold; and enable proactive budgeting and allocation of resources. The Standards Update Notifications inform the enterprises of upcoming changes in the standards and identify the impacted products and records portfolio.



Booth 509 http://www.ophirrf.com

Designer and manufacturer of High power RF amplifiers, microwave amplifiers, linear amplifiers, solid state power amplifiers, wideband amplifiers and band specific amplifiers.



EXHIBITOR PROFILES



http://www.cumingmicrowave.com

PPG Cuming Microwave Corporation is an ISO 9001:2015, US manufacturer of C-RAM® RF/Microwave absorbers, C-STOCK® low-loss dielectric materials, and C-SHIELD[™] conductive materials, serving military & aerospace and commercial market segments for over 40 years. With a full range of RF and power testing capabilities, our materials are tested and validated to meet industry standards. Cuming Lehman Chambers, a wholly owned subsidiary, provides design, project management and installation of new and refurbished anechoic chambers, host facilities, and specialty test boxes.

PRÂNA RECHERCHE ET DEVELOPPEMENT Booth 321

http://www.prana-rd.com

PRÂNA is a French company specialized in the design and manufacture of RF and microwave power amplifiers for broadband applications such as Electromagnetic Compatibility (EMC) testing, instrumentation and radio communication. PRÂNA products cover the frequency range of 4 kHz - 6 GHz with an output power of up to 16kW CW. All amplifiers meet the stringent requirements of EMC test standards.



R&K COMPANY LIMITED Booth 205

https://rk-microwave.com/

R&K is a manufacturer of cutting-edge RF/microwave products. R&K's solid-state power amplifiers are powering the world's advanced accelerators for high energy physics research applications and comprehensive EMC test requirements. With a large installed base of amplifiers located in key labs worldwide, R&K is a proven provider for your power requirements. RATLR, INC Booth 704

https://ratlr.net/ Innovator in EMC testing solutions



RAYMOND EMC ENCLOSURES LTD. Booth 700

http://www.raymondemc.ca

Raymond EMC specializes in the design, fabrication, installation, and testing of custom radio frequency (RF) shielded enclosures and anechoic chambers for military, government, high tech, medical and industrial applications. Raymond EMC prides itself on being an industry leader in product quality, performance and innovation while providing unmatched client care and product support throughout the design, fabrication, and installation process.

RF Exposure Lab

RF EXPOSURE LAB Booth 302

http://www.rfexposurelab.com

RF Exposure Lab, LLC is an independent, privately owned SAR Testing Lab. We are A2LA Accredited and have significant expertise in SAR Testing from both an industry and a laboratory environment. We provide SAR testing for companies and other test laboratories. We are located in Southern California.

ROBUSTPHYSICS

ROBUST PHYSICS Booth 323

https://www.robustphysics.com/

RobustPhysics was founded in 2010 to develop statistical wave mechanics modeling software specifically for the needs of E/E engineers responsible for EMC qualification of large, complex and "uncertain" electronic systems.

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ROHDE & SCHWARZ USA, INC. Booth 415

http://www.rohde-schwarz.com

Rohde & Schwarz is the leader in EMC testing and has been supplying EMC test equipment for over 50 years. Our test experts have been advising EMC standard authorities on T&M issues for decades. Rohde & Schwarz has a wide-ranging test equipment portfolio that is based on in-depth EMC compliance, precompliance, and debugging expertise and supports all relevant commercial, wireless, automotive, military and aerospace EMC standards. Rohde & Schwarz is a proven supplier of state-of-the-art EMC test solutions and a reliable service partner for our current products and our extensive back-catalog.

安全与电磁兼容 SAFETY & EMC

SAFETY & EMC CHINA Booth 802

https://www.safetyandemc.com

"SAFETY & EMC" is the unique official publication (CN 11-3452/ TM, ISSN 1005-9776) synthetically introducing the safety and EMC technology of electronic and electric industry at present in China, which is supervised by Ministry of Industry and Information Technology of PRC and sponsored by China Electronic Standardization Institute (CESI).

"SAFETY & EMC" started the first publication in 1989, it has maintained its characteristics in forward-looking, professional, practical and knowledgeable. Providing its readers with the latest policies and regulations, certification procedures, testing methods, as well as cutting-edge research technology, academic information and so on.



SCHLEGEL ELECTRONIC MATERIALS INC. Booth 213

http://www.schlegelemi.com

Schlegel EMI is a trusted and preeminent manufacturer of EMI / Thermal products.

We offer EMI shielding products, including FOF gaskets, Absorbers, Elastomers, Thermal Interface Materials, Hybrid thermal/absorber, I/O backplane shielding gaskets, BeCu Fingerstock, Conductive foams and tapes, and laminates. Our shielding products combine highly conductive materials with flexible foams and coatings, providing the latest EMI containment solutions, meeting global EMC requirements. Schlegel's shielding gaskets are available in hundreds of profiles and unique designs, with attachment options.

SIEMENS

Booth 710

https://www.siemens.com/

Siemens AG is a multinational technology conglomerate. Its operations encompass automation and digitalization in the process and manufacturing industries, intelligent infrastructure for buildings and distributed energy systems, rail transport solutions, and health technology and digital healthcare services.

SPIRA

SPIRA MANUFACTURING CORPORATION Booth 615

http://www.spira-emi.com

Spira is at the forefront of EMI gasket innovation, design and customer service. Providing superior EMI/RFI shielding products that are cost effective & reliable for the life of a system. ISO 9001/AS9100 certified, expert technical support, and made in the USA.



STEPPIR COMMUNICATION SYSTEMS Booth 422

http://www.steppir.com

SteppIR-EMC, a division of SteppIR Communication Systems, is a manufacturer of products for use in EMC test applications. These product offerings include a tunable Yagi antenna that replaces the biconical antenna for more efficient radiated susceptibility testing with lower harmonic content. SteppIR EMC also provides expert consulting and training services in electromagnetic compatibility to industry.

TATSUTA ELECTRIC WIRE & CABLE CO., LTD. Booth 714

http://www.tatsuta.com

Tatsuta has a proven track record of over 20 years in manufacturing and developing functional materials. Our expertise lies in the production of EMI shielding and conductive bonding films, which have gained widespread popularity in the consumer electronics industry. Notably, Tatsuta has pioneered the development of the world's FIRST EMI shielding film for FPC, a crucial component for mobile devices like smartphones. This breakthrough product has garnered significant market share on a global scale.



EXHIBITOR PROFILES

TDK LAMBDA AMERICAS Booth 805

https://www.us.lambda.tdk.com

TDK-Lambda Americas, Inc. is a leading manufacturer of high reliability Low/High Voltage Programmable DC and High Voltage Programmable Capacitor Charging power supplies and DC Electronic Loads. Programmable DC products include the Genesys[™] Series, the GENESYS+[™] Series, the ALE Series and the SFL Series. For more information, please visit https://www. us.lambda.tdk.com.



TDK RF Solutions is a world leader in the design, development, and manufacture of technical solutions for the electromagnetic compatibility testing and antenna measurement industries. We offer a complete range of solutions including automated test systems, TDK anechoic chambers, RF absorbers, antennas, software, and a wide range of test products. Our team utilizes TDK's global technical expertise and resources and has become the preferred provider of EMC solutions, research & development, product design, and test products for the worldwide RF community. We call it Total RF Expertise ™.



THE BOEING COMPANY Booth 523

http://www.boeing.com

As a leading global aerospace company, Boeing develops, manufactures and services commercial airplanes, defense products and space systems for customers in more than 150 countries. As a top U.S. exporter, the company leverages the talents of a global supplier base to advance economic opportunity, sustainability and community impact. Boeing's diverse team is committed to innovating for the future, leading with sustainability, and cultivating a culture based on the company's core values of safety, quality and integrity.



THE EMC SHOP Booth 608

http://www.theemcshop.com

The EMC Shop is a stocking distributor of testing equipment. We empower businesses to evaluate options to perform testing based on short and long-term needs. With our uber professionalism and technical prowess, our reputation has impressed well in a mature industry.

The EMC Shop is engaged with consultants and other engineers involved in frontline experimentation of electromagnetic effects on emerging technologies. With remote staff in California, Texas, New Jersey and Mexico, regular company meetings keep the team versed on developments and company direction based on standards or test changes, economic conditions, or technological developments. Regular seminars made for the public are also attended by The EMC Shop personnel, ensuring everyone has an excellent grasp of the needs of its customers and technical competence in electromagnetic testing.



Quest for Precision

TOYOTECH US LLC Booth 419

http://toyotechus.com EMC Software, Solutions Provider Test Equipment, System Integration

TRA Specialists

TRANSIENT SPECIALISTS, INC. Booth 703

http://www.transientspecialists.com

We specialize in EMC test equipment rentals. Transient surge and burst generators, and ESD simulators for compliance testing to IEC, UL, Automotive, Military and Telecom standards. While we are the sole U.S. distributor for Ametek CTS ESD equipment, we carry Teseq, Solar Electronics, EMC Partner, and Haefely EMC equipment for rental. Accredited calibrations. Flexible rental terms - 4 days transit time free with all rentals.

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TÜVRheinland® Precisely Right.

TUV RHEINLAND Booth 300

http://www.tuv.com

TÜV Rheinland offers a comprehensive service portfolio for testing and certification, which includes regulatory, interoperability, performance, safety and security. As an EMC Notified Body (CAB) and international service provider, TÜV Rheinland can help you meet the requirements of the EMC directive 2004/108/EC as well as FCC and Industry Canada requirements. Our EMC/wireless labs are equipped with 3, 5, and 10 meter chambers as well as OTA and SAR test systems for a wide range of products. We are a TCB for the US and an FCB for Canada and can provide the wireless product certifications required for wireless radios. We are an authorized test lab for Wi-Fi, ZigBee, Thread, Bluetooth, LoRa and many others.



V TECHNICAL TEXTILES, INC. Booth 813

http://vtechtextiles.com

V Technical Textiles, Inc. (VTT) is a specialized, conductive textile company and integrator of custom designed RF shielding solutions. Our comprehensive range of products includes portable RF shielding enclosures, curtains, pouches, and garments. We serve a diverse customer base, spanning industries such as aerospace, automotive, military, medical and defense sectors. We collaborate closely with our customers to develop tailor-made solutions from initial concept to final manufactured product. Our expertise lies in utilizing world renowned Shieldex conductive textiles, leveraging cutting-edge conductive textile plating technology for the development of these products.



VECTAWAVE Booth 211

http://www.vectawave.co.uk

Vectawave is a manufacturer of robust, air cooled, class A broadband power amplifiers for use in industrial, military and medical applications. Our range covers 9kHz- 6GHz with powers up to 4kW. Vectawave have been designing and manufacturing power amplifiers for 25 years. These amplifiers are in daily use in EMC labs and test houses around the world. Our amplifiers have been designed to meet the specific EMC applications, and are ideal for integration into EMC immunity test systems.



Booth 522

https://wrtestlabs.com/

Fully Independent RF and EMC Testing and Certification laboratory and with multiple locations in Michigan, USA



WURTH ELECTRONICS MIDCOM INC. Booth 325

http://www.we-online.de

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



XGR TECHNOLOGIES Booth 711 https://xgrtec.com/ Custom Board Level EMI Shields

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ATTENDEES

Photo by Richard Georgerian



EMC+SIPI 2023 ONCE AGAIN COMBINES ELECTROMAGNETIC COMPATIBILITY AND SIGNAL & POWER INTEGRITY INTO ONE INSPIRING SYMPOSIUM

A full, 5-day attendee registration includes:

- Access to all of EMC+SIPI 2023
- Multiple days of EMC+SIPI original papers
- Five days of practical EMC+SIPI Workshops and Tutorials
- Experiments and Demonstrations of fundamental and advanced topics
- Exhibit Hall, showcasing the latest EMC+SIPI products and services
- Welcome Reception
- Gala Event
- Awards Luncheon
- Symposium Proceedings with all Workshop & Tutorial slide presentations and Technical papers

REGISTRATION TYPES

We offer three types of registrations: Attendee, Companion, & Exhibitor.

ATTENDEE:

- We offer two types of badges:
- 1- to 5-Day Registrations: You have access to all EMC and SIPI paper sessions, Workshops & Tutorials, and Exhibit Hall. There are many categories.
- Exhibit Hall Only: For adult customers and clients of our exhibitors. Exhibitors and their reps must register through EXHIBITOR registration. No charge.

COMPANIONS:

For family and friends of all ages who accompany a registered, technical attendee or exhibitor. We offer two types of badges:

- Companion Club: includes gift, breakfasts, Welcome Reception ticket, and access to the Exhibit Hall. Individual registrations are required. A fee applies.
- Basic Badge: for Exhibit Hall entrance and/or Youth Technical Program registration. Sign up your companion within your own registration. No bar code, no tracking, no charge.

EXHIBITOR:

All adult exhibitor staff, reps, and booth workers must register using the *link and discount code* sent to the Exhibitor/ Sponsor contact to receive an EXHIBITOR ribbon and early access to the Exhibit Hall. More details can be found in the EMC+SIPI 2023 Website on the EXHIBITORS registration page. https://emc2023.org/registration.html

IMPORTANT REGISTRATION INFORMATION

AUTHORS: Symposium registration (Member or Non-Member) is required by at least one author, or the speaker. Failing to meet this requirement will result in the paper not being published or presented – no exceptions. Your registration confirmation number will be needed for the final paper submittal.

ADVANCE REGISTRATION: You must be paid in full by midnight PDT, June 26, to receive the Advanced rates.

EMC SOCIETY MEMBERS: Special rate for full, 5-Day Technical Registrations only. Your membership must be in good standing and paid in full for 2023. If you are not a member and would like to become a member, please visit <u>www.ieee.org/membership/join</u> or call 1-800-678-IEEE. Please note that you must be a member at the time of registration to receive the member rate.

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SISTER SOCIETY MEMBERS: Members of IEEE EMC-S Sister Societies are eligible for the discounted EMC-S Member rate at the annual symposium. Contact the Registration Service to obtain this discount.

IEEE LIFE MEMBER: There is a further rate reduction for IEEE Life members. IEEE Life Membership is automatically bestowed upon an active IEEE member based on age and years of membership.

EMC-S HONORED MEMBER: You must be an EMC Society Honored Award recipient who was presented with this award in a prior year. No discount code is necessary to register; this is a special rate category.

EMC-S RETIRED OR UNEMPLOYED: Special ADVANCE rate discount for retired / unemployed EMC Society members only; discount reverts back to the EMC-S rate after June 26. Have your last place of employment and the date of retirement or unemployment ready when registering.

COMPANY GROUP RATE: Sign up to request a company-wide discount code now! We will give each employee a special discounted rate which is roughly 35% off the non-member rate, and over 10% off the EMC-S Member rate! Send an email to: **EMC@iplanitmeetings. com** to receive your Company Discount Code.

Com to receive your Company Discount Code. **Cost:** Advance rate is \$715/person (before June 26);

- Each company must have 10 or more employees with a PAID 5-day attendee registration (not including Exhibitor or Booth Staff) registered by June 26 (advance rate) or July 17 (special rate).
- Employees may register and pay individually using the specially provided discount code. Company name must be the same for all registrations.
- There is no need for all to be from the same central office or company branch.
- Void if not registered and paid by July 17. After July 17, regular rates will apply. (Those who registered before June 26 will be charged the advance rate.)

FULL-TIME STUDENTS: Special rates for both IEEE members and non-members. You must be enrolled in a full time course of study at a college or university to register in the student categories. Have your college ID number and advisor's name & email ready when registering. **Note:** Student 5-Day registration packages will include the attendee bag, Symposium Record, and tickets to the Welcome Reception & Awards Luncheon. The Gala ticket however is NOT included, but may be purchased separately or awarded through volunteering at the symposium.

More details at the EMC+SIPI 2023 Website AUTHOR/PRESENTER page

EMC+SIP

OTHER INFORMATION:

CERTIFICATE OF PARTICIPATION

A Certificate of Participation may be used to officially document attendance at the Symposium. A personalized certificate will be available at no charge to all registered Symposium attendees and participants. Please visit the Registration Desk to verify your name and affiliation and to pick up your certificate. If you have any questions, please email: emc@iplanitmeetings.com.

PAYMENT

Payment is due upon submittal of your registration. Payment can be made by:

- Credit Card: Visa, MasterCard, American Express, Discover Card.
- Check (in USD) made out to IEEE EMC+SIPI 2023, and mailed within 2 weeks.
- Wire Transfer. (Note: Banks usually charge a fee for wire transfers. These are the responsibility of the registrant.)
- Invoice (Government Purchase Order)

Payments by credit card will be charged immediately upon submission of registration. Checks and Wire Transfers must be received within two weeks of the registration date.

CANCELLATION POLICY For Registration and total order:

- Notice of cancellation must be received in writing via email, sent to emc@iplanitmeetings.com.
 A \$50.00 (USD) processing fee will be charged for registrations cancelled by June 20, 2023. For cancellations between June 20 and July 10, 2023, a 50% refund will be given. There will be no refunds after midnight PDT on July 10, 2023.
- If you applied for a Visa and it is denied, a full refund will be issued less a \$20 service charge.
- In the event of a full cancellation of the conference, IEEE and EMC Society are not responsible for, and will not reimburse, flight costs and other expenses incurred by the attendee

FOR SOCIAL EVENTS, TOURS AND EXTRAS ONLY

- Notice of cancellation of an individual "extra" item must be received in writing via email, sent to emc@iplanitmeetings.com, by June 26, 2023. There will be no refunds after midnight PDT on June 26, 2023.
- The EMC 2022 Symposium Committee reserves the right to cancel any tour that does not meet the minimum requirement. If a tour is cancelled, you will receive a full refund and will be contacted prior to the symposium.

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REGISTRATION FEES & INCLUSIONS

REGISTRATION CATEGORIES					IN	CLI	JSIO	NS	;	
You must be paid in full by midnight EDT, June 26 to receive the Advance rates.	Advance on or Before June 26	Regular After June 26	Technical Sessions	Exhibits	Record*	Tote Bag^	Welcome Reception	Gala Event	Awards Luncheon	Companion Suite
5-Day Technical Program Regis	stration									
EMC-S Member	\$830	\$980	Х	Х	Χ	Χ	Х	Χ	Х	
IEEE Member	\$875	\$1030	Х	Χ	Χ	Χ	Х	Χ	Х	
Non-IEEE Member	\$1100	\$1290	Х	Χ	Χ	Χ	Χ	Χ	Х	
IEEE Life Member	\$385	\$435	Х	Χ	Χ	Χ	Χ	Χ	Χ	
EMC-S Honored Member	No Charge	No Charge	Х	Χ	Χ	Χ	Χ	Χ	Χ	
EMC-S Retired/Unemployed (special rate; advance only)	\$440	\$980	х	Х	X	X	X	X	х	
Student, IEEE Member	\$275	\$325	Х	Χ	Χ	Χ	Х		Х	
Student, Non-IEEE Member	\$300	\$355	Х	Χ	Χ	Χ	Х		Х	
5-Day Technical Program Registration – Company Group Rate ¹ (must register by June 26)										
Minimum of 10 employees	\$715 each	N/A	Х	Χ	Χ	Χ	Х	Χ	Χ	
1-Day Technical Program Regis	stration									
IEEE Member	\$290	\$340	Х	Χ	Χ	Χ				
Non-IEEE Member	\$360	\$425	Х	Χ	Χ	Χ				
Student, IEEE Member	\$90	\$105	Х	Χ	Χ	Χ				
Student, Non-IEEE Member	\$100	\$115	Х	Χ	Χ	Χ				
Companion Registration (accompanying a tech. attendee or exhibitor- no tech. sessions included)										
Companion Club (18+)	\$110	\$130		Χ		Χ	Χ			Х
Jr. Companion Club (8-17) (PG)	\$75	\$85		PG		Χ	PG			PG
Companion Club children under 8 (PG)	No Charge	No Charge		PG			PG			PG
Basic Badge, non-technical (for Exhibit Hall, Socials, Tours, and/or Youth Tech. Program)	No Charge	No Charge		x						
Exhibition Registration: TU, WE, TH (technical program sessions not included except sessions in the exhibit hall)										
Exhibit Hall Only; 3-Day pass	No Charge	No Charge		Х						

Notes: ¹Company name must be the same for all registrations; however, employees can purchase their registrations separately using a discount code provided upon purchase of a "Company Group Rate" package.

* Symposium Record includes the Proceedings and all Workshop/Tutorial (W/T) slide presentations.

[^] Tote Bag and contents will differ according to registration category.

PG = Accompanied by a registered adult.

ADDITIONAL OPTIONS

ADDITIONAL OPTIONS					
You must be paid in full by midnight EDT, June 26, to receive the Advance rates.			Reg.		
CLAYTON R. PAUL GLOBAL UN	IIVERSITY (5-Day Symposium registration is required i	n addition to ti	he G.U. fee)		
Global University			\$400		
SPECIAL: SIPI SHORT COURSE (1-Day or 5-Day Symposium registration is requ	with John Golding - Siemens EDA				
SIPI Short Course (Tuesday, Augu	ust 1 – 1:30pm -5:30pm)	\$75	\$100		
YOUNG PROFESSIONALS ACTI	VITIES (B.S. degree within past 15 years)				
Monday Night Social: Speed Datin	a with FMC Experts	\$30	\$40		
Tuesday Night Social: After the We	elcome Reception Social	\$20	\$20		
PROFESSIONAL DEVELOPMEN	T HOURS (PDH)				
Fee for processing and recording of	credit hours earned	\$35	\$35		
Special for EMC-S members: (<i>mus</i>	st be a member at time of registration)	\$ 25	\$25		
TECHNICAL TOURS	, i i i i i i i i i i i i i i i i i i i				
Thursday, August 3: EMC Center and Innovations & Design Center, Grand Valley State University- 5:30pm-8:00pm			\$25		
Friday, August 4: Intertek Grand Rapi	ds Lab Tour – 9:00am-12:00pm	\$35	\$40		
VISA INVITATION LETTER (Must have a technical registration and be paid in full. Allow a minimum of 4 to 6 weeks for your government to process your visa.)					
Visa letter via email or fax; no char	No Charge	N/A			
Visa letter via FedEx International;	fee applies.	\$75	N/A		
SOCIAL EVENTS – additional ticket					
	Adult, Ages 18+	\$90	\$100		
I uesday Welcome Reception	Junior, Ages 8–17 (PG)	\$60	\$65		
Wednesday Evening Colo	Adult, Ages 18+	\$110	\$120		
wednesday Evening Gala	Junior, Ages 8–17 (PG)	\$75	\$80		
Thursday Awards Luncheon	Adult, Ages 18+	\$60	\$70		
	Junior, Ages 8–17 (PG)	\$40	\$45		
BREAKFAST CLUB (For the Compa attendee; limit 1 per Companion Club regi					
1 Breakfast with your Companion Club member			\$30		
Breakfast Club – 4 breakfasts (MO – TH)			\$100		
COMPANION TOURS (Please sign minimum number of tickets have not been	up for tours early; the tour may be cancelled if a sold by June 15.)				
Monday, July 31: Grand Rapids Walking Tour – 9:00am -11:00am			\$25		
Tuesday, August 1: Grand Lady Riverboat Cruise – 9:00am -12:00pm			\$65		
Wednesday, August 2: Frederik Meijer Gardens- 9:00am -12:00pm			\$65		
Thursday, August 4: Aroma Labs Experience -9:00am-11:00am			\$50		
YOUTH TECHNICAL PROGRAM: ENGINEERING MEETS ART WITH E-TEXTILES					
Open to Jr. companions and guests aged 8-19. Younger children are welcome if accompanied by an adult or older, responsible sibling. Register early to be guaranteed a project kit.			No Charge		

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2023 TECHNICAL REVIEWERS

THE EMC+SIPI 2023 TECHNICAL PROGRAM COMMITTEE WOULD LIKE TO EXTEND OUR GRATIDUE TO THIS YEAR'S REVIEWERS FOR THEIR SUPPORT OF THE SYMPOSIUM AND DEDICATION TO A HIGH-QUALITY TECHNICAL PROGRAM.

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