2006 IEEE International Symposium on Electromagnetic Compatibility

SPECIAL SECTION

Technical Program, Exhibitor Preview, Social Program, Special Events, and more!

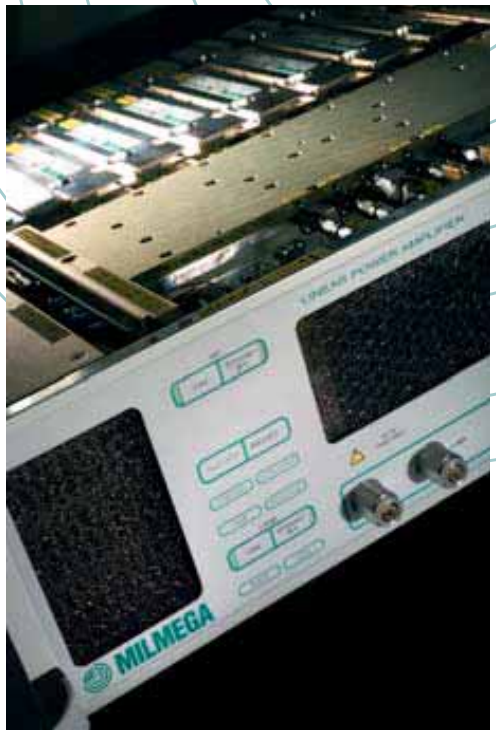
EMC 2006

Portland, Oregon

Be part of "Exploring EMC Frontiers" as we step into the future of Electromagnetic Compatibility

IEEE EMC SOCIETY

6GHz Testing to IEC 61000-4-3 Edtn 3



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Welcome to Portland!

by Henry Benitez
Chairman, IEEE EMCS 2006 Committee

The EMC 2006 Steering Committee welcomes everyone to Portland, Oregon for the 2006 IEEE International Symposium on Electromagnetic Compatibility scheduled for August 14 through 18. Our theme is "Exploring EMC Frontiers" as we celebrate the 200th year anniversary of the Lewis and Clark expedition, which cumulated in Oregon. We also pay tribute to the 300th year anniversary of the birth of Benjamin Franklin, one of our first EMC engineers!

The Pacific Northwest is a beautiful place to be at this time of year. We encourage all to bring your companions and family if possible. There is more than enough for them to do while you are enjoying the remarkable technical program. Companion tours are listed on the website as well as a multitude of activities that can be done on your own. The social programs will be great as always as they are ingrained within our EMC Society.

The technical program for the EMC symposium has grown each year. We now have a wide range of formats for the presentation of technical information. Workshops have grown in popularity each year and have now filled out the time slots allocated on Monday and Friday. Special Sessions are also a popular way to focus on a particular topic utilizing invited papers. Demonstrations are back by popular demand. Demonstrations allow for demonstration of real results and allow the presenters to interact with the audience in a personal manner. Demonstrations have been one of my favorite parts of the symposium technical program.

The "technical papers" are still the bread and butter of the technical program. The technical program is now divided into two presentation formats. The "traditional" format is the same as in years past; that is, PowerPoint type presentations are made to the audience for a finite amount of time followed by a few questions and answers.

New this year for technical papers is the "Close Format" presentation. This is an exciting new format designed to allow more time for a presentation as well as in a more intimate and less formalized format. The presenter has two hours, rather than only 30 minutes in the traditional format. The presenter still has access to PowerPoint slides and screen, but has more flexibility for the utilization of dry/erase boards, paper charts, and interaction with the audience. All technical papers are reviewed equally as reviewers do not know in what format of presentation they will be presented.

We will have a "New Products and Services Showcase" that will allow exhibitors the opportunity to make PowerPoint presentations on stage about their new products. This is a continuation of the "New Product and Services Showcase" initiative that debuted at the 2005 IEEE International Symposium on EMC in Chicago. The Showcase idea has expanded to include a special section of tabletop displays for showcasing only new products.

We believe this will be one of the best EMC programs ever. The ability of the EMC symposium committees to be innovative and come up with new ideas year to year without inhibition has helped evolve the EMC Symposium into one of the best in the IEEE. I thank the tremendous EMC 2006 committee for their diligent and earnest efforts to make this a remarkable event.

See you in Portland!

EMC 2006 Symposium Committee

www.EMC2006.org

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Role of Engineers in Poverty Reduction: Challenges and Opportunities

Symposium Keynote Address
Tuesday, August 15
8:00-8:50 am
Oregon Ballroom, Oregon Convention Center

by
Bernard Amadei
Professor, University of Colorado
Director, Engineering for Developing Communities Program
Department of Civil, Environmental and Architectural Engineering,
Boulder CO 80309-0428, USA

Abstract:
In the next two decades, almost two billion additional people are expected to populate the Earth, 95% of them in developing or underdeveloped countries. This growth will create unprecedented demands for energy, food, land, water, transportation, materials, waste disposal, earth moving, health care, environmental cleanup, telecommunication, and infrastructure. The role of engineers will be critical in fulfilling those demands at various scales, ranging from remote small communities to large urban areas, and mostly in the developing world. As we enter the first half of the 21st century, the engineering profession must embrace a new mission statement—to contribute to the building of a more sustainable, stable, and equitable world. In particular, we need to train a new generation of engineers who could better meet the challenges of the developing world and address the needs of the most destitute people on our planet. Today, an estimated 20% of the world's population lacks clean water, 40% lacks adequate sanitation, and 20% lacks adequate housing.

The lecture will present the challenges and opportunities associated with practicing engineering in the developing world and the education of engineers through organizations such as Engineers Without Borders. The lecture will also discuss the importance of integrating engineering with non-engineering disciplines when addressing the needs of developing communities.

Professor Bernard Amadei
Bernard Amadei is Professor of Civil Engineering at the University of Colorado at Boulder. He obtained his MaSc. degree in Civil Engineering in 1979 from the University of Toronto and his Ph.D. degree in Civil Engineering in 1982 from the University of California, Berkeley.

Professor Amadei's current interests cover the topics of sustainability, green construction, and international development. At the University of Colorado at Boulder, he is leading a new paradigm shift in engineering education and practice called Earth Systems Engineering (ESE: http://ese.colorado.edu). It emphasizes the interaction between the built environment and natural systems. As part of the ESE initiative, Professor Amadei started a new program in Engineering for Developing Communities (www.edc-cu.org). Its overall mission is to educate globally responsible engineering students and professionals who can offer sustainable and appropriate solutions to the endemic problems faced by developing communities worldwide.

Professor Amadei is also the Founding President of Engineers Without Borders - USA (EWB-USA: www.ewb-usa.org) and the co-founder of the Engineers Without Borders-International network (www.ewb-international.org). The mission of EWB-USA is to partner with disadvantaged communities to improve their quality of life through implementation of sustainable engineering projects, while involving and training internationally responsible engineering professionals and students.

Professor Amadei is the recipient of the 2002 Colorado Bank One Award for outstanding outreach community service, a 2003 CU Boulder Subaru Award; a 2003 E-Achievement Award from E-Town; the 2005 Nayudamma Award from the Nayudamma Center for Development Alternatives in Nellore, India; the 2005 AAES Norm Augustine Award for outstanding achievement in engineering communication; a 2005 Service Award for Professional Excellence from Rotary International; the 2005 Sabbagh Award for Excellence in Engineering Construction (with EWB-USA) from the World Federation of Engineering Organizations; and the 2006 General Palmer Award from the American Council of Engineering Companies of Colorado. He is working on a new book entitled "Engineering With Soul."

Description of Technical Sessions at the 2006 IEEE International Symposium on Electromagnetic Compatibility

August 14-18
Portland, Oregon

143 papers that have been accepted into the technical program are eligible for the best paper award. 118 of the technical papers will be presented in the Traditional Format Presentations and 25 papers will be presented in the brand new Close Format Presentations. This year, presentations and workshops will fall into one of the following five categories. New categories have been created to provide all attendees with the most value for their money.

Traditional Format Presentations
Traditional Format Presentations are what everyone has come to know and love as the symposium's technical presentations. These presentations are designed for authors of technical papers to provide a 20-minute lecture to attendees, based upon an approved technical paper. In Portland, each lecture will be followed by a 10-minute question and answer session.

Close Format Presentations
This is an entirely new format designed for EMC 2006 to accommodate technical papers whose topics are difficult to convey in a 20-minute lecture. The venue of the presentation is designed to allow close proximity of the speaker to the audience, providing for a more intimate presentation. Close Format Presentations will be a great forum for papers that require significant explanation to revel the complexities that were discovered during its conception. To aid with the information exchange, each presenter will have a computer display for presentations, as well as a whiteboard. Each Close Format Presentation will be for a period of two hours, giving as many people as possible the opportunity to stop by and visit each presentation.

Workshops
This year, EMC 2006 will be offering more Workshops than has ever been offered at an IEEE International EMC Symposium. There are five Workshop tracks on Monday and on Friday. Several popular Workshops return for another year and several new ones have been created for the advancement of the attendees. Workshops give attendees the opportunity to attend presentations with specific real world teaching and application.

Demonstrations and Experiments
Returning again this year to the IEEE International Symposium on EMC are the ever-popular Demonstrations and Experiments. At past symposiums, Demonstrations and Experiments have been viewed by attendees as a fantastic way to learn in a hands-on environment. Topics have included demonstration of the effects of PC board radiation coupling, component-cable crosstalk, grounding and shielding strategies, spectral analysis techniques using test hardware, effective EMC test methods and practices, use of EMC instrumentation to measure interference at the device or component level, and the role of EMC standards as part of overall measurement practices. Demonstrations and Experiments will again be very helpful in illustrating that basic test hardware can be used to measure a full range of electromagnetic effects.

Special Sessions
The Technical committee has committed to bring EMC 2006 attendees a set of top quality Special Sessions. These special, invited papers will be presented by recognized industry experts and are grouped together at the Symposium for a strong topical focus. The Special Sessions will be presented in a traditional lecture format, covering leading edge developments in EMC technology, test methods, and computer modeling.

Workshops and Tutorials to be Presented at the 2006 IEEE International Symposium on Electromagnetic Compatibility

Please visit the website www.emc2006.org for the complete schedule of workshops and updates. Note this is a partial listing of workshops; workshops will also be presented by Professor Aziz Inan of the University of Portland on "EMC Fundamentals for Beginners and Students"; by Jim Drewniak of the University of Missouri-Rolla on "Fundamental Aspects of Signal Integrity"; by Dr. Charles Bunting of OSU on "Introduction to Fullwave Modeling Techniques"; and Ross Carlton of Freescale on "IC EMC". Information shown below is current as of press time. Check the website for more information!

Advances in Site Validation Techniques above 1 GHz
Dr. Vince Rodriguez, ETS-Lindgren

For some time now, the American National Standards Institute (ANSI) Accredited Subcommittee (ASC) C63 (Electromagnetic Compatibility) Subcommittee 1 has had a working group in place tasked with developing new procedures for validating EMC test sites above 1 GHz. As this work begins to bear fruit, this workshop is intended to bring a number of contributors together to detail the progress to date and look at options available for EMC testing at higher frequencies in the future. This workshop will provide an introduction to the validation techniques that are likely to be required in the near future, as well as discussion of the difficulties likely to be faced. It is an ideal opportunity for attendees to obtain valuable information about upcoming requirements in an informal classroom atmosphere. The agenda includes:

- EMC International Standards Update Above 1 GHz, including related activity in ANSI ASC C63, CISPR, and the IEC, by Don Heirman, Don HEIRMAN Consultants
- Site Qualification Above 1 GHz by Mike Windler, Underwriters Laboratories Inc.
- Absorber Placement Requirements, including a summary of specific CISPR/A activity in this area, by Werner Schaefer, Cisco Systems, Inc.
- Antenna Characteristics Above 1 GHz, including a review of antenna theory and the importance of pattern information by Vince Rodriguez, ETS-Lindgren

The Future of EEE Testing, New Requirements on the Horizon
John Osburn, Lockheed Martin

The workshop opens with a statement of the urgency, as seen by the US Air Force, of developing and emplacing new, much more stringent electromagnetic requirements for aircraft and avionics equipment. The recent years have seen an increase in RF transmission capability to the point where incident EM events are threatening the loss of aircraft. This section covers the main threats. The requirements for equipment and aircraft are derived from the threats described above. This section addresses the threats on an individual basis, and sets the test and performance levels for the various cases. Given advanced requirements for aircraft and equipment, and the investment necessary to support EEE testing of equipment, the test methods for extremely high levels such as 2000 V/m need to be based, wherever possible, on existing equipment or on available test accessories. This section describes alternative or adopted test methods for evaluation at these levels. Note that it may be necessary to measure coupling functions and re-inject higher levels at alternative injection sites, as opposed to direct RF illumination. Some experiences with design for high-level EM fields are reported. The workshop closes with a brief review and various discussions regarding the need for these test levels and the willingness to accept alternative methods for testing.

Nano-technology and EMC
M.S. Sarto, University of Rome "La Sapienza"; C.L. Holloway, NIST

Nanotechnology is functional engineering on an extremely small scale that can be used to develop innovative advanced materials (e.g. metamaterials, frequency selective surfaces, photonic band gap, etc.) components, devices, and implants for numerous industrial applications. It involves the control of materials with a nanoscale fine structure, and with the manipulation of tiny objects at the dimension of molecules and atoms. The potential benefits of nanotechnology are revolutionary. Nanotechnology is currently exploited in microelectronics, optoelectronics, material science, but its application in EMC is still not very wide. Advanced nanostructured materials can be designed and optimised to realize frequency-selective smart surfaces to be used for shielding, or as a substrate for PBC and antenna applications. Carbon nanotubes can be used to realize nano-scale components, circuits, and low-reflection materials. The scope of the workshop is to present the most advanced applications of nanotechnology in the field electromagnetic compatibility. The workshop will cover the following main topics:

- The application of carbon nanotube based nanodevices and nanostructured materials for nanointerconnects and shielding materials.
- Issues related to the fabrication, the measurement of the electrical and electromagnetic properties, and the electromagnetic modelling at radio frequency will be treated.
- The application of metamaterials for antennas and EMC

Practical Applications and Limitations for Real-World Modeling
Bruce Archambeault, IBM

The workshop is intended to build on the workshop where the basic modeling/simulation techniques are introduced. We will discuss each of the various modeling techniques; give specific examples where the modeling technique works well for an application, and, more importantly, where each of the various modeling techniques does not work well. Also, there will be a detailed discussion on methods to validate the accuracy of the models.

Basic Antenna and Probe Use in EMC
Candace Suriano, Suriano Solutions

Antenna and Probe Fundamentals provides an introduction to antenna and probe theory with application relevant to EMC. This workshop covers fundamental principles of operation for various common antenna and field probe configurations covering the frequency spectrum associated with EMC testing. The essential descriptive characteristics of antennas and probes are defined. The nature of radiation and coupling for various types of antennas is described and illustrated including consideration of near field and far field effects. The use of antennas in EMC testing is covered including comparison of reverberant, anechoic, and open air testing. The implications of the antenna characteristics on EMC testing are discussed including the nature and use of antenna factors, gain, radiation resistance, VSWR, etc. Processing and interpretation of antenna signals by receivers and analyzers is discussed including discussion of signal type, signal bandwidth and filtering of signals. The use of soft ferrites in conjunction with antennas in EMC testing is covered. Unintentional radiators/receptors will also be discussed. This workshop has been given at three of the past IEEE EMC symposiums to standing room only crowds. Speakers include Zhong Chen from ETS-Lindgren, Tom Holmes from Agilent Technologies, Candace Suriano from Suriano Solutions, Qin Yu from Lucent Technologies Inc. and Paul Zdanowicz from Fair-Rite Products Corp.

Wireless Devices and EMI; Presented in Two Workshops, Parts A and B
Dan Hoolihan, Hoolihan EMC Consulting
This workshop will address the interference aspects of the proliferation of wireless devices in the modern world. It will include both interference from product to product as well as spectrum allocation issues. Topics to be addressed include (1) EMI from licensed transmitters, (2) EMI for unlicensed transmitters, (3) TCB issues with EMI and wireless, (4) EMI and future technologies, and (5) International and regulatory aspects of EMI and Wireless. A panel discussion will conclude the workshop.

New Applications for Reverberation Chamber Testing Technology
John Ladbury, NIST; Dennis Lewis, The Boeing Company; Garth D'Abreu, ETS-Lindgren
For many years, primarily the military, aerospace, and automotive markets used reverberation chamber testing methodology. EUTs were commonly full sized vehicles and very large products. Recently, this testing methodology is now being used for testing smaller EUTs and for much wider applications. Due to the cost effective nature of reverberation chamber testing, additional test applications continue to be explored. This workshop will review new applications for using reverberation chambers from a practical point of view. Test time, limits, effectiveness, and test costs will be reviewed. Trade offs, as well as pros and cons, for this type of testing for various products will also be addressed. Agenda items include:

- Practicalities of Reverberation Chamber Testing, Chris Holloway, NIST
- Alternative Stirring Methods: Comparing Paddle, Frequency, and Location Stirring, John Ladbury, NIST
- Aircraft Shielding Measurements Using Reverberation Chamber Techniques, Nathan Horton, Boeing
- Reverberation Chamber Test Applications in RFID, Dr. Charles Bunting, Oklahoma State University
- Simulating Wireless Environments in a Reverberation Chamber, Chris Holloway, NIST
- Antenna Efficiency Measurements in a Reverberation Chamber, Dennis Lewis, Boeing
- Use of Small Reverberation Chambers for Wireless Measurements, Garth D'Abreu, ETS-Lindgren

The New EU EMC Directive
Gary Fenical, Laird Technologies
Speakers Ivan Hendrikx, Independent EMC/Safety Expert, Belgium, Keith Armstrong, EMC Engineer/Consultant, UK, Dave Imeson, Chairman, European Commission of Notified Bodies, UK and Donald Sweeney, President, DLS Electronic Systems Inc. USA, will address:

- Market Surveillance
- Fixed Installations
- The New Guidance Document for the Directive
- Perspective from the US Point of View

Tutorial on Basic EMC Measurements
Donald Heirman, Don HEIRMAN Consultants
This workshop will be an introduction to basic EMC measurements with a primary focus on emission testing. While intended for those new to these disciplines, the latest activity in national and international standards related to EMC measurements will be presented. A special focus will be on measurements and associated issues above 1 GHz as well as measurement uncertainty. An open discussion will follow the presentations.

Having ESD problems? From Basics to Solutions
David Pommerenke, University of Missouri - Rolla
This workshop objective is to enable engineers to understand what is tested for in a system level ESD test, and how to locate the exact cause of a problem. As EMC problems now often directly relate to IC design, developing IC level immunity standards will be explained and an update will be given on improvements within the ESD system level standard IEC 61000-4-2. Product examples will start a panel discussion.

Guide to Accreditation of EMC Laboratories in the US
Werner Schaefer, Cisco Systems, Inc.
The workshop is planned as a true exchange of information between laboratory personnel who are either considering accreditation for their laboratory or who are already accredited. A formal outline of the workshop is prepared and can be followed. However, emphasis is placed on answering questions from the audience to ensure that the true interests of attendees are covered. The author, a lead assessor with A2LA, also manages the quality system for accredited laboratories and is actively participating in and contributing to national and international EMC standards work. The presenter's extensive background knowledge about RF and microwave test instrumentation allows for an in-depth discussion of complex subjects such as suitability of test equipment calibration services, test equipment suitability, and measurement uncertainty calculations. The workshop consists of five parts covering reasons for obtaining accreditation for an EMC laboratory, what does accreditation really mean, accrediting bodies in the US, prerequisites for an accreditation, implementation of a quality system, based on ISO 17025, plus equipment calibration requirements, measurement uncertainty requirements, test equipment and test environment suitability and other considerations for laboratory accreditation.

EMC Standards
Qiubo Ye, Communications Research Center, Ottawa, Canada
Chair, EMC Society Standards Education and Training Committee
The purpose of this workshop is to acquaint the international EMC community with selected EMC standards and standards-related issues applicable to the design, test, and production of electrical/electronic equipment for the worldwide market. It includes an introduction of standards principles, history of the standards activities, filter measurement techniques, EMC of policy-based adapted radio, progress towards the development of standards and recommended practices for validating Computational Electromagnetic (CEM) techniques, probe calibration, and measurement of shielding effectiveness for shielded enclosures.

Product Safety
Richard Georgerian, Carrier Access
The Product Safety Workshop is intended to provide a practical overview of several key product safety areas. The presentations provide an overview of current requirements and up-coming changes, and then focus on areas of interest, based on technical complexity or regulatory changes. The final element of the workshop will be a dialog covering areas of particular interest; there will be a panel discussion open to all topics. In the past, the Product Safety Workshop has attracted a wide audience ranging from product safety experts looking for an exchange of information to EMC engineers wishing to get background in product safety and up-coming regulations. The workshop is a good opportunity to compare notes and see more of the forest after focusing on the trees. It is an opportunity to meet and hear some of the leaders in the respective fields.

Advanced EMC Design
Lee Hill, SILENT
This workshop features four presentations on EMC design focusing on printed circuit board and shielding design issues. Each author is a past IEEE EMC Society Distinguished Lecturer with many years of experience in high-speed design. Presentations include Cheung-Wei Lam of Apple Computer on "Common Misconceptions about Inductance and Current Return Path," Bruce Archambeault of IBM on "Advanced PCB Decoupling," Colin Brench of Hewlett Packard on "Advanced Topics in EMC Shielding," and Lee Hill of SILENT on "Overlooked Characteristics of Ferrites for PCB EMI Suppression." This session will provide attendees with the opportunity for significant questions and time with the speakers.

Abstracts for Papers to be Presented at the 2006 IEEE International Symposium on Electromagnetic Compatibility

August 14-18, Portland, Oregon

Following is a listing of abstracts shown in random order.
Please check the website www.emc2006.org after June 15 for the schedule of papers to see when a particular paper will be presented during Tuesday through Thursday of the Symposium week. Tutorials and Workshops will also be scheduled and the speakers, topics, and more on the Technical Program will be available for review on the website after June 15.

Shielding Measurements of the Space Shuttle (Part I – Testing the NASA Endeavour)

Kenneth Brezinski, Naval Air Warfare Center; Diane Kempf, Naval Air Warfare Center

The Naval Air Warfare Center (NAWC) at Pax River teamed with the National Institute of Standards and Technology (NIST) to perform a shielding test of the NASA Space Shuttle Orbiter "Endeavour." Pax River was responsible for testing in the high frequency range up to 18 GHz. NASA imposed some very tight limitations on the time allotted to perform the test and the amount of power that could be radiated during the performance of the test. This required Pax River to perform much development work on our existing shielding effectiveness test method using reverberation techniques in order to meet NASA's needs. This paper discusses the method in detail and describes the development work and its validation.

Shielding Measurements of the Space Shuttle (Part II – Testing the NASA Endeavour)

Kenneth Brezinski, Naval Air Warfare Center; Diane Kempf, Naval Air Warfare Center

Testing was conducted on the NASA Space Shuttle Orbiter, Endeavour, to determine the high frequency shielding capability of three major cavities; the flight deck, the mid-deck/crew quarters and the payload bay. Testing was performed using highly modified reverberation techniques. The hangar at the Shuttle Landing Facility at Kennedy Space Center served as the "reverberation chamber" for the spacecraft. An account of the test method is presented in detail, along with setup diagrams, photos, and graphs of the shielding measurements.

Closed-Loop Method to Assess RF Interference Impact on Wireless Transceivers

Mike Schaffer, Intel Corporation

Platform RF Interference generated by Gaussian and non-Gaussian sources can have a significant performance impact on wireless transceivers. Higher frequency platform noise is being generated by faster performance clocking and signaling technologies. Encroaching into the wireless band, this noise can have a significant degradation to wireless throughout performance. An approach to mitigation must start with a measurement methodology that establishes the dynamic performance of the wireless transceiver in the presence of RFI. The conducted effects of the degradation are investigated using various clocking and signaling interference sources. The consequences of various clock and signal encoding techniques coupled with the suggestions of this paper are discussed with respect to reproducibility and severity.

Study of EMC Problems Caused by Lightning Using Cartesian Analytical Expressions

Jose Pissolato Filho, UNICAMP; Geraldo Caixeta, Sao FranCisco University; Fernando Zago, UNICAMP; Fernando Zago, UNICAMP; Geraldo Caixeta, Sao FranCisco University; Jose Pissolato Filho, Unicamp; Fernando Zago, UNICAMP

The numeric technique TLM (Transmission Line Modeling Method) was applied to determine the transient currents caused by lightning on Lightning Protection Systems (LPS) and the induced transient voltages on circuits localized inside them. Using this technique in one-dimension and Cartesian expressions in time domain to calculate the electromagnetic field, all conductors and the lightning channel were considered such as transmission lines. This work presents a computational analysis of transient currents on LPS and the electromagnetic field achieved inside them that induces voltages on internal circuits when lightning directly strikes them or their vicinity. The approach adopted offers flexibility to design and discuss some kinds of LPS or their geometric configurations. It allows us to find the best protection at each situation and to take into account financial aspects as to the number of conductors and insulation levels required.

Direct Lightning on Grounding Grids and EMC Problems

Fernando Zago, UNICAMP; Jose Pissolato Filho, UNICAMP; Henry Mesa, UNICAMP; Geraldo Caixeta, Sao FranCisco University; Fernando Zago, UNICAMP

This paper presents simple models that can be computed in seconds and give a good estimate of EMC problems caused by transient current and voltage on grounding grids, which are caused by lightning surges. The TLM (Transmission Line Modeling Method) is employed with a model of underground conductor or transmission line in time domain computational simulations and some examples of problems are considered to illustrate the simplicity and the reliability of the method. This numeric technique has been chosen, because the correct boundary conditions can be obtained easily and the representation of different kinds of loads is achieved.

Novel Calibration Technique for EMI Antenna Using Reverberation Chamber

Katsushige Harima, National Inst. of Info. and Com. Tech.

A reverberation chamber can create a multipath environment. When two antennas are placed opposite each other in an ideal reverberation chamber, the mean value of the complex received value equals the direct wave component between them because the vector sum of reflected waves with random phases is zero. Therefore, the free-space

antenna factor can be determined from the mean value of the complex received value. However, when using conventional reverberation chambers, reflected waves with unvarying path lengths off of the walls without a stirrer are included in the mean value. We describe a novel technique for reducing the effect of these reflected waves.

Partial EBG Power Distribution Network using Remnants of Signal Layers in Multi-layer PCB

Youngwon Kim, KAIST; Eakhwan Song, KAIST; Joungho Kim, KAIST; Junho Lee, Hynix

In this paper a partial electromagnetic band-gap (EBG) power distribution network (PDN) using remnants of the signal layer in a multilayer printed circuit board PCB) are presented. A partial EBG PDN is embodied in a conventional four-layer stack-up PCB without any additional layer, and the efficiency of the proposed method on signal transmission quality improvement and power plane noise mitigation is investigated experimentally. It is shown that the proposed method provides an improved signal return current path, resulting in better signal transmission quality and higher signal noise margin than conventional methods. In addition, the method enables lower power noise generation.

Microwave Thawing Examinations of a Frozen Material (Tuna) in a Microwave Oven

Shinya Watanabe, Aoyama Gakuin University; Youichi Kakuta, Aoyama Gakuin University; Osamu Hashimoto, Aoyama Gakuin University; Shinya Watanabe, Aoyama Gakuin University

In this paper, temperature distribution of heated material (frozen tuna) in a microwave oven is calculated by the method which combines FDTD for electromagnetic field calculation with Heat Transport Equation (HTE) considering melting heat and the nonlinear and rapid change of complex relative permittivity and heat conductivity during defrosting. Meanwhile, the temperature distribution is measured by heating experiment using a microwave oven of production model and thermo-graphy is compared with the calculated one. As a result, the calculated temperature distribution of heated material agrees well with the measured one, and the validity of the combined method considering melting heat and the change of complex relative permittivity and heat conductivity is confirmed.

Approaches and Particularities for Achieving EMC with Regard to Functional Safety

Bernd Jaekel, Siemens AG

Safety functions are more and more carried out by electrical, electronic or programmable electronic systems. Such systems are exposed to electromagnetic phenomena like they typically exist in installations and therefore they could potentially be affected. As a consequence a failure of the safety function could arise which might cause harm to people. Thus appropriate immunity has to be achieved which is not ensured in every case by complying with normal EMC requirements because they are usually derived from issues of reliability and economic circumstances. Therefore EMC and safety requirements have to be brought together. This paper describes an approach how to assess EMC of complex safety-related systems and how to establish proper function and/or reaction of such safety functions when being exposed to electromagnetic disturbances. Particular immunity levels are suggested to be introduced in combination with a special performance criterion "Functional Safety". Furthermore the situation is discussed regarding immunity levels and their relation to safety integrity levels.

A Differential-Signaling Analysis with the Decoupling-Capacitor Loaded Rectangular Power-Bus by a Fast Calculation Method

Sungtek Kahng, University of Incheon

This paper analyzes the decoupling capacitor (DeCap)'s mitigating effects on the resonance from the differential signaling for the rectangular power-bus structure. Besides, it is suggested the single-sum modal expression is used to consider lumped-element loading in the structure without loss of accuracy and it leads to fast calculation. The validity of the present single-sum expression is proven by the use of the double sum and the FDTD method. And the DeCap is shown to improve the differential-signaling performance.

Anechoic and Reverberation Chamber Shielding Measurement at Frequencies Above 1 GHz

Andrew Marvin; Yong Cui, University of York

Based on the new definition of Shielding proposed in [1], measurements are performed in both anechoic and reverberation chambers. The relationships between the measurement results of each measurement environment are discussed and conclusions are drawn. It is shown that whilst the Shielding measurements are comparable in both measurement environments the rapid spatial field variations present in the radiating near field still pose a measurement problem. The work is informing new developments in IEEE Standard 299.

A Comparative Study of Vector Fitting and Orthonormal Vector Fitting Techniques for EMC Applications

Giulio Antonini, University of L'Aquila

Broadband rational approximations of multiport systems are of great importance for accurate transient analysis of electrical systems. To this aim, fitting techniques have been found extremely useful in providing rational models for sampled data in the frequency domain. This paper presents a comparative study of two fitting methods, namely the standard Vector fitting (VF) and the orthonormal vector fitting (OVF) techniques. The latter is found to be better conditioned, reduces the numerical sensitivity to the choice of starting poles and limits the number of iterations and, thus, the global cpu-time to obtain the rational approximation.

Rectangle Wave Propagation in Electromagnetic Field Analysis Using CIP and R-CIP Methods

Shinya Watanabe, Aoyama Gakuin University; Youichi Kakuta, Aoyama Gakuin University; Osamu Hashimoto, Aoyama Gakuin University

In this paper, for the fundamental examination, Constrained Interpolation Profile (CIP) and Rational function-Interpolation Profile (R-CIP) methods are applied to electromagnetic field analysis. And the dependency of Courant Friedrichs Lewy (CFL) condition when a rectangle wave propagates is examined using FDTD, CIP and R-CIP method. As a result, the dependency on CFL condition when a rectangle wave propagates is also confirmed on FDTD, CIP and R-CIP methods.

The EMC Analyzing and Optimizing with High Frequency Interference in PCB Design

Lanfen Qi; Jie Liu, Electromagnetic Fields and Microwave Techniques

In this paper, we make use of the software Ansoft Designer to analyze the high-frequency interference in the PCB, and get the current plots & EM (electric & magnetic) near field plots to see the effect on the

PCB's EMC by the high-frequency interference. According to the current plots & EM near field plots, we can analyze the EMC of the PCB and optimize the layout design.

Narrowband and Broadband Discrimination with a Spectrum Analyzer or EMI Receiver

Werner Schaefer, Cisco Systems

Spectrum analyzers and scanning receivers are widely used in EMI laboratories today. Their use for measuring both narrowband and broadband signals requires specific understanding of certain instrument and signal characteristics in order to correctly interpret the displayed results. This paper explains methods for the discrimination between narrowband and broadband signals and provides guidance for the proper operation of test instrumentation.

Modeling of Hierarchical Power/Ground Network Based on Segmentation Method for Package/Board Co-Design and Simulation

Jaemin Kim, KAIST

Hierarchical power/ground network is the most common structure in system, however it is hard to extract the impedance property of it, because of the interaction between structures in system, such as package and board. With resonant cavity model, segmentation method and two special issues on hierarchical network, we can find out the total impedance of system. The result has been verified by comparing with the result of 3D full wave simulation in frequency domain.

Design and Analysis of Improved Multi-Module Memory Bus using Wilkinson Power Divider

Jingook Kim, KAIST; Myunghee Sung, Samsung; Jonghoon Kim, Samsung; Eakhwan Song, KAIST; Jaemin Kim, KAIST; Byungse So, Samsung; Joungho Kim, KAIST

Branch connections in multi-module memory bus are usually sources of impedance mismatching, resulting in resonance in the branch stub. An effective way has been proposed to reduce stub resonance by using Wilkinson power divider. The effect of Wilkinson divider has been verified by experiments in both frequency and time domains.

Correlation of Radio Frequency Interference Tests with Low Dropout Voltage Regulators

Cyrous Rostamzadeh, Robert Bosch Corporation

Suppliers of automotive electronic products and modules can select from various component level RF immunity measurement techniques to evaluate and quantify EMI compliance requirements. RF immunity tests are designed to expose the electronic device to EMI threats that are seen in the real world. In this paper, we investigate the correlation between four different test methods used in the automotive electronics industry to test for component compliance due to narrowband conducted and radiated electromagnetic energy. The test methods are described by the ISO 11452 and SAE J1113 standards. A low dropout regulator is exposed to RF fields by several RF immunity tests and the results are discussed. The frequency range of observed RF effects correlate well between different measurements.

Properties of Ferroelectric/Antiferroelectric Materials in the Application of EMC

Huadong Li, University of Dayton; Guru Subramanyam, University of Dayton; Huadong Li, Pioneer Automotive Technologies, Inc.

This paper studied the applications of nonlinear dielectric constants of ferroelctrics/antiferroelctrics in EMC. Influences of the nonlinearity of the constant on noise filtering, component self-resonance and parallel resonance are investigated.

A Comprehensive Evaluation of an Outdoor Vehicular Test Range

Robert Johnk, NIST

This paper summarizes a joint industry/government effort to evaluate a large outdoor automotive antenna range owned by a large U.S. automotive manufacturer. This effort was undertaken to improve accuracy and to reduce overall measurement uncertainties. Results are presented from an extensive series of measurements and full-wave electromagnetic numerical simulations. The study revealed the antenna range turntable/dome combination as a source of significant errors in automotive antenna pattern measurements.

Experimental Study of Induced Voltage Between Two Bare Horizontal Electrodes in Ground

Mohamed Nayel, China South Power Grid Co.; Zhao Jie, China South Power Grid Co.; Jinliang He, Tsinghua University

This paper investigates induced voltage between two identical finite horizontal electrodes in same plan (horizontal and vertical). Various arrangements of horizontal electrodes were tested to study the lower and higher induced voltages. Injected voltage and current and induced voltage waveforms were measured to obtain peak voltage and mutual resistance. Measured results for different cases were tabulated and analyzed. It has been found that the current injected in a middle of the electrode shows lowest peak voltage and the lowest induced voltage to the other electrode. Also, induced peak voltage from the upper electrode to the lower electrode is less than that from lower to upper case.

A Study on the Model of the Aperture Distribution for Cosecant-Squared Antennas

Dong-an Song, Nation Key Laboratory of Electromagnetic Compatibility

The field on aperture of cosecant-squared antennas is different from universality radar's. So, it is not to use the universality model of aperture field to calculate the near-field of the shaped-beam antennas. The model of the aperture distribution for the shaping antenna has been studied by Woodward-Lawson Method and transform technology in this paper. The near-field of a test antenna which vertical-plane pattern is cosecant-squared pattern has been investigated both in theory and experiment. The theoretical results and measurements are compared by plotting the curves of both them. The conclusions are that the model is particularly useful for calculating the near-field in the regions of main beam of the cosecant-squared antennas.

A Study of Zero Reference Effects on Electromagnetic Transient Measurements of a Grounding Electrode

Jinliang He, Tsinghua University; Zhao Jie, China South Power Grid Co.; Mohamed Nayel, China South Power Grid Co.; Akihiro Ametani, Doshisha University

This study concern of zero reference used in measurements of transient characteristics of a grounding electrode. Experimental measurements of many cases of Zero reference have been carried out. Different lengths (20 m, 40 m and 60 m) of the zero reference wire in same and right angel directions to the lead wire direction were examined to obtain their effects on transient voltages of the grounding electrode. Zero reference wire was replaced by a cable with dif-

ferent sheath ends grounding in same and right angel directions. Open end and grounded end of zero reference for different cases were tested and studied. The results show that as the length of zero reference wire increase the measured results accuracy increased. Replacing zero reference wire by the cable of grounded sheath at both ends gives the most accurate result.

Impedance Analysis of Overhead Medium Voltage Power Lines for Broadband PLC

Young jin Park, Korea Electrotechnology Research Institute; Kwan ho Kim, Korea Electrotechnology Research Institute; Young song Cho, Chodang University; Gi deok Yang, Ansan College; Young chul Lee, Kyungnam University; Chull chai Shin, Ajou University; Dong wan Chun, Ajou University

In this paper, impedance characteristics of overhead medium-voltage (MV) power lines are reported for power line communication (PLC) over an MV power line network. For analysis, a two-port equivalent network model of MV power lines is derived. By applying the transmission line theory, reflection behavior and impedance of power lines are investigated. For verification, impedance of power lines is measured at a test field for an MV PLC. The results show that impedance of MV power lines is between 150 Ω and 350 Ω and converges to a half of their characteristic impedance.

An Equivalent Circuit Model for Predicting EM Radiation from a PCB Driven by a Connected Feed Cable

Motoshi Tanaka, Akita University; Hiroshi Inoue, Akita University; Yoshiki Kayano, Dept. of Electrical and Electronic Engineering, Akita University

An equivalent circuit model for predicting common mode (CM) radiation from a printed circuit board (PCB) driven by a connected feed cable is proposed and demonstrated. The equivalent circuit model is based on consideration of concepts of CM antenna impedance and distributed constant circuit to the conventional mechanisms of current- and voltage-driven. Good agreement between the predicted and measured results shows validity of the equivalent circuit model. The proposed model can predict and explain frequency response of CM current with engineering accuracy, and also express the intermediate state of the current-driven and the voltage-driven. This study is a basic method and consideration to establish methods predicting an EM radiation from the PCB driven by the connected feed cable.

A Generation Method of Rotating-EM Field Using Four-Septum TEM Cell and Its Basic Characteristics

Hiroko Kawahara; Majid Tayarani; Fengchao Xiao; Yoshio Kami; Kimitoshi Murano, Tokai University

A new kind of TEM cell having four septa (Four septum TEM cell) is studied. By applying different DSB-SC signals to the four septa, a rotating-EM field can be generated inside the four-septum TEM cell and the field would be used as an incident-EM field for RF radiated immunity/susceptibility test. In this paper, a generation method of rotating-EM field in the four-septum TEM cell is studied and the basic characteristics of the field generated inside the cell is examined experimentally.

Numerical Calculation of Grounding Current Through Capacitive Voltage Transformer Due to Substation Switching Operation

Lei Liu; Xiang Cui; Changzhen Gao; Lei Qi; Lei Liu, North China Electric Power University

The constituent of Capacitive Voltage Transformer (CVT) are almost capacitances in primary side, and they act essentially as a short circuit to the transient current produced by a switching operation, which will generate high grounding current. Because capacitance is lumped parameter, so this paper use Finite-Difference Time Domain method (FDTD) to build calculation formula of Multi-Conductor Transmission Lines (MTL) whose branch points has lumped parameter network. On this base, the grounding current through CVT produced by substation switching operation has been calculated. The result of this paper has certain consult meaning for the research of substation electromagnetic interference (EMI) on primary and secondary equipments.

Parallel Computation of the Large Grounding Grid in Multi-Layer Soil

Changzheng Gao; Lin Li; Zhibin Zhao; Xiang Cui, North China Electric Power University

A parallel MoM method is developed for the computation of large grounding grid in multi-layer soil. All of the time-consuming steps in this method are designed supporting parallel computing on a PC Cluster. Compared with the experimental results, this method is proved correct and because of its good acceleration ratio, it is practical for the analysis of large grounding grid.

Transient Plane Wave Coupling to Overhead Line Above a Multi-Layer Soil

Lei Qi; Xiang Cui; Tiebing Lu; Lei Qi, North China Electric Power University

Considering the displacement current in the multilayer soil, the formulas of the ground return impedance and the Fresnel reflection coefficients are derived in frequency domain. These expressions are valid for discretional soil conductivities and the whole range of frequencies. For the convenience of transient analysis, the vector fitting method is adopted to expand the time-domain forms of the ground return impedance and the Fresnel reflection coefficients into the sum of finite exponential functions, which are easy to be treated. Based on the recursive algorithm for the time-domain convolution, the finite difference time-domain (FDTD) method improved by the authors is used for the transient analysis of the external excited overhead line. Compared with the existing method applicable for homogeneous soil, the proposed method is demonstrated to be correct.

Application of the Statistical Method and Quality Factor Decomposition to Determine Microwave Fields Inside an Equipment Cavity

Raphael Bendel, Nucletudes

Many previous papers have shown theoretical works concerning the use of statistical models to determine EM (Electromagnetics) radiations inside an overmoded cavity. Some studies have also stated a decomposition of the EM quality (Q) factor for electrically large and lossy cavities. All of these works have found many interests in EMC and more recently in mobile communication applications. We present here a practical study concerning a new application of both theories. This deals with the characterization of a microwave environment inside an equipment cavity filled with PCB and wires.

Damping of Cavity-Mode Resonances in PCB Power-Bus Structures using Lossy Slot Resonators

Stefan Dickmann, Helmut Schmidt University; Matthias Hampe, Helmut Schmidt University

In this paper, a novel technique suppressing cavity mode resonances in PCB power-bus structures by using lossy slot resonators is pre-

sented. Guidelines for an optimized damping of the modal resonances are specified, which are based on rules derived recently for an appropriate selection and placement of damping capacitors. The effectiveness of the presented damping technique is shown by simulations as well as measurements considering several PCBs of different shape.

Measurements of Spurious Emission with a Time-Domain EMI Measurement System Using Multi-sampling Techniques

Peter Russer, Institute for High-Frequency Engineering; Stephan Braun, Institute for High-Frequency Engineering

Time-domain EMI Measurements allow reducing the measurement time by a factor of 2000 in comparison to measurements in frequency domain. EMI receivers use a preselective filter to obtain a high spurious free dynamic range for stationary and transient signals. In this paper a novel method is introduced that enhances the spurious free dynamic range of the Time-domain EMI Measurement System. This allows the application of the system to measurements of spurious emissions of communication systems. A correction of nonlinearities of the ADCs is performed to suppress harmonics and intermodulation products. Several measurements are performed with different sampling rates of the ADCs to remove spurious signals from the spectrum. A spurious free dynamic range of 90 dB has been achieved for a stationary signal in the frequency range 30 MHz - 1 GHz. The spurious free dynamic range for stationary signals has been investigated and compared with results obtained by an EMI receiver.

Some Simple Spacecraft Considerations

Edward Heise, Parker Hanafin

Electronic units installed on spacecraft encounter environments far different from that on earth. Electromagnetic compatibility still has to address shielding and filtering but with the added concerns of being enveloped in a plasma of various particle energies, being (line-of-sight) exposed to high intensity radio and radar signals, having to be compatible with sensitive receiver systems, and surviving the effects inherent in a space orbit.

IEEE P1302: Characterization of Shielding Gaskets

Johan Catrysse, KHBO

By 26 June 1998, the first edition of the standard IEEE-Std 1302/1998 "IEEE Guide for the Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz" has been published. In the meantime, a lot has changed on technologies and measuring methods. Related to this background, a new PAR 1302 has been introduced for reviewing and updating the actual version. The first meeting of this PAR 1302 has been held during the IEEE EMC Symposium of August 2002 in Minneapolis. A lot of work has been done, and the draft of the second edition of this standard will be available for discussion at the time of the next IEEE EMC Symposium of August 2006 in Portland. The aim of this paper is to open the forum for discussion and voting, related to the development of this second edition.

A New Technique to Improve Gasket Performance That Uses Elastomer or Rubber Material

Theodore Anthony, Army Research Laboratory; Youn Lee, Army Research Laboratory

Elastomer material loaded with conductive metal powder is frequently used as EMI (electromagnetic interference) gaskets, and open or closed cell polymer or rubber is used as the core material of wire-mesh gasket or conductive fabric. Reported and well documented, and many shielding effectiveness test personnel know that, especially on some applications requiring very high level of shielding, these gaskets frequently fail to meet performance requirements because of compression set [1]. New test results reveal ways to circumvent this kind of failure, and we suggest a new test procedure in choosing the polymer material to address the existing problem.

Numerical and Experimental Investigation of PCB Ground-Fill on Radiated EMI

Cyrous Rostamzadeh, Robert Bosch Corp; Bruce Archambeault, IBM

Influence of the ground-fill used in multi-layer PCB implementations is investigated both experimentally and numerically, using finite-difference time-domain (FDTD) modeling. Ground islands can cause impedance discontinuities on signal traces and affect the signal integrity of high-speed clocks and their harmonic contents as well as increase EMI emissions. Several test boards were developed to evaluate the impact of the ground fill on radiated emissions. Measurements and numerical results are in good agreement. Numerical analysis and radiated emission measurements should be useful for developing PCB EMI design guidelines.

Temperature Distribution of λ/4 Type EM-Absorber Using Resistive Film Under High Power Injection

Shinya Watanabe, Aoyama Gakuin University; Kota Saito, Aoyama Gakuin University; Osamu Hashimoto, Aoyama Gakuin University; Toshifumi Saito, TDK Corporation; Hiroshi Kurihara, TDK Corporation

In this paper, first, FDTD, Semi-Implicit Method for Pressure Linked Equations (SIMPLE), Monte Carlo and Radiative Energy Absorption Distribution (READ) methods are combined to calculate electromagnetic field and all the heat transfer phenomena of heat transport, heat transfer by air convection and heat radiation (It is called FDTD-SIMPLE-MR method.). The temperature distribution of λ/4 type EM-absorber using resistive film under high power injection is calculated using FDTD-SIMPLE-MR method and a traditional method. Next, the high power injection experiment is examined using the absorber and high power RF instruments to get the temperature distribution experimentally. Finally, the calculated and measured temperature distributions of the absorber are compared. As a result, the calculated temperature distribution by FDTDSIMPLE-MR method agrees well with the measured one and the validity of FDTD-SIMPLE-MR method is confirmed.

The Transient Response Analysis of EMP Coupling Through Apertures

Yan Zhe, Harbin University Science and Technology; Yang Xin, Harbin University Science and Technology; Jiaxiang Yang, Harbin University Science and Technology; Xiaoliang Bi, Harbin University Science and Technology

The exterior electromagnetic pulse coupling through apertures to circuits inside the metal enclosure, the transient response may be analyzed either using the time-domain method or the frequency-domain method. In this paper, a new time-frequency domain analysis method is presented. Taking the discrete fractional Fourier transform (DFRFT) of the measured induced voltage data in time-domain and obtaining the time frequency representations of the transient response. The analysis of the results show the magnitude and phase are changed with the different angle rotation-□, which can't be obtained from the classical Fourier Transform.

Method of Evaluating Shielding Effect for Electronic Equipment Case using Wire Grid Model and Radiation Source from 1 GHz to 3 GHz

Ryo Ishikawa, NTT Advanced Technology Corp.; Fujio Amemiya, NTT Advanced Technology Corp.; Naoya Nakashio, Kyushu Institute of Technology; Toshirou Nishimura, Kyushu Institute of Technology; Nobuo Kuwabara, Kyushu Institute of Technology

Electronic equipment cases are important item to suppress unwanted emission from digital processing circuits. However, slits and apertures of the case decrease the shielding effect at high frequency. In this paper, the shielding effect of an electronic equipment case was evaluated from 1 GHz to 3 GHz where CPU was operating. The case was modeled by wire meshes. The radiation source was placed in the mesh model, and the shielding effect was evaluated. Disc-corn antenna with O/E converter was used as the radiation source. The radiation source and the mesh model were presented by a wire grid model to calculate the radiated electric field, and the shielding effect was obtained from the results. The mesh model with the radiation source was placed in anechoic chamber, and the shielding effect was measured. The results indicated that the calculation results almost agree with measured one, and the wire grid model could be used to evaluate the shielding effect. The shielding effect of actual PC cases was compared with the results by the mesh model. The results indicated that the mesh size of less than 0.5 cm was needed to present a metallic case less than 3 GHz.

TDR/TDT Analysis by Crosstalk in Single and Differential Meander Delay Lines for High Speed PCB Applications

Dong Gun Kam, KAIST; Joungho Kim, KAIST; Gawon Kim, KAIST

Meander (serpentine) delay lines are generally used for controlling the skew of the traces in high-speed Printed Circuit Board (PCB) applications. They consist of equal-length unit lines closely packed to each other. However the meander lines deteriorate the total time delay and the waveform distortion in the end of the lines, since each unit line is tightly coupled. In this paper, to predict accurate Time-Domain Reflectometry/Time-Domain Transmit (TDR/TDT) waveforms by crosstalk in the single and differential meander line, simple TDR/TDT equations are proposed in point of the signal integrity. The proposed TDR/TDT waveform equations are verified by using TDR/TDT measurements in the single and differential meander delay lines.

Pointing Vector from Measured Distributions of Adjacent Vector Electric and Magnetic Field

Masahiko Sakurada, TAIYO YUDEN CO., LTD., Hiroshi Tsutagaya, TAIYO YUDEN CO., LTD., Satoshi Kazama, TAIYO YUDEN CO., LTD.

We have developed an adjacent electromagnetic field distribution measurement system using a unique sensor and three-input phase-difference measurement system that can simultaneously measure vector electric and magnetic field distributions up to 6GHz with about 1 mm spatial resolution. The system is useful for analyzing the EMC issue between digital and radio circuit in mobile communication equipment. Pointing vector distribution across the measured plane can be estimated from vector electric and magnetic field distributions on the plane measured by this system. The distribution gives us useful information for understanding an antenna and emissions.

Corona Onset Voltage at 60 Hertz for an Isolated, Cylindrical Electrode

William Price, The Boeing Company; David Thiel, Griffith University; Robert Olsen, Washington State University; John Drapala, The Boeing Company

Corona on electrified conductors is a significant source of electromagnetic interference. The Townsend integral, which describes breakdown in non-uniform fields, is derived from the Boltzmann transport equation. Predictions of corona onset are made using recent formulae for net ionization. Measurements of 60 Hertz corona onset for an isolated, cylindrical electrode were made and are compared with predictions.

Reduction of Radiated Emission from Signal Traces using Modified and Small-Sized Ground Patterns

Phil-Sung Park, Hankuk Aviation University; Jae Wook Lee, Hankuk Aviation University; Taek Kyung Lee, Hankuk Aviation University; Choon Sik Cho, Hankuk Aviation University; Jaeheung Kim, Kangwon National University

We analyze the radiation and coupling problem from a single microstrip transmission line and two signal traces. In this paper, it is shown that the reduction of the radiated emission from the signal traces can be accomplished by using the novel patterns on the ground planes. The radiation mechanism from the transmission line on a novel ground plane is predicted and measured by using the commercially available software and experiment, respectively.

Proposal of Electromagnetic Environment-Aware Wireless Network using Multi-hop Wireless Network System

Shinichi Miyamoto, Osaka University; Seiichi Sampei, Osaka University; Takashi Tamura, Osaka University

In coming ubiquitous network society, many equipments with wireless communications function (wireless nodes) are used in a private space. When everyone uses these wireless nodes to get a lot of information, the electric wave is radiated from many wireless nodes in a private space, and the electromagnetic environment falls into the chaotic situation. In this paper, in order to solve the chaotic situation of electromagnetic environment in future ubiquitous network society, we propose the electromagnetic environment-aware wireless network using multi-hop wireless network system. In the proposed system, by using the many nodes, dynamic adaptive routing, and transmission power control according to the selected route, both the electromagnetic environment and the communications environment like throughput performance can be adaptively controlled. Numerical results will show the trade-off between the requirements concerning the electromagnetic and communications environments, and the proposed system can achieve a good balance between electromagnetic and communications environments.

Influence of Magnetic Field of AC Transmission Lines on Parallel DC Transmission Systems

Jian Tang, Tsinghua University

Based on magnetic induction and Fourier series theory, a method is presented to calculate the direct current flowing into the converting equipments induced by parallel proximate AC transmission lines. Through an example, the generated direct currents due to magnetic induction from AC lines are calculated and analyzed in the condition of steady state and fault state. Discussions are performed to illustrate the effects of various parameters upon the direct currents flowing into the converting equipments. It provides insight on how to control the generated direct current by induction of AC lines.

Novel Design Technique for Reducing Common-Mode Current on Wire Harness Connected to ECUs

Yuchi Mabuchi, Hitachi Lid.

A key parameter that controls common-mode current on the cable connected to electronic control units (ECUs) is investigated. Supply

currents for the CPU on ECUs and parasitic inductance / capacitance of supply traces on printed circuit boards (PCBs) generate common-mode current on the cable. We found the amount of common-mode current can be reduced sensitively by adjusting the balance of parasitic inductance capacitance. The new approach proposed in this paper allows minimizing the common-mode current and suppress the radiation less than the currently achievable level. This technique is proven experimentally with evaluation boards and the influence of these parameters on common-mode current is confirmed by our simulation technique.

Improvement of Mode Conversion for LTCC Multi-Layer Common Mode Filter by Vertical Twisted Differential Lines Structure

Bin-Chyi Tseng, Feng Chia University; Lin-Kun Wu, National Chiao Tung University

With increasing demands on information and data storage, higher clock and data rate in electronic devices is requested. In high-speed data communication, differential signaling has found increasing applications. In proportion to the more system functionality and circuit complexity, more unwanted common mode radiation is introduced and the signal integrity is degraded. By using the twisted pair architecture for the differential transmission traces, the mode conversion of the differential signal is minimized in LTCC multi-layer common mode filter design. Furthermore, a high-frequency and wide-band common mode noise rejection is achieved.

A Potential Effect of Decoupling Capacitor Placement on Radiated Emissions: The Rerouting of Current

Rodney Slone, Sun Microsystems, Inc.

Many papers have been published on the topic of decoupling in various EMC forums; however, it seems as if many of those papers' primary focus is on the EMC effects through a signal integrity analysis. That is, those papers seem to focus on ensuring that the path taken by transient currents generated from switching devices is such that either the low frequency impedance seen by those currents, or the area enclosed by the current path, is minimized. This paper proposes that these targets may not always be the best way to measure the utility of decoupling for EMC. This paper will show that, for a real-world product, lowering (or attempting to lower) the impedance of the power distribution system by adding discrete decoupling capacitors can actually increase the radiated emissions by more than 15 dB. The reason for such a drastic increase in emissions is that the return currents can be redirected into a "sensitive" area (where those currents had a much lower magnitude in that area before lowering the impedance of the power distribution system) of the system from which the currents can radiate more efficiently. In summary, this paper proposes that the location of decoupling capacitors can be critical on a multi-layered, moderately thin dielectric, printed circuit board, not because of their ability or inability to provide charge to an active switching device, but rather because of how return currents can be redirected into areas in proximity to "sensitive" areas.

Modeling Radiation Sources of Electronic Components

Christian Arcambal, IRSEEM; David Baudry, IRSEEM; Anne Louis, IRSEEM; Bélahcène Mazari, IRSEEM; Michel Stanislawiak, Thales Air Defence; Sylvain Alves, Thales Air Defence; Philippe Eudeline, Thales Air Defence; Yolanda Vives Gilabert, IRSEEM

Taking into account the integration of electronic components on the boards, the consideration of electromagnetic perturbations is more and more important. The aim of this paper is to present a methodology to model the electromagnetic behavior of the radiation of electronic components so as to predict and avoid future possible interferences. As an application, the radiated behavior of a microcontroller has been modeled.

Immunity Research of Wireless Communication in Switch Cabinet Monitoring and Control

Zhiqiu Li, Tsinghua University; Xiaozhe Wang, Tsinghua University; Liangzhong Yao, AREVA T&D; Christian Sasse, AREVA T&D; Yulonghuang Huang, Tsinghua University; Rong Zeng, Tsinghua University

In this paper we chose Bluetooth and 802.11b from several commercial wireless communication solutions for the purpose of cabinet monitoring and control, and proceeded 50 Hz magnetic field, pulse magnetic field and gap breakdown immunity tests on them. According to the test result, we learned the immunity property of the two candidates preliminarily and will carry out further feasibility investigations.

PEEC Modeling of Linear Magnetic Materials

Giulio Antonini, University of L'Aquila

This paper presents a 3D electromagnetic modeling technique that extends the PEEC approach to analyze arbitrary inhomogeneous structures constituted by conductors, dielectrics and magnetic materials. The proposed approach, while preserving the topology of PEEC elementary circuit, allows to use the PEEC method to model more general materials (e.g. chiral media, metamaterials) and extends its applicability to power systems involving magnetic materials as well as to RFIC systems requiring modeling of both dielectric and magnetic materials.

Common Mode Interference in Unshielded Twisted Pair Cables Due to ESD

Spartaco Caniggia; Francescaromana Maradei, University of Rome "La Sapienza"

Common mode interference produced by ESD events in UTP cables is investigated by a numerical prediction model and by measurements. Typical installation setup of UTP connecting differential driver and receiver both placed in shielded enclosures is considered. A suitable full wave model of the adopted test configuration is developed by using the commercial software tool Microwave Studio based on the finite integration technique. In the proposed full-wave approach, the ESD generator is simulated by an advanced model, which permit to reproduce the discharge current in the contact mode taking into account the load effect. The validation of the proposed numerical prediction model is carried out by comparison with measurements.

A Size-Reduced Trapezoid Ground Plane for the Antenna Calibrations in Standard Site Method

Kai-Wen Tien; Ken-Huang Lin; Hsing Feng Chen, Sun Yat-sen University

This study proposes a size-reduced trapezoid ground plane on which the antenna calibrations by the modified standard site method (SSM) can be conducted. The calibrated antenna factors (AF) are compared with those obtained on a 10 m□10 m rectangular ground plane. The investigation has been performed numerically with the method of moments (MoM) in the horizontal and vertical polarizations. The results show that the size of ground plane can be reduced by 75 % if the trapezoid ground plane is applied.

Modeling and Measurement of Radiated Emission through a Cutout on the Power/Ground Plane

Junwoo Lee, Hynix Semiconductor

This paper characterizes the power bus noise radiation through a cutout on the power/ground plane of printed circuit boards (PCB). Analytical model of the radiation is proposed and it is verified by a full wave simulation and experiment. Both the full wave simulation and measurement show good agreement with the model up to 3 GHz. The results show that the radiation through a cutout is substantial at the resonant frequencies.

Broadband Multicarrier Channel On Distribution Networks Constrained By Source Power And Radiated Emission

Marcello D'Amore, University of Rome "La Sapienza"; Maria Sarto, University of Rome "La Sapienza"

A new procedure is proposed for the evaluation of the optimum bit loading on the multi-carrier channel of distribution power networks in the broadband frequency range. The constraints imposed by the source power level and the limit of the radiated electromagnetic field, and the signal-to-noise ratio are taken into account. A very accurate simulation model of the medium-voltage power network made of branches of finite length overhead lines above a dissipative ground is utilized. The radiated electromagnetic field is predicted by means of a full wave procedure in the high frequency range taking into account the ground propagation. The procedure is applied in the frequency range between 1.705 MHz and 30 MHz for the computation of the bits allocation on the sub-channels of a medium voltage power network with a tree-type configuration taking into account the FCC limit of the radiated electric field.

Full-Wave Analysis of Shielded Cable Coupling Effects Under EMP by the FDTD Method

Chaoqun Jiao; Xiang Cui, North China Electric Power University

A numerical method is proposed to model transients in a shielded cable embedded in a three-dimensional far and near field domain by using the finite-difference time-domain (FDTD) method. The coaxial-shielded cable is assumed to be a multiconductor transmission line (MTL). The in cell voltage and the current on the external shield surface are calculated by a full wave method, while the core current and the core-to-shield voltage are analyzed by assuming the validity of the quasi-TEM propagation mode inside the shield. The internal and external shield surfaces are coupled by the transfer admittance and by the transfer impedance of the cable shield. The solution is obtained by the FDTD method combining the MTL equations with the field equations. The validation of the procedure is performed in simple test configurations.

An Off-Vehicle Measurement Procedure for Predicting On-Vehicle Tire Pressure Transmitter Performance

Joseph Brunett, University of Michigan

This paper outlines the development of an off vehicle measurement procedure to ensure on-vehicle tire pressure transmitter performance. Measurements of electrically small transmitters mounted on a rim and tire are made on an Open Area Test Site (OATS) and in an anechoic chamber. Comparing emissions data collected along with in-vehicle performance, an optimal measurement procedure is selected. This procedure successfully correlates off-vehicle and on-vehicle sensor performance, allowing evaluation without full vehicle testing.

Investigation of Radiated Emissions Test Site Validation Method above 1 GHz

Katsuyuki Tanakajima; Hidenori Muramatsu; Jiro Kawano; Chiharu Miyazaki, Mitsubishi Electric Corporation

The validation method of the radiated emissions test site above 1 GHz has been discussed in CISPR SC-A. The authors think that further discussions are necessary about this site validation method. In this paper, we describe the matter of the positions of a transmitting antenna, the influences of the directivity of a receiving antenna and the size of a receiving antenna, based on the measurement results.

EM Modeling and Design of Electrically Thin Laminated Absorbers

Maria Sarto, University of Rome "La Sapienza"; Sandra Greco, University of Rome "La Sapienza"

The paper describes an equivalent circuit approach for the analysis and the electromagnetic design of innovative thin absorbers. The use of thin bilayers of metamaterials as spacer in dielectric Salisbury screen is discussed. It is demonstrated that narrow-band thin absorbers can be obtained using both positive and negative materials, whereas broadband thin absorbing screen can be realized only with bilayer of epsilon-negative and mu-negative materials.

Design Parameters for Efficient Stirring of Reverberation Chambers

Olof Lundén, Swedish Defence Research Agency; Mats Backstrom, Swedish Defence Research Agency; Niklas Wellander, Swedish Defence Research Agency

We have investigated the design parameters for stirrers in reverberation chambers. The efficiency of a stirrer is defined as the lowest possible frequency for which the stirrer gives a certain number of uncorrelated samples. Rotating stirrers generates cylindrical volumes when rotated about its axis. The impact of a change of the stirrer diameter is cubic compared with a change of the stirrer height. Another principle for stirring is to translate the stirrer along a fixed direction in space. The efficiency of translated stirrers is inversely proportional to the stepping increment and to the square root of the area of the projection of the stirrer on a plane orthogonal to the direction of translation.

The Efficiency of Stirrers in Reverberation Chambers Calibration of Electric Probes for Post-Processing of Near-Field Scanning Data

Adam Tankielun, Fraunhofer IZM/University of Paderborn; Heyno Garbe, University of Hanover, Germany; Werner John

In order to compensate nonideal receiving characteristic of electric probes used in planar electromagnetic near-field scanning, calibration and post-processing method based on deconvolution is proposed. The receiving characteristics of two electric probes are directly determined from field measurement and full-wave simulation of the calibration structure. Specific algorithm for reduction of post-processing errors due to noisy input data is proposed. The probe compensation is successfully validated with two planar test objects. The method greatly improves spatial resolution of near field scans and accurately determines distribution of normal electric field strength in absolute levels.

Influence of H-Plane Pattern Performance of the Omnidirectional Transmit Antenna to the Site VSWR Result

Alexander Kriz, ARC Seibersdorf Research GmbH

In this paper shows the first analysis of the influence of the H-plane

performance to the Site VSWR result. An effective model to estimate the error is presented. Measurements with four different antennas in three different test sites prove the correctness of the model. The measurement error depends on the pattern performance as well as on the chamber performance itself. Guidance to improve the reliability of Site VSWR measurement result is given.

Numerical and Experimental Analysis of Boundary Fields in Reverberation Chambers

Franco Moglie, Università Politecnica delle Marche; Valter Mariani Primiani, Università Politecnica delle Marche; Alessio Pignotti, Università Politecnica delle Marche; Anna Pastore, Università Politecnica delle Marche

Starting from the theory, this paper presents an analysis of the field properties in proximity of the reverberation chamber boundary. Three particular boundary geometries, a wall, a bend and a corner are analyzed, experimentally, measuring the three field components and calculating their statistics and variances, and numerically, with a previously assessed method using a summation of random plane waves and calculating fields with FDTD formulas.

Dynamic C-V Characteristic for Analysis of Crosstalk Caused by a Varactor Load

Takemi Watanabe, National Defense Academy; Fujihiko Matsumoto, National Defense Academy; Yasuaki Noguchi, National Defense Academy; Apiruk Sangkrasin, National Defense Academy

In this paper, crosstalk analysis of parallel microstrip lines with a varactor load is described. The varactor load has a transition characteristic. The transition characteristic causes a complicated reflected wave. It is difficult to estimate crosstalk induced by the reflected wave accurately. To estimate the crosstalk, the transition characteristic is investigated. The transition characteristic is expressed as the dynamic C-V characteristic. The crosstalk is simulated using the dynamic CV characteristic. The result of the simulation agrees with the measured crosstalk. This agreement shows that the dynamic CV characteristic is effective to estimate crosstalk.

Crosstalk Analysis of Parallel Microstrip Lines with THE NEW EMC DIRECTIVE 2004/108/EC

Christopher Marshman, York EMC Services Ltd

The new EMC Directive 2004/108/EC includes a number of changes as well as clarification and simplification when compared with the old EMCD, 89/336/EEC. This paper summarizes the application of the new EMCD and identifies the changes and the new responsibilities placed on manufacturers. It raises concerns regarding: interpretation of terms used in the wording of the Directive: 'state of the art', 'good engineering practices', the fixed installation and the definition of responsible person and the role of the Notified Body.

The New EMC Directive was Published in the OJEU on Enhancing Feature Selective Validation (FSV) Interpretation of EMC/SI Results with Grade-Spread

Antonio Orlandi; Giulio Antonini; Carmine Ritota; Alistair Duffy, De Montfort University

The comparison of high volumes of potentially visually complex data requires an automated method to support the engineers involved. The Feature Selective Validation (FSV) method is becoming increasingly popular as a solution to this. This paper reports on an enhancement to the method which uses the confidence in the FSV's component measures to provide a means of relative weighting of them and thus improving the ability of the method to satisfy one of the key criteria: mimicking human response.

Package-to-Board Transition Via Parasitic Effects on Simultaneous Switching Noise

Steve Schicht, GSI Technology; Xin Wu, Fluent Inc.

In this paper, we present a simultaneous switching output (SSO) or simultaneous switching noise (SSN) analysis methodology with package-to-board transition interconnects (vias) parasitics included. A quasi-static field solver is used to simulate the parasitic effects and equivalent circuit models are extracted for SPICE simulation. The simulation results demonstrate that the via impact on SSO push out is not negligible. Field solver based equivalent circuit model can characterize the return path effects and the mutual inductive effects accurately, which are important factors for SSO modeling.

Novel Integrated Electro-optic Sensor for Intensive Transient Electric Field Measurement

Rong Zeng; Weiyuan Chen; Xidong Liang; Jinliang He, Tsinghua University

A novel intense electric field measurement system based on the electro-optic Pockels effect has been designed and implemented by using the integrated electro optic chips for intensive electric field measurement. Principles of the sensor are illustrated and a sensor design for intensive field measurement is given. Compared with traditional electric field measurement system, this sensor has small size, less than 20 mm core length, optical signal transfer provide safe test of intensive field and immune to external EMI noise, broad band response from DC to GHz. The sensor's transfer function is quite flat and the maximum E-field that can be measured is close to 106 V/m. And the lightning impulse experiment upon the 1m long air gap ensures that the sensor is suitable for the intensive electric field measurement.

Multiconductor Transmission Line Modeling of SWCNT Bundles in Common-Mode Excitation

Maria Sarto, University of Rome "La Sapienza"; Alessio Tamburrano, University of Rome "La Sapienza", Italy

The multiconductor transmission line formalism is applied to the modeling of bundles of metallic and semi conducting single-walled carbon nanotubes. The developed approach accounts for the effects of electron transport at nanoscale and for the propagation of the voltages and currents along the bundle at the macroscopic level. The expressions of the matrices of the per-unit-length equivalent impedances and admittances of the bundle are derived considering the effect of wrapping and twisting of the nanotubes along the length of the bundle. Numerical calculations are performed in order to predict the current distribution among the metallic nanotubes of the bundle and the attenuation/transmission characteristics of the resulting multiconductor nano-transmission line.

A Reciprocity-Based Methodology for the Expedient and Accurate Prediction of Electromagnetic Field Coupling to Multiconductor Transmission Lines

Johannes Russer, University of Illinois at Urbana-Champaign; Andreas Cangellaris, University of Illinois at Urbana-Champaign; Peter Russer, Technische Universität München

A reciprocity-based methodology is proposed for the computationally efficient computation of induced electromagnetic interference at the loads of a multiconductor transmission line system due to an external electromagnetic field. The proposed methodology is validat-

ed through comparisons with results for the induced interference obtained using a full-wave electromagnetic field solver.

The Measurement of Radiated Electromagnetic Field from Coaxial Cable with Connector Contact Failure

Hideaki Sone, Tohoku University; Yu-Ichi Hayashi, Tohoku University

A transmission line created by cables adjoined by connectors is influenced by noise from connectors with contact failure, and such noise degrades communication quality. In order to simulate the noise interference added into Internet communication through CATV lines, the authors proposed a model of the contact resistance increase by a connector and the condition of contact in a coaxial transmission line. Using this model, the electromagnetic near field around a cable driven by HF signal was measured to estimate the noise interference into the transmission line as an electromagnetic coupling between the line and its environment. The result shows that a coaxial line with contact failure has radiation directivity depending on the condition of contact, and that such is a cause of noise interference.

Signal Integrity Constrained Optimization of Flexible Printed Interconnects for Mobile Devices

Silvia Acquadro, Politecnico di Torino; Michelangelo Bandinu, Politecnico di Torino; Flavio Canavero, Politecnico di Torino; Ilkka Kelander, Nokia Research Center; Markku Rouvala, Nokia Research Center; Stefano Grivet-Talocia, Politecnico di Torino

This paper presents a systematic procedure for optimizing the geometry of high-speed data links based on Signal Integrity constraints. The structures under consideration are flexible printed circuits typically found in mobile devices having moving parts. Since the geometry of such interconnects is approximately translation-invariant, we adopt multiconductor transmission line models, characterized by broadband frequency dependent per-unit-length parameters that implicitly account for losses and dispersion. Each interconnect is characterized by several geometrical and material parameters, which constitute the free variables for optimization of the link. Signal integrity constraints such as return loss, impedance, attenuation, or ultimately eye diagram opening are used as goals in a closed-loop optimization process. We employ an efficient model parameterization scheme based on the Generalized Method of Characteristics to reduce the number of RLGC computations and to convert the parameterized model into a SPICE-ready deck for transient simulation and eye diagram generation under realistic loading conditions. Several numerical results illustrate the feasibility of the approach.

Common-Mode Radiation Resulting from Hand-Assembled Cable Bundles on Automotive Platforms

Shishuang Sun, University of Missouri Rolla; James Drewniak, University of Missouri Rolla; David Pommerenke, University of Missouri Rolla

A statistical cable harness model is developed to account for the random disturbance of the wire positions along the bundles. The non-uniform random bundles are modeled as n-cascaded segments of uniform multi-conductor transmission line. At each section, all wire positions are disturbed with random numbers obeying a Gaussian distribution. In addition, a spline interpolation function is used to ensure the overall smoothness of wires winding along the bundle. The common-mode current distribution along the bundle calculated with SPICE is injected into a full-wave tool, e.g., FDTD, as impressed current sources. Thus, the full-vehicle electromagnetic emissions from the automotive harness can be predicted. The model has been experimentally validated with a controlled laboratory setup.

Characterizing Package/PCB PDN Interactions from a Full-wave Finite Difference Formulation

Shishuang Sun, UMR; Kai Xiao, Intel Corporation; David Pommerenke, UMR; James Drewniak, University of Missouri - Rolla

A novel approach of circuit model extraction is developed for modeling of integrated package and PCB power distribution networks (PDN). The integrated PDNs are formulated with a full-wave finite difference method, and the resulting matrix equations are converted to equivalent circuits. The equivalent circuits as well as the decoupling capacitors and the attached circuit components can be analyzed with a SPICE like solver in both the time and frequency domains. The modeling of dielectric loss and conductor loss is also addressed. PDN analysis of a BGA package mounting on a PCB is investigated with this method to understand the PCB and package power planes and SMT decoupling, and interaction between the PCB and package power planes.

Complex Random Excitation of Electrically-short Transmission Lines

Sergio Pignari, Politecnico di Milano; Diego Bellan, Politecnico di Milano

This paper investigates statistical properties of radiated susceptibility of electrically-short two-conductor transmission lines exposed to superposition of random plane waves. The proposed model handles electromagnetic disturbances composed of continuous or discrete superposition of waves, striking the line from the total or a specific element of the solid angle.

A Study of Platform EMI from LCD Panels

Jin Shi, Intel Corporation; Kevin Slattery, Intel Corporation; Xiaopeng Dong, Intel Corporation; Gordon Chinn, Intel Corporation; Al Bettner, Intel Corporation

High-speed signals running on a liquid crystal display (LCD) panel in a notebook have been known for some time can create electromagnetic interference (EMI). This EMI not only can be an issue for FCC compliance, it also poses an even greater problem for wireless devices that are now being put in notebooks. The objectives of the work described herein are to study the impact of LCD noise on the wireless radio performance, the root causes and the mitigation methods.

Bounds on the Accuracy of the Measurement of Plane-Wave Coupling Into Cavity Structures Using Near-Field Sources

Mark Waller; Tom Shumpert; Robert Scharstein, University of Alabama

A near-field line source and a true uniform plane wave are used to excite, through a slot aperture, a cylindrical cavity. Frequency dependence, including closed-cavity resonances as well as global cavity-plus-aperture resonances, is studied for both electromagnetic polarizations. A minimization of the mean square error between the aperture field induced by a true plane wave and the simulating finite source provides a bound on the performance of a proposed near-field measurement technique. The analytical model is demonstrably accurate and convergent.

Transmission Line Impedance Optimization by Simulation

Anttoni Rautio, Nokia Corporation

An optimization of 2-layer transmission line (TL) impedance for differential high-speed digital signal is presented. Two different lengths of transmission lines with two different terminations, ideal and realistic, are optimized for a frequency range from 0 Hz to 4 GHz and the results compared in frequency and time domain. The introduced

simulation and optimization method can be applied for any kind of transmission line, e.g. flexible printed circuit board (FPC), printed circuit board (PCB). The system that is being simulated, consist of a differential Input/Output Buffer Information Specification (IBIS) source, 20mm length TL connected to 100mm TL that is connected to 50mm TL and terminated by 100ohm in ideal case, and with 100ohm and receiver (RX) differential IBIS model in realistic case.

Experimental Investigation of PCB Guard Traces on Radiated EMI

Cyrous Rostamzadeh, Robert Bosch Corporation

Guard traces used in multi-layer PCB implementations to reduce cross coupling between adjacent traces and radiated emission is investigated experimentally. Guard traces can cause impedance discontinuity on signal traces and affect the signal integrity of high-speed clocks and their harmonic contents. Several test boards were developed to evaluate the impact of guard trace on radiated emission. CISPR 25 radiated emission measurement method was used to evaluate the impact of guard trace. Measurement results should be useful for developing EMI design guidelines.

Transposing the European EMC Directive into National Legislation

Brian Jones, EMC Consultant

This paper will describe the process of creating the EMC Regulations in the United Kingdom (UK) to implement the new EMC Directive 2004/108/EC. The content of the draft Regulations will be described, as will the consultation process that will be followed. National legislation includes aspects not covered in the EMC Directive itself, such as identification of responsible persons, enforcement techniques and penalties.

Crosstalk Analysis for Nonparallel Transmission Lines using PEEC with a Dynamic Green's Function Formulation

Michael Cracraft, University of Missouri - Rolla; James Drewniak, University of Missouri - Rolla

The calculation of crosstalk on printed circuit boards (PCBs) can be critical to board design. Where coupling occurs between parallel sections, transmission line theory is sufficient. However, if the dominant sections are not parallel, a full-wave method, like PEEC can be used. In this paper a dynamic Green's function is utilized for the PEEC coefficient calculations. This paper includes a discussion of how analytic expressions for quasi-static PEEC calculations can be reused in the dynamic Green's function calculations, removing the need to derive new integration formulas. In addition, a subgridding approach is utilized to increase the integration accuracy.

Comparing Numerical and Experimental Results for the Shielding Properties of a Doubly-Periodic Array of Apertures in a Thick Conducting Screen

Derik Love, National Institute of Standards and Technology; Edward Rothwell, Michigan State University

The application of mode matching to determine the shielding properties of thick screens containing a doubly-periodic array of apertures has been demonstrated through numerical results. The geometries used for generating the numerical data were intended to represent typical choices for aluminum honeycomb. In this paper, experimental results will be presented in order to validate this application of mode matching. One set of measurements was produced using a bench top transmission setup, while the second set was produced using the nested reverberation chamber technique. The measured data for each technique is compared to numerical data obtained using mode matching.

Reduction in Radio Interference through PWM Frequency Dithering

Heri Rakouth, Delphi; Robert Hozeska, Delphi; Luke Comstock, Delphi Automotive Systems

Solutions to meet Electro-Magnetic Interference (EMI) limits (e.g., CISPR 25, GMW3097, etc.) are usually quite expensive. In some systems 30% of the whole cost is related to EMI/EMC for large filters, shielding, etc. In current-controlled electric motor driven systems the main contributor to RF noise is the Pulse Width Modulation operation. The PWM generates narrow-band noise in the form of a spike at every integer harmonic of the switching frequency. An automobile's radio is a serious victim to narrow-band noise, as the harmonics can appear as distinct tones at the output. For this reason, the CISPR 25 noise amplitude limit is at least 19 dB stricter for narrow-band noise than for broadband noise. The solution discussed here converts the narrowband noise into broadband noise and reduces the interference in radios by varying the switching frequency within a small range.

Electromagnetic Interferences on Implantable Medical Devices Onboard of High Speed Trains

Romeo Rizzi, University of L'Aquila; Antonio Orlandi, University of L'Aquila; Vittorio Ricchiuti, Technolabs; Giulio Antonini, University of L'Aquila

This paper reports a study of electromagnetic interferences on implantable medical devices (pacemakers) on board of high-speed trains due to magnetic fields generated by filters along the tracks. The magnetic flux density is computed by using different numerical techniques and compared with experimental data; further, the voltage induced on a pacemaker is computed. An analysis of the Standards regarding interferences in pacemakers is carried out leading to find the limit values of flux density and induced voltage, which may cause a malfunctioning of such devices.

Impact of Common-to-Differential Mode Conversion on Crosstalk in Balanced Twisted Pairs

Sergio Pignari, Politecnico Di Milano; Giordano Spadacini, Politecnico Di Milano

In this paper, a transmission line model for crosstalk prediction in twisted-wire pairs (TWPs) with non-perfectly balanced terminations is derived and discussed. In the first part, basic properties of balancing devices are described by resorting to modal impedances, modal gains, and common-mode rejection ratio (CMRR). In the second part, the combined impact of: a) random non-uniformity of the twist-length along the TWP; b) common-to-differential mode conversion at the TWP terminations, is investigated. Predictions based on the proposed model show that, when CMRR is high, non-uniformity of twist length is the dominant effect, whereas at frequencies where CMRR is low, mode-conversion severely affects crosstalk levels. Experimental measurements performed with an ad hoc setup confirm the results of the proposed analysis.

A Simple Implementation of PEC Structures in the FDTD Technique

Anna Pastore, Università Politecnica delle Marche; Barbara Cottone, Università Politecnica delle Marche; Franco Moglie, Università Politecnica delle Marche

An off-grid boundary condition within Yee's finite difference time-domain (FDTD) is presented. The boundary fields are extrapolated from the internal computational domain using the Theory of Image. The method enhances the flexibility of the FDTD method with respect to complex geometrical domains in a uniform standard FDTD mesh, using the standard FDTD code. Curved surfaces are introduced without reducing the time and maintaining the stability of the simulation.

Statistical Electromagnetics: An End Game to Computational Electromagnetics

Darren James, British Telecom

This paper presents a rebuttal to the view that current simulation practices will consider progressively more complex problems, containing progressively more parameters, until an end-game is reached when simulation 'models reality'. It is argued that an increase in problem complexity leads to the consideration of parameters that are better described statistically. It is shown that assuming single values for such parameters leads to a number of 'traps' that fundamentally undermine the validity of simulation. An alternative approach (Statistical Electromagnetics) is introduced. This embraces those statistical parameters and treats the simulation solution similarly. An example of a problem that benefits from statistical analysis is presented: that of the radiated emissions level created when a number of equipment items with common emissions frequencies are assembled into a system.

Numerical Analysis of Sandwiched Composite-FSS Structure

Ji Chen, University of Houston

A numerical procedure to analysis sandwiched FSS composite structures is proposed. This procedure is based on using the dispersive FDTD method in conjecture with a novel FDTD method to model the periodic insertion of the FSS elements. Some preliminary results are provided to show the effectiveness of this technique.

Modeling of Multilayered Packages and Boards using Modal Decomposition and Finite Difference Methods

Krishna Srinivasan; Krishna Bharath; Madhavan Swaminathan; Arif Engin, Georgia Institute of Technology

Simultaneous switching noise (SSN) is a major signal integrity (SI) and electromagnetic interference (EMI) problem. SSN involves the interaction between the power/ground planes and the transmission lines. Through the power/ground planes, there can be noise coupling not only in the transversal direction between two planes, but also vertically from one plane pair to another through the apertures and via holes. In addition, transmission lines can excite the planes at return path discontinuities. Due to the large size of systems packaging, it is difficult to analyze such problems using full-wave simulators. We present an accurate and efficient modeling approach based on the finite difference method (FDM). Power/ground planes are modeled using FDM, while the transmission lines are incorporated using a modal decomposition method.

Prediction of Low Frequency Radiated Fields from SMPS

Ugo Reggiani, University of Bologna; Leonardo Sandrolini, University of Bologna; Gian Lorenzo Giuliattini Burbui, University of Bologna

This paper investigates the low frequency electric and magnetic fields radiated by a SMPS. The fields are calculated by means of equivalent circuits that represent the magnetic and electric coupling mechanisms between the EMI sources of a SMPS and a reference victim circuit. The proposed model is tested on three different boards and three heat sinks showing good agreement. The model is also applied to a real SMPS well predicting the noise voltage measured by the receiver. The final paper will describe in details the transfer functions of the magnetic and electric mechanisms between a SMPS and a triple loop antenna (TLA). Electric coupling mechanism, magnetic coupling mechanism,

Stopband Prediction with Dispersion Diagram for Electromagnetic Bandgap Structures in Printed Circuit Boards

Yoshitaka Toyota, Okayama University; Arif Engin, Georgia Institute of Technology; Tae Hong Kim, Georgia Institute of Technology; Madhavan Swaminathan, Georgia Institute of Technology

Electromagnetic bandgap (EBG) structures, which prevent propagation of electromagnetic waves within a frequency range, are quite effective for suppressing simultaneous switching noise (SSN) in power planes. This paper presents the dispersion diagram analysis with the Z parameters of a unit cell of the EBG structure formed in power/ground planes. This analysis predicts the stopband accurately without full-wave electromagnetic (EM) simulation for the entire structure. This method is also applicable for predicting the stopband of the EBG structure in the actual printed circuit boards (PCBs) by measuring a test coupon of one unit cell placed on the same board.

Effects of Skew on EMI for HDMI Connectors and Cables

Chaitanya Sreerama, Intel Corporation

This paper describes the effects of intra-pair skew on electromagnetic interference (EMI) for High Definition Multimedia Interface (HDMI) connectors and cables using both simulations and measurement validation. Measurement methods like VLSI GTEM and current clamps are used to show the effects of skew on EMI for terminated HDMI connector/cable assemblies. Numerical simulations are used to study several factors contributing to skew in a differential cable and their impacts on EMI. Both the measurement and simulation data show a clear trend of increase in EMI with increase in skew. Thus, emphasizing the need for a lower cable skew specification for high-speed connector/cables to be able to pass FCC regulations.

Model-to-Hardware Correlation of Physics Based Via Models with the Parallel Plate Impedance Included

Christian Schuster, IBM T.J.Watson Research Center; Young Kwark, IBM T.J.Watson Research Center; James Drewniak, Giuseppe Selli, EMC Laboratory, University of Missouri-Rolla

The electrical characterization of high speed digital links discontinuities, such as via transitions in printed circuit boards (PCBs), has been widely investigated and numerous modeling attempts can be found in the literature. Among these, so-called "physics based" models are of special interest. Physics based models use only few elements and a realistic topology to obtain a circuit model that represents with good accuracy the discontinuities the signal undergoes when transitioning layers. In this article a physics based via model is presented with parallel plate impedance included and compared to measurements utilizing a recessed probe launching technique. Comparison of S-parameter data obtained by simulating such models with measured data shows good correlation up to 40 GHz. Measurements and simulations were conducted at the IBM T. J. Watson Research Center.

Design and Mitigation Techniques for EMC for Functional Safety

Keith Armstrong, Cherry Clough Consultants

Certain kinds of equipment must maintain sufficiently low risks to users and third parties over their entire lifecycles, despite at least one fault, and despite foreseeable misuse. Where electromagnetic interference (EMI) could foreseeably have an effect on such equipment, it will need to maintain an adequate level of electromagnetic (EM) immunity over its lifecycle. This is the concern of 'electromagnetic compatibility (EMC) for Functional Safety'. The EM environment that such equipment could experience over its whole lifecycle can be very different from that tested by standard 'EMC compliance' immunity tests. IEMI – Intentional EMI – could also be a concern. The physical and climatic environments, plus the wear and tear and misuse that such equipment is subjected to over its lifecycle can cause circuit EM behavior to alter, and can degrade the performance of EM mitigation measures such as shielding and filtering. It is not generally practical to prove that equipment is safe enough – as far as EMI possibilities are concerned – solely by EMC testing. In all areas, including software, safety is achieved by the use of appropriate design techniques, plus testing, and this is also true for EMC for Functional Safety. This paper briefly describes the EMC design techniques that help achieve an adequate level of safety. Although this paper focuses on safety concerns, the design techniques it discusses are also important for high-reliability, mission-critical and legal metrology equipment, or to help control financial or security risks. Testing techniques that help achieve EMC for Functional Safety will be covered in a future paper.

Study on Delay Time Characteristics of Multilayered Hyper-Shielded Meander Line

Kohji Koshiji, Tokyo University of Science; Shigeo Nara, Tokyo University of Science

In order to match the timing between two or more signals, many meander lines, which can intentionally make delay time using zigzag trace, have often been used. In this paper, in order to improve the delay time characteristics of the meander lines, multi-layered shielded meander lines which use the ground layer as a shielding conductor, and multi-layered hyper-shielded meander lines which the shielding conductor grounded through the vias is inserted between the parallel lines in the turn up section of the multi-layered shielded meander lines, were proposed and investigated.

Signal Link-Path Characterization Up To 20 GHz Based On A Stripline Structure

Jianmin Zhang, University of Missouri, Rolla; James Drewniak, University of Missouri, Rolla; David Pommerenke, University of Missouri, Rolla; Richard DuBroff, University of Missouri, Rolla; Zhiping Yang, Apple Computer, Inc.; Wheling Cheng, CISCO Systems, Inc.; John Fisher, CISCO Systems, Inc.; Sergio Camerlo, CISCO Systems, Inc.

Dielectric properties and losses are two critical issues in signal link-path characterization. To obtain the substrate dielectric properties for a planar transmission line, an analytical solution is derived and validated based on a stripline structure and measured scattering parameters with TRL de-embedding. The characterized dielectric property is used to evaluate dielectric loss and conductor loss. The total loss is thereby found from their summation. The calculated total loss is compared to the measured total loss, and the conductor loss and dielectric loss are then quantifiable. Since the conventional description using the loss tangent and dielectric constant to represent material properties is usually insufficient as the frequency reaches 20 GHz, a Debye model is proposed. The second order Debye parameters are subsequently extracted using a genetic algorithm. A full wave simulation is implemented to verify the determination of 2nd Debye model parameters.

Influence of An Extended Stub at Connector Ports on Signal Launches and TRL De-embedding

Jianmin Zhang, University of Missouri, Rolla; James Drewniak, University of Missouri, Rolla; David Pommerenke, University of Missouri, Rolla; Zhiping Yang, Apple Computer, Inc.; Wheling Cheng, CISCO Systems, Inc.; John Fisher, CISCO Systems, Inc.; Sergio Camerlo, CISCO Systems, Inc.; Bruce Archambeault, IBM, Research Triangle Park

Characterization of PCBs (Printed Circuit Boards) is usually associated with measurement using a VNA (Vector Network Analyzer) in the frequency-domain or a TDR (Time Domain Reflectometer) in the time-domain. The often used signal launch techniques on PCBs based on the VNA or TDR measurement in the microwave frequency range use SMA or 3.5 mm connectors, in edge-launch or vertical-launch fashions. The signal transition between the launch port and the DUT (Device Under Test) introduces errors in the measurement, which is dominant when compared with a transmission line itself on the PCB as the technologies of PCB manufacture are well developed today. Discontinuities at connector ports depend on the port structures and the dielectric properties of the substrate materials. However, an extended stub at a connector port may significantly influence signal launches, or even corrupts a TRL calibration in a measurement.

Modeling Radiated Emissions from Cables Attached to Printed Circuit Boards Driven by Power Bus Noise

Ken Morishita, NEC Corporation; Naoki Kobayashi, NEC Corporation; Takashi Harada, NEC Corporation; Haixin Ke, University of Missouri-Rolla; Todd Hubing, University of Missouri-Rolla

This paper describes a two-step technique for modeling the radiated electromagnetic emissions from a printed circuit board with attached cables when the source of the emissions is noise between the board's power and ground planes. The first step calculates the electric fields at the edges of the power-ground plane pair. The second step replaces the power plane with equivalent sources embedded within the ground plane structure. Examples are provided that demonstrate the accuracy of this approach.

Power Integrity Considerations for CPU EMI-Reducing Interconnect Design

David Hockanson, Sun Microsystems, Inc.

A CPU core-power interconnect design has been proposed for reducing radiated emissions that result from current injected into a motherboard. The EMI-suppressing design increases the inductance to the motherboard to filter the harmonics of the processor. The change in inductance and resistance, however, may prove detrimental to the core power integrity. The effect on power integrity is discussed herein.

Crosstalk and Delay Time Analysis of High Density Interconnects on LTCC Substrate

Antonio Orlandi, University of L'Aquila; Cinzia Moca, University of L'Aquila; Antonio Ciccomancini Scogna, CST of America, Inc; Giulio Antonini, University of L'Aquila

In this paper crosstalk and time delay propagation on a complex LTCC system is computed. The analysis has been performed implementing FIT technique; the analyzed model has been designed from real layout of the front end of a complex multiplexer system. After a preliminary characterization of the system in time domain with a gaussian pulse, crosstalk voltage and delay time have been computed by a time domain convolution.

Analysis of Noise Coupling Result from Overlapping Power Areas within Power Delivery Network

Gang Feng, University of Missouri-Rolla; Giuseppe Selli, University of Missouri-Rolla; Kundan Chand, University of Missouri-Rolla; Mauro Lai, University of Missouri-Rolla; Liang Xue, University of Missouri-Rolla; James Drewniak, University of Missouri-Rolla; Bruce Archambeault, IBM, Research Triangle Park, NC; Connor Samuel, IBM Systems & Technology Group

Large area fills or entire planes constitute the backbone of the power delivery network in multi-layer printed circuit boards (PCBs). The overlapping of power areas at different voltages, though, may cause coupling among them. Full wave methods can be used to model this type of structures, and the coupling effect can be accurately analyzed by means of finite element method (FEM), finite difference time domain (FDTD) and others. However, full wave methods, are usually time consuming. In this paper, a cavity model approach is proposed to analyze the noise coupling among plane pair in multi-layer configurations. The cavity model has analytical expressions for the impedance (Z) matrix associated to ports defined on regularly shaped planar circuits and it is computationally efficient. The combination of such approach with the segmentation method allows the extension of the analysis to irregularly shaped and multi-layer structures. A multi-layer PCB with three power planes is analyzed in this article by means of the proposed cavity model approach and a full wave FEM method. A comparison between the simulation results obtained with the two different methods is finally provided.

New Extraction Procedure of Shielded Cable SPICE Macro-Model for the Prediction of Signal Integrity and Conducted Immunity

Rodolfo Araneo, University of Rome "La Sapienza"; Spartaco Caniggia; Francescaromana Maradei, University of Rome "La Sapienza"

An improved extraction procedure is here proposed to carry out shielded cable macro-model suitable to be implemented in any SPICE based circuit simulator. The proposed procedure permits to account frequency-dependent losses as skin effect, and frequency-dependent behavior of the transfer impedance. The shielded cable is modeled by a four-port network with lumped time-constant parameters obtained by applying the proposed improved fitting technique. The proposed macro-model is validated by comparing the results with those obtained by measurements.

Near Electric Field in Microstrip/Coplanar Circuits and Antennas - Simulation and Measurement

Keren Li, NiCT; Tetsuo Anada, Kanagawa University

A detailed investigation of the near electric field distributions in electromagnetic circuits such as microstrip/ coplanar circuits and patch antennas is very useful for physical understanding, studies of electromagnetic coupling effects for EMC and EMI and for optimization of electromagnetic circuit designs. The aim of this paper is to show how to simulate and measure the near electric field distributions in microstrip/coplanar circuits and patch antennas. The full-wave analysis is carried out by using a finite-difference time domain technique, commercial-software Sonnet10.2 and its measurement is carried out by using a very small probe antenna. The leakage phenomenon, which is not obtained by the simulation using a conventional FD-TD, is observed by measurement of near electric field distributions of resonance modes of microstrip/coplanar resonator and patch antennas. It is considered that this leakage-phenomenon is caused by the electromagnetic coupling between the resonance mode of microstrip resonator and the surface wave TM0 mode of covered dielectric slab that propagates from DC. The proposed measurement system offers a valid means for predictions in the theoretical analysis of more complicated discontinuity problems. Thus, the proposed measurement system offers a valid means for predictions in the theoretical analysis of more complicated discontinuity problems.

Estimate Method on Daily Radio Usage Concerning Ambient Noise

Sungwon Park, Radio Research Laboratory

Radio usage, the occupancy of the radio signal, is necessary to decide the policy on radio spectrum management. The Gaussian noise character should be considered to set the reference level of radio usage for various radio services, especially low power communication system. Results showed that radio usage of TV broadcasting is 100%, TV signal could be observed in the field. And radio usage of the special low power radio station is 0%, that signal was no appearance in the field.

An Iterative Method to Calculate Absorption Loss in Conductive Dielectrics

Mihai Badic, Research Institute for Electrical Engineering - ICPE; Mihai-Jo Marinescu, Research Institute for Electrical Engineering - ICPE; Maria Stefan, Research Institute for Electrical Engineering - ICPE; Lia Elena Aciu, University Transilvania Brasov

The paper deals with deduction respectively theoretical and experimental verification of a new formula expressing the electromagnetic absorption in the most general case – conductive dielectrics - function of macroscopic parameters _, _, _, radiation frequency and material thickness. Although the model used in this deduction is based on the well-known Schelkunoff isomorphism, this relation was not yet utilized. It has a great importance, both theoretical and practical, for EMC field, as well as for Physics, in general. In order to highlight the degree of generality of these equations, authors have imagined an experimental setup inspired from Optics.

PCB to Chassis Grounding Graphic Architectures for Minimizing Radiated Emissions

Dheena Moongilan, Lucent Technologies

A properly designed and installed metal chassis reduces radiated fields from Printed circuit boards (PCBs). The chassis provides short terminations for electric fields, and field cancellations for magnetic fields. It drains the common mode noise current from PCBs and reduces coupling into the radiators such as traces, inductors, component conductors and attached cables. The size of the chassis, separation distance from the PCB, the location and the number of interconnections from PCBs, and dielectric media between the chassis and PCB are some important parameters to be considered in a chassis design. In this paper the radiated emission level variations for different separation distances and number of interconnections to the chassis are investigated. This paper discusses daisy chain, tree, star, collinear, star-daisy chain and mesh interconnection architectures for stacked multiple PCBs that use a single chassis. The radiated emissions measured from highly integrated PCBs for daisy chain, tree, and star architectures are presented and results discussed.

Engineering of Ferrite-Graphite Composite Media for Microwave Shields

Marina Koledintseva, University of Missouri-Rolla; Poorna Ravva, University of Missouri-Rolla; James Drewniak, University of Missouri-Rolla; Alexander Kitaitsev, Moscow Power Engineering Institute (Technical University); Andrey Shinkov, Moscow Power Engineering Institute (Technical University)

An electromagnetic shielding of objects using ferrite-graphite composites is considered. The analytical model, using the Maxwell Garnett formulation for multiphase mixtures, results of computations based on this model and plane-wave formulation, and some experimental results are represented.

Design and Optimization Of LTCC Digital Demodulator Used For Aerospace Satellite Applications

Antonio Ciccomancini Scogna, CST of America

Aim of this paper is to offer the complete design and the performance study of a digital demodulator used for aerospace satellite applications and realized with low temperature co-fired ceramic (LTCC) technology. The digital device is simulated and optimized by means of three-dimensional electromagnetic simulation and an accurate prediction in terms of signal integrity (SI) and EMI is achieved. The inductive effect due to bond wires on the S-parameters is then evaluated and the case in which the bond wires are replaced with bond strips is also studied. A simplified approach based on the segmentation of each bond wire in just three parts is then proposed and the obtained results are compared with those coming from a more realistic assumption.

High Speed Cable Assembly Electrical Performance Modeling

Kai Wang, Intel

High-speed digital cables in giga Hz range are widely used recently. This paper summarized the methodology to simulate the high-speed differential cables and introduced a cable assembly simulation methodology based on S parameter measurement. Parameters that affect the SI performance such as cable impedance variance, intra-pair and inter-pair skew are included in the models; the effects of those parameters on the Eye opening are discussed.

An Investigation of the Effect of Chassis Connections on Radiated EMI from PCBs

Naoki Kobayashi, NEC Corporation; Takashi Harada, NEC Corporation; Ahmed Shaik, University of Missouri-Rolla; Todd Hubing, University of Missouri-Rolla

Printed circuit boards are often mounted to a metal plate or chassis. Sometimes an electrical connection between the board and the chassis is made at the mounting points and other times no electrical connection is made. This paper investigates the effect of grounding or floating printed circuit boards at chassis connections. Two test boards were evaluated. The first test board was a two-layer board with solid copper planes on each layer. The second test board consisted of a single microstrip trace on one layer and signal return plane on the other. Both test boards were mounted to a metal plate using metal or nylon grounding posts. Radiated EMI from the boards was measured by changing the number, size and location of the metal grounding posts. The results show that boards properly grounded to a chassis plate exhibit significantly lower radiated emissions. However improper grounding can significantly increase radiated emissions at some frequencies.

Prediction of System-Level Emissions Performance via Equipment Shelf Primary Power Bus Frequency Response Characteristics

Hirayr Kudyan, Lucent Technologies, Inc.

This paper experimentally demonstrates that the behavior of the Primary Power Bus extended over the components of the system Equipment Shelf is a crucial predictor of the system's EMC performance. In particular, the Conducted and Radiated Emissions characteristics of the system can be predicted before the system is fully assembled, and long before System-Level formal compliance testing. The frequency pass-bands and resonances of the Primary Power Bus are identified and these outcomes are closely correlated with independently obtained Conducted and Radiated Emissions spectra for the populated system Equipment Shelf.

EMI Antenna Model Based on Common-Mode Potential Distribution for Fast Prediction of Radiated Emission

Tetsushi Watanabe, Industrial Technology Center of Okayama Prefecture; Osami Wada, Kyoto University; Ryuji Koga, Okayama University; Youhei Sakai, Okayama University

In this paper, the authors expand the common-mode antenna model, which was previously proposed by them. The common-mode antenna model represents a printed circuit board (PCB) to predict the common-mode excitation and radiation. The new common-mode antenna model is introduced here based on the common-mode potential distribution, which is calculated from the normal-mode voltage and the common-mode potential conversion factor (CPCF). The EMI is evaluated with the common mode antenna, and the calculation is much faster than using a real structure. Results of this method attain good accuracy with experimental results and that obtained with the numerical analysis of FDTD method.

Electromagnetic Topology Simulations for Cable Coupling with a Radiating Dipole at an Aperture

Phumin Kirawanich, University of Missouri-Columbia; S. Yakura, Air Force Research Laboratories; N. Islam, University of Missouri-Columbia

Field penetration through apertures and their coupling with a cable linking two personal computers have been carried out using a topological network simulation code. The interaction processes simulated include the integration of experimentally determined scattering parameters for the cable. The aperture field is treated as a distributed source elements on the cable and the transfer function for the topological network is generated by assuming a radiating dipole at the aperture. The driving sources for the dipole are determined by short-circuiting the opening at the aperture using FDTD-simulations. Topology based simulations show that the nature of the external pulse, scattering parameter and the aperture affects the cable response.

A Discussion of the Susceptibility of a Brokaw Bandgap to EMI

Nicola Montemezzo, University of Padova; Enrico Orietti, University of Padova; Simone Buso, University of Padova; Gaudenzio Meneghesso, University of Padova; Andrea Neviani, University of Padova; Giorgio Spiazzi, University of Padova

In this paper, the susceptibility of a Brokaw bandgap voltage reference towards Electromagnetic Interferences (EMI) superimposed to the power supply is investigated. The attention is focused on the bandgap cell itself, verifying that it is the main responsible for the device malfunction when radio frequency noises are injected in the chip through the supply rail. In particular, the rectification phenomena of bipolar transistors, used in the bandgap cell, are proved to cause the voltage reference performance degradation. Some possible hints to overcome this problem are also explored, suggesting design modifications, filtering solutions and layout changes.

Effect of the Dielectric Properties of Tissue-Equivalent Liquid on SAR-Probe Calibration

Lira Hamada, National Institute of Information and Communications Technology; Jisun Ryu, National Institute of Information and Communications Technology; Soichi Watanabe, National Institute of Information and Communications Technology; Takashi Iwasaki, University of Electro-Communications

In 2005, IEC international standard 62209-1 was issued, which is concerning about the SAR measurement procedure including the uncertainty estimation. In the SAR measurement, there are many uncertainty factors. The influence of the liquid electrical property, which is one of major uncertainty factors on the SAR-probe calibration procedure, was investigated.

Time Domain Simulation of the Effect of Decoupling Capacitor Location on Printed Circuit Boards

Samuel Connor, IBM; Jay Diepenbrock, IBM; Bruce Archambeault, IBM

This work describes the simulation of the effectiveness of decoupling capacitors on printed circuit boards using the time domain. Various distances from the IC and various dielectric thicknesses are included. Analysis allows cycle-by-cycle analysis to determine if the IC receives enough current in order to function properly, and to insure minimal EMI emissions.

Using Reciprocating Duty Cycles to Create Reduced EMI Clock Signals

Gregory Ebert, Intel Corporation

A technique to modify the frequency domain distribution of clock signal energy. This allows the frequency content to be moved away from "problem" EMI frequencies. It is assumed that the clock is differential and must be DC balanced. This technique moves the frequency content of the clock signal by lengthening the fundamental period of the clock signal while maintaining a fixed time relationship between the rising (or falling) clock edges.

RCS Frequency Response of Printed-Circuit-Boards in a GTEM Cell Using the Method of Moments

David Poubè, Technical University Berlin

The behavior of reradiated fields from PCBs, with the radar cross section being the main parameter of interest is investigated in this work. A rigorous approach to predict radiation from PCBs in a GTEM cell is presented. The analysis is based upon the use of the reciprocity theorem in combination with the method of moment applied to the scattered field. Thus, yielding a generalized impedance matrix, whose determinant represents the characteristic polynomial of the scattering system. The effectiveness of the method is demonstrated by investigating some canonical circuit configurations and structures illustrating sources of fundamental EMI mechanism. The validity and the accuracy of the analysis become obvious in view of the one-tone correlation with measurements.

PEEC Modeling of Antenna Characteristics

Sofia Sundberg; Jonas Ekman, Luleå University of Technology

This papers deals with the modeling of antenna characteristics including input impedance and radiation diagrams using Partial Element Equivalent Circuit (PEEC) models. The input impedance is computed using the currents and voltages at the feedpoint of the antenna. The radiation diagrams are computed by treating each volume cell as an infinitesimal dipole and using the superposition principle to compute the radiated field. The computed results are compared to analytical results for dipoles. For more complex antenna structures the computed results are compared with experimental results and results from other computational methods.

Applicability of GTEM Cells for Transient Testing

Holger Thye; Michael Koch; Sven Fisahn, University of Hannover

This paper deals with short electromagnetic pulse propagation in GTEM cells. Aim of the investigation is to find out to what extent a voltage pulse applied to the feeding port via a coaxial cable is distorted when transformed into a field pulse in the testing volume. Only if the pulse shape remains unchanged or the distortion can be determined with a certain accuracy, it will be possible to stress the DUT with a field pulse of defined properties and determine its level of susceptibility. The involved calculations are carried out with different commercially available numerical codes. Forced variations in modeling due to the mathematical method underlying the code are investigated. The resulting different simulation results are analyzed and discussed. In all cases the equipment is restricted to standard computer equipment easily available to most EMC testing facilities. It is shown, that different simulation tools lead to significantly differing results.

Higher-Order FDM Modeling of Grounding Systems Using Non-Uniform Grid

Josef Tlusty, Czech Technical University in Prague; Tu Vu, Czech Technical University in Prague

This paper investigates a way of modeling grounding systems using Higher-Order 2D and 3D Finite Difference Methods (HO-FDM). In particular, we use a new technique of non-uniform grid HO-FDM for modeling the geometry of rod electrode and elements of grounding grid. This numerical method examined to several different kinds of electrodes and grounding grid. Their solution obtained by the iterative methods of Jacobi, Gauss-Seidel and Successive-Over-Relaxation (SOR) is presented. The results have shown that the proposed method is acceptable and suitable for modeling and calculating any shape of grounding systems buried in uniform, two-layer and multilayer soils. Specially, the solution obtained by the nonuniform grid approach has highly accuracy.

Analytical Expressions for Small Loop Antennas – With Application to EMC and RFID Systems

Yuxin Feng, North Dakota State University; Benjamin Braaten, North Dakota State University; Robert Nelson, North Dakota State University

Closed form expressions are provided for currents induced in small loop antennas and the magnetic fields created (e.g., scattered) by those induced currents. The accuracy of the expressions has been verified with MININEC, a commonly used electromagnetics software code. Applications of this work are noted, one of which is a new way of thinking about the operation of inductively coupled RFID (radio frequency identification) systems. As an alternative to viewing such systems in terms of the coupling coefficient (as commonly done with transformer type systems) we view it from an induced-current/scattered field perspective. The closed-form expressions developed here can be used as tools for EMC and RFID personnel to estimate the fields scattered from RFID loops. The results can also be used to improve general understanding of inductively coupled noise, and to provide estimates of the voltage and current induced in small "sniffer" probes.

High-Frequency RFID Tags: An Analytical and Numerical Approach for Determining the Induced Currents and Scattered Fields

Benjamin Braaten, North Dakota State University; Yuxin Feng, North Dakota State University; Robert Nelson, North Dakota State University

RFID systems will soon become ubiquitous. This paper provides insight into one way of viewing the operation of high-frequency RFID systems that use passive tags. The relationship between the impedance of the tag circuit and the fields scattered by the tag are highlighted using two independent numerical codes. In addition, analytical expressions and numerical results for the current induced on the tag and the resulting scattered electric field are provided for a dipole with an assumed sinusoidal current distribution. Such results provide EMC engineers with an approximate method of determining the fields scattered from passive, high frequency RFID tags.

High Added-Value EM Shielding by using Metal Foams: Experimental and Numerical Characterization

Luca Catarinucci, University of Lecce

Metal foams represent an extremely versatile novel class of materials which mechanical properties, not yet completely investigated, promise new challenging perspectives in many application fields. In this work, their use in electromagnetic (EM) applications is investigated. More specifically, the realization of high added-value electromagnetic shields has been considered and experimental Shielding Effectiveness (SE) measurements have been performed, demonstrating very good performance. In order to allow the design of metal foam EM shields, however, their numerical simulation is mandatory; because of the intrinsic heterogeneity of foams, among the several available techniques, the Finite Difference Tine Domain (FDTD) methods appears to be the most appropriate candidate. An extremely accurate metal foam model is presented and preliminary SE numerical estimation performed by using a state of-the-art parallel variable-mesh FDTD code.

High Power EMI on Digital Circuits within Automotive Structures

Yakup Bayram, The Ohio State University; Paul Chang, The Ohio State University; John Volakis, The Ohio State University; Kyechong Kim, University of Maryland; Agis Iliadis, University of Maryland

This paper considers the impact of high power electromagnetic interference on performance of digital electronics, more specifically timer, used for controlling spark plug sequence in an automobile. We carry out measurements on a commercially available timer to observe soft and hard upsets and identify important circuit and interfering signal parameters pertaining to the upsets. We observed that as bias voltage decreases, the device becomes less immune to interference. This implies that EMI effects will become more dominant on next generation integrated circuits since bias voltage drops in proportional to the technology size. Subsequently, we proceed to address a more practical case where a timer inside an automobile is subject to a train of high power Gaussian pulses. For the latter case, not only do we investigate characteristics of the interfering signal such as pulse width and magnitude, but also we study impacts of scan angle (incident angle) since scattering from the automobile highly contributes to EMI interference to the timer. Our analysis suggests that pulse duration and scan angle are critical to assessing EMI effects on the timer operation. Experiments are complemented with an analysis that employs our recently developed hybrid S-parameters approach to integrate numerical EM tools (Method of Moments and HFSS) with circuit tools such as Advanced Design System (ADS). Such approach enables us to address EMI analysis of complex structures housing mixed signal circuits with a high simplicity and flexibility. Implications of our findings are discussed and future work that will lead to a more practical and realistic assessment of EMI on performance of electronic systems is addressed as well.

Effects of Using an Unshielded Cable as a Reference Standard in Cable Shielding Measurements, or, Do You Really Want to Base Your Results on a Naked Cable?

John Ladbury; Jason Coder, University of Colorado

We examine the effects of using an unshielded cable as a reference standard for the evaluation of the high-frequency shielding effectiveness of cables. We placed an unshielded cable (wire) in five different configurations in our reverberation chamber. In each configuration, we measured the coupling between the cable and a source antenna. We observed large variations (up to 20 dB) in the results, which we traced to impedance mismatches associated with the various configurations. We used post-processing to correct for these mismatches, and the results were much more consistent from configuration to configuration, and were also consistent with a well-matched horn antenna. However, two configurations still showed anomalies, illustrating some of the problems associated with using bare wires as reference standards.

Modeling Complex EMC Problems Using Finite Element Tearing and Interconnecting Algorithm

Kezhong Zhao, The Ohio State University; Jin-Fa Lee, The Ohio State University

This paper presents a novel approach, based on the domain decomposition method in conjunction with finite element tearing and interconnecting (FETI) algorithm, to model complex EMC problems. FETI algorithm results in the computation of numerical Green's function, which can be compressed efficiently via an efficient rank-revealing SVD algorithm. The numerical Green's function, once obtained, can be readily combined with other domains as a matrix-vector multiplication in the DDM solution process. Few examples are shown to validate the present approach.

Detectors Correlation Factor of Broadband Measurements Used in Automotive EMC

Clane Cammin, Delphi

Current CISPR12 broadband test limits are based on a 20 dB correlation factor between peak and quasi-peak measurements at 120 kHz bandwidth. This value is based on the experimental data accumulated in several countries. Electric/hybrid vehicle power handling technologies produce new types of impulsive noise that call for a review of the current correlation factor. This document provides analytical insight on the empirical 20 dB correlation factor. Recommendations accounting for the new power technologies are given at the end of the paper.

Using Via Fences for Crosstalk Reduction in PCB Circuits

Asanee Suntives, McGill University; Arash Khajooeizadeh, McGill University; Ramesh Abhari, McGill University

Crosstalk is one of the major signal integrity concerns at high-speed and high frequency electronic circuits. Via fences or in another term guard traces are increasingly used to alleviate this problem as dense interconnect layouts emerge. In this paper, first the effect of loading of a via fence on signal transmission in a microstrip line is investigated through parametric studies. Subsequently, a via fence structure is designed and optimized to reduce coupling between two adjacent

traces. Additionally, experimental results, while compared with full wave simulations, are presented to demonstrate crosstalk reduction. Index Terms—Via fence, guard trace, crosstalk, coupled PCB microstrip, signal integrity.

Time Domain Gating of Frequency Domain S-parameter Data to Remove Connector End Effects for PCB and Cable Applications

Samuel Connor, IBM; Jay Diepenbrock, IBM; Bruce Archambeault, IBM

This paper demonstrates the ability to remove the effects of discontinuities in high frequency S-parameter data caused by the test connectors on the Printed Circuit Boards (PCBs) and cables being measured. The frequency domain S-parameters are converted to the time domain to get the impulse response. Time domain gating is then used on this impulse response to remove reflections due to end connectors and/or other discontinuities. The gated impulse response is then transformed back to the frequency domain. The final result is a much-improved S-parameter data set with unwanted resonance removed, allowing the PCB trace or cable loss to be determined.

Predicting TEM Cell Measurements from Near Field CAN Data

Daryl Beetner, University of Missouri-Rolla; Haixiao Weng, University of Missouri - Rolla

A procedure is proposed for predicting TEM cell measurements from near field scans by modeling near-field scan data using equivalent sources. The first step in this procedure is to measure the tangential electric and magnetic fields over the circuit. Electric and magnetic fields are estimated from probe measurements by compensating for characteristics of the probe. An equivalent magnetic and electric current model representing emissions are generated from the compensated fields. These equivalent sources are used as an impressed source in an analytical formula or full wave simulation to predict measurements within the TEM cell. Experimental verification of the procedure using a microstrip trace and clock buffer show that values measured in the TEM cell and calculated from near field scan data agree within a few decibels from 1 MHz to 1 GHz.

Quantifying Electric and Magnetic Field Coupling from Integrated Circuits with TEM Cell Measurements

Vijay Kasturi, University of Missouri-Rolla; Shaowei Deng, University of Missouri-Rolla; Daryl Beetner, University of Missouri-Rolla; Todd Hubing, University of Missouri-Rolla

One of the most widely used methods for evaluating the electromagnetic compatibility of integrated circuits (ICs) involves mounting the IC on a printed circuit board embedded in the wall of a TEM cell. TEM cell measurements are influenced by both electric and magnetic field coupling from the IC and its package. This paper describes how a TEM cell and a hybrid can be used to isolate electric field coupling from magnetic field coupling. Knowledge of the dominant field coupling mechanism can be used to troubleshoot radiated emissions problems due to ICs.

Analysis of the Effects of Series Filtering in Coupled-Strip Sections

FranCisco-Javier Pajares, ETSEEI La Salle – Ramon Llull University; Pablo Rodríguez-Cepeda; Miquel Ribó; Joan-Ramon Regué; Lluís Pradell; FranCisco Pajares, Enginyeria La Salle – Ramon Llull University

Due to the high strip density in nowadays PCB circuits, high speed signal paths are often placed next to other signal strips. These strips, commonly routed over a ground plane, generate coupled microstrip sections. If these high-speed signals have high harmonic components, they can easily interfere other signal strips. In order to reduce this high harmonic content, a series impedance is sometimes placed into the signal path to filter this high harmonic content. In this paper, the effect of this series filtering is analyzed from a multimodal point of view. A multimodal analysis, very common in EMC, allows a simple interpretation of the phenomena involved in the integrity of the signals propagated through the strips. This multimodal analysis will show that the series filtering over coupled strips can be useless. In order to test the adequacy of this multimodal approach, two PCB circuits are analyzed, circuitally simulated and measured. The good agreement between circuit simulation and measurements validates this multimodal approach, showing that the series filtering of the interference can worse the situation.

Proposal of a New Compact Isotropic Antenna

Edvaldo da Silva Pires, UFCG

In this paper we propose a new dipole geometry to generate an isotropic radiation pattern. Derivate from the classical half-wave dipole the pattern in the H – plane has the same distribution for both cases. In the case of E – plane we obtain an axial ratio near to one for the new geometry. The new geometry allows the development of compact measurement/sensor antennas.

Measurement of Electric Field Probe Error for Pulsed Signals

Antonio Šarolić, University of Split; FESB

Electric field probe performance is measured inside a calibration waveguide. The electric field probes based on diode detection are designed and calibrated for continuous signals. When measuring electric field strength of a pulsed waveform, performance degradation is expected. The degradation is measured in terms of measurement error. It is defined as electric field strength reading on the probe vs. actual electric field strength in the test volume of a calibration waveguide. Two such probes were measured. Test signals were pulsed (ASK) signals with fixed duty cycle of 1/10 and varying repetition frequency. The results show great differences between the two probes measured. One probe shows only slight degradation in terms of increased reading (positive measurement error) for high repetition frequencies. The second probe shows the same feature but of even greater extent, together with significant degradation for low repetition frequencies in terms of decreased reading (negative measurement error). The existence of such errors demands a great amount of caution during EMC measurements using diode-based electric field probes.

Wideband SSN Suppression and EMI Reduction from Printed Circuit Boards using Novel Planar Electromagnetic Bandgap Structure

Jie Qin, University of Maryland; Omar Ramahi

A novel design of planar electromagnetic bandgap (EBG) structure with "super cell" configuration for mitigating simultaneous switching noise (SSN) is proposed. A wide bandgap covering the frequency range from 250MHz to 5GHz is demonstrated by both simulation and measurement, and a good agreement is observed. The disadvantage of this EBG-based power plane is that its imperfect plane may cause spurious and unwanted radiation. In this paper, leakage radiation through this perforated plane is also carefully investigated. Finally a novel concept of using this EBG structure for electromagnetic interference (EMI) reduction is introduced.

A Method for the Characterization of EMI Coupling Paths and Source Properties in Complex Systems

Gang Feng, University of Missouri-Rolla; Shishuang Sun, University of Missouri-Rolla; Cong Ding, University of Missouri-Rolla; David Pommerenke, University of Missouri-Rolla; James Drewniak, University of Missouri - Rolla

A method for charactering EMI coupling paths in complex systems is presented. While it is relatively easy to determine the EMI antenna structures and the sources of EMI, it is often quite difficult to identify and even more difficult to quantify coupling paths. By indirect measurements and two-port matrix theory, EMI coupling paths are quantified and source strengths are determined that cannot be directly measured. Knowing the coupling path allows deriving guidelines for circuit design, e.g., the permissible common mode current in a differential signal, such that the EMI can be better predicted from an IBIS or SPICE circuit level simulation.

Polyaniline and Polypyrrole with PVC Content for Effective EMI shielding

Mathew Kattackkal, Cochin University of Science and Technology; A.V. Praveen Kumar, Cochin University of Science and Technology; Hooney John, Cochin University of Science and Technology

Conducting polymers are characterized by attractive features like high anticorrosion property, controlled conductivity, high temperature resistance, low cost and ease of bulk preparation. These properties make conducting polymers as good shielding materials for electromagnetic interference. Poly aniline and polypyrrole with different proportion of PVC are prepared and studied at S band microwave frequency. Dielectric parameters such as, dielectric constant, dielectric loss, conductivity and S-parameters are evaluated. Suitability of these materials for EMI shielding is discussed.

A New Composite Absorbing Material Which is Highly Effective at the Lower Frequencies of the VHF Range and its Applications.

Andrzej Vogt, University of Wroclaw; Hubert Kolodziej, University of Wroclaw; Andrzej Sowa, Wroclaw University of Technology

The authors present here a new composite absorbing material, which is highly effective at the lower frequencies of the VHF range. Due to the effectiveness of these materials it is possible to produce flat very thin double-layer absorbers made of ferrite and the new composite material. Such an arrangement shows the unique properties at the lower end of the VHF range – its reflectivity is markedly reduced in comparison to the reflectivity of just ferrite.

Fully Integrated Active Magnetic Probe for High-definition Near-Field Measurement

Satoshi Aoyama, Graduate School of Electronic Science and Technology, Shizuoka University; Shoji Kawahito, Shizuoka University; Masahiro Yamaguchi, Tohoku University

In order to diagnose the topical EMI problem in ICs, a fully integrated active magnetic probe has been developed in SOI-CMOS technology. A 2-turn differential coil, differential amplifiers, a differential to single-ended converter, an output buffer and bias circuits are all integrated in a single-chip. Measurement result shows that it gains the high e-field suppression ratio of 38.0 dB at 50 MHz. Furthermore, the first 2D magnetic distribution map has been drawn by the active probe. The obtained image is finer than that of a shielded loop coil and it can prove an active probe to be a pragmatic diagnosis tool.

A Novel Method for the Analysis of ESD Generators and Coupling using Frequency Domain

Jayong Koo, Giorgi Muchaidze, Qing Cai, David Pommerenke, University of Missouri Rolla

A concept for analyzing ESD generators and coupling to EUTs in the frequency domain is presented. Its novelty lies in taking the radiation effects of structural elements and electrical components located within the ESD generator into account, without discharging the ESD generator. Using frequency domain this is achieved by substituting the electrical breakdown within the ESD generator (contact mode) by one port of a network analyzer. The network analyzer excites all pulse forming and radiating elements of the ESD generator as they would be excited during a discharge. This offers the advantage of the increased dynamic range of frequency domain techniques without having to simplify the complex radiation properties of real ESD simulators.

Laser Optical In-Circuit Measurement System for Immunity Applications

David Pommerenke, University of Missouri-Rolla; Chong Ding, University of Missouri-Rolla

During immunity testing (ESD, EFT) of a digital circuit, the waveforms of critical signal nets need to be measured for analyzing the failure mechanism. However, it is difficult to measure the induced voltage in the circuit under test due to the unwanted coupling pickup by the non-ideal shielding of the probe cable. A new implementation using an optical link with a small high-speed laser used as a transmitter to measure induced voltage is proposed. The system has advantages such as high immunity to EM field coupling, relatively high input impedance, small size and low cost.

Broadband Signal Integrity Characterization of a High Speed Differential Backplane Pair

Antonio Ciccomancini Scogna, CST of America; Fabrizio Zanella, CST of America

The present paper discusses the need of using full wave analysis for signal integrity studies on high-speed differential backplane pairs with signals ranging from 2.5 to 6.25 Gbs. The traces and the associated vias are imported from a commercial layout tool and then simulated by means of a 3D full wave simulator. The impact of the back drilling technique to control the via stub effect and the impact of the ground vias surrounding the signal pair is studied in terms of both S-parameter and eye-diagram waveforms. An equivalent circuit model is then extracted by using the Model Order Reduction (MOR) technique built in the same simulation tool.

ACCOMMODATIONS

Special rates have been negotiated for the 2006 IEEE International Symposium on Electromagnetic Compatibility in Portland, Oregon at the following hotels:

- **Hilton Portland & Executive Tower Hotel $135.00 USD Headquarter Hotel**
- **Embassy Suites Portland Downtown $142.00 USD**
- **Doubletree Lloyd Center $119.00 USD**

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The Hilton Portland & Executive Tower Hotel is located in the heart of Portland's city center financial and entertainment districts. The Hilton's central location is within blocks of downtown Portland's best restaurants. Upscale shopping is very close by. Area attractions nearby are the Portland Art Museum, Pioneer Courthouse Square, the Rose Garden Arena, PGE Park, The Washington Park Zoo, OMSI, Oregon Convention Center, Portland State University, Classical Chinese Garden, Japanese Garden and Forest Park, the largest park within city limits in the United States. All of these attractions are available by walking or by using the MAX Light Rail system. The Portland International Airport is also accessible via the MAX Light Rail which is located just one short block from the hotel.

All guestrooms feature the new Hilton Serenity Collection that includes the Hilton Suite Dreams bedding with plush-top mattresses, European-style triple sheet linens, down duvets, and allergen-free goose down pillows. High-speed internet access is available for a small fee.

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Portland, Oregon 97204

The award-winning Embassy Suites Downtown Portland Oregon Hotel is located in the historic Multnomah Hotel near the Oregon Convention Center, Portland Art Museum, the US Bancorp Tower, Pioneer

Courthouse Square, Pearl District, and Portland Center for Performing Arts, Pioneer Place Shopping Mall, Rose Garden and Portland Saturday Market. This full-service, upscale all-suite hotel is just minutes from the campus of the Oregon Health & Science University, NIKE campus, Intel, Portland International Airport - PDX, and Portland State University. The Columbia River Gorge, Mt. Hood, Mt. St. Helens and the beautiful Oregon Coast are all just a 90-minute drive from the hotel.

Guests of the Embassy Suites Downtown Portland hotel stay in spacious two-room suites and receive a complimentary cooked-to-order breakfast and a nightly manager's reception. High-speed internet access is available throughout the hotel. The hotel offers an indoor pool, fitness facility, Salon and Day Spa. The hotel is home to the Portland Steak and Chophouse Restaurant and is located two blocks from the nearest MAX Light Rail stop.

Doubletree Lloyd Center
1000 NE Multnomah Street
Portland, Oregon 97232

The Doubletree Hotel & Executive Meeting Center in Portland, adjacent to the Lloyd Center Mall, is convenient to Portland International Airport (PDX) and to downtown restaurants, attractions and entertainment via the MAX light rail system. Walk to the newly expanded Oregon Convention Center, the Rose Garden Arena, and Memorial Coliseum, or take advantage of free downtown transportation in the Fareless Square from our first-class, full service hotel.

Our beautifully appointed guest rooms and suites feature large work desks, high-speed internet access, and incredible views of the city skyline or the Cascade Mountains. Dine in one of our two excellent restaurants.

In addition to a great location and close proximity to dozens of major regional and national corporations, the hotel is also convenient to the campuses for Oregon Health Science University, Portland State University, and Concordia University. Explore Portland attractions like the Riverplace Esplanade, Washington Park Zoo, or The Pearl Historical District. Enjoy the natural splendor of scenic Oregon. The helpful hotel staff looks forward to welcoming you to beautiful Portland with their special, signature warm chocolate chip cookie at check-in.

RESERVE ON-LINE AT WWW.EMC2006.ORG

Tours

Sunday, August 13: Mt. St. Helens Tour (8 Hrs.) $77 *and* Friday, August 18: Mt. St. Helens Tour (8 Hrs.) $77

Make a visit to Oregon's sister State of Washington, heading north to Mt. St. Helens. Stops at the National Volcanic Monument Visitors Center at Coldwater Ridge, Hoffstadt Bluffs and the Forest Learning Center are in order. See the monumental devastation left by the eruption on May 18, 1980. This powerful explosion sent pulverized rock and ash almost 14 miles into the atmosphere. The force of the blast flattened trees and destroyed nearly everything in its path. Come now and witness the rebirth that has occurred since that Sunday morning. Includes a box lunch.

Sunday, August 13: Visit with Lewis & Clark (9 Hrs.) $88

Venture westward along the Columbia River to the historic city of Astoria. Visit the Astor Column, constructed by descendants of the fur trader, John Jacob Astor and the Northern Pacific Railway. This structure is the only one of its kind in America and is listed on the National Register of Historic Places. Next, stop at Fort Clatsop, once the winter headquarters in 1805-1806 of the Lewis and Clark expedition and the first U.S. military post west of St. Louis. Located on the site of the original fort, Ft. Clatsop is a National Memorial. During the afternoon, visit the Columbia River Maritime Museum containing one of the finest displays of nautical artifacts and ship models. Next, continue on your journey heading south passing through the beach community of Seaside before heading inland and back to the city. Includes a box lunch, entry to Fort Clatsop and Columbia River Maritime Museum.

Monday, August 14: Columbia River Gorge, Mount Hood Loop, Hood River (9 Hrs.) $39

Take in the breathtaking view from Crown Point Vista House located on the Historic Scenic Highway high above the Columbia River. This tour passes several waterfalls, including Multnomah Falls with a vertical drop of 620 feet. Observe the unusual rock formations on your way to visit Hood River, known for wind surfing and lush fruit orchards. Enjoy the beautiful alpine scenery while you make your way to Timberline Lodge on Mount Hood. This National Historic Landmark features year round downhill skiing, and is the frequent training site of the U.S. Olympic Ski Team. Scattered lunch on your own in Hood River.

Tuesday, August 15: Portland City Tour (5 hrs.) $32

Visit the "City of Roses" a beautiful location at the confluence of the Willamette and Columbia Rivers. Take in the sights, fountains, public art and more. This tour includes the Pearl District, financial district, Chinatown, and the Old Town sections. Visit Washington Park, home to 10,000 roses, with 4-5,000 different varieties in the International Rose Test Gardens. Walk through the Pittock Mansion, former home to Portland pioneers Henry and Georgiana Pittock, one time owner of the Oregonian newspaper. The Pittock Mansion is a fully furnished, magnificent, turn-of-the century, architectural treasure offering a sweeping view of the surrounding Cascade Mountains and the City of Portland, Oregon. Lunch on your own downtown.

Wednesday, August 16: The Oregon Garden & Shopping in Woodburn (7 hours) $46

Spend a day a one of Oregon's newest attractions, the lovely Oregon Garden. A motorized tram provides visitors with an excellent overview of The Garden's many features. Passengers have unlimited on-off privileges at five stopping points. Visit the gift shop in the new Visitor's Center, which offers something for everyone. Garden enthusiasts can browse in the greenhouse wing for plants and seeds, garden tools, and books about horticulture. Visitors can purchase a fun Oregon Garden shirt or hat. Wine lovers can even find a crisp Oregon Chardonnay or an award winning pinot noir. Time is included to view The Gordon House, which was designed by Frank Lloyd Wright, widely heralded as the greatest architect of the 20th Century. It is the only Wright-designed building in Oregon and the only one in the Pacific Northwest that is open to the public.

Following the garden visit, head north to Woodburn for an afternoon of shopping. With more than 80 stores, Woodburn Company Stores is the largest outlet center in the Pacific Northwest. Big name brands, skylight-covered walkways, and beautiful Northwest architecture and landscaping make this a unique and fun shopping experience year round. Lunch on your own.

MT. ST. HELENS PHOTO COURTESY OF THE USGS/CASCADES VOLCANO OBSERVATORY. ALL OTHER TOUR PHOTOS COURTESY OF THE PORTLAND OREGON VISITORS ASSOCIATION.

Thursday, August 17: Seashells at the Seashore, Seaside Cannon Beach, Tillamook (9 Hrs.) $39

Head west to the Oregon coast and take in a quick stop at the

Astoria Column. Continue south along the coastline to Seaside and Cannon Beach, two popular towns on the Oregon coast that offer tourists more than just sand and sea. Stroll along the boardwalk or visit the many unique boutiques that offer a wide variety of beach memorabilia. Listen to the sounds of the surf while viewing Haystack Rock monolith. Continue on to Tillamook, where you will have time a visit to a local cheese factory. Lunch on your own.

Saturday, August 19: Evergreen Aviation Museum (Spruce Goose) & Winery (6 hours) $76

The Evergreen Aviation Museum houses the Hughes Flying Boat, known as the "Spruce Goose". It was to be the biggest airplane ever built and probably the most prodigious aviation project of all time. Inside this truly amazing place is also home to several other planes such as cargo aircrafts, bombers, fighters, trainers, commercial aircraft and many more. A guided tour of

the museum and the aircraft exhibits. After the museum visit, stop at a local winery for an opportunity to taste good wines, as well as learn of growing and wine making techniques. The Willamette Valley is the home of many premier vineyards producing world-class, internationally renowned wines. Includes box lunch.

ON-YOUR-OWN

In addition to the pre- and post-conference tours, the Portland area offers many options for self-guided tours and recreational activities for your companion and/or family during and after the conference. In addition to the many activities in the City accessible by a short walk or bus/MAX ride, within a short drive are many scenic attractions and outdoor activities in the Willamette Valley and the world-famous Columbia River Gorge. See our Family Activities list and Tours section for some of the things you can do: http://www.emc2006.org/pages/tours.htm and http://www.emc2006.org/pages/familyfun.htm.

Social Activities

A ticket to the following events is included with full registration. Guest registration includes one ticket to the Welcome Reception. Additional tickets may be purchased with your registration or at the Symposium.

WELCOME RECEPTION
Portland Hilton and Executive Towers
Tuesday, 15 August, 6:00 pm – 8:00 pm

Welcome to Portland! The Symposium Steering Committee invites attendees to join old friends and meet new acquaintances during an evening of refreshment and drink at the Hilton Hotel. This event has proven to be very popular and is an excellent way to meet and network with others from the EMC community. Finger foods and local wines and beers will be featured.

GALA EVENT
Oregon Ballroom, Oregon Convention Center
Wednesday, 16 August, 6:30pm – 10:30 pm

Join with your fellow attendees and their companions in an evening of socializing, fun, and entertainment. A reception, followed by dinner and world-class entertainment is planned. Extra transportation will be available on the MAX and Symposium buses.

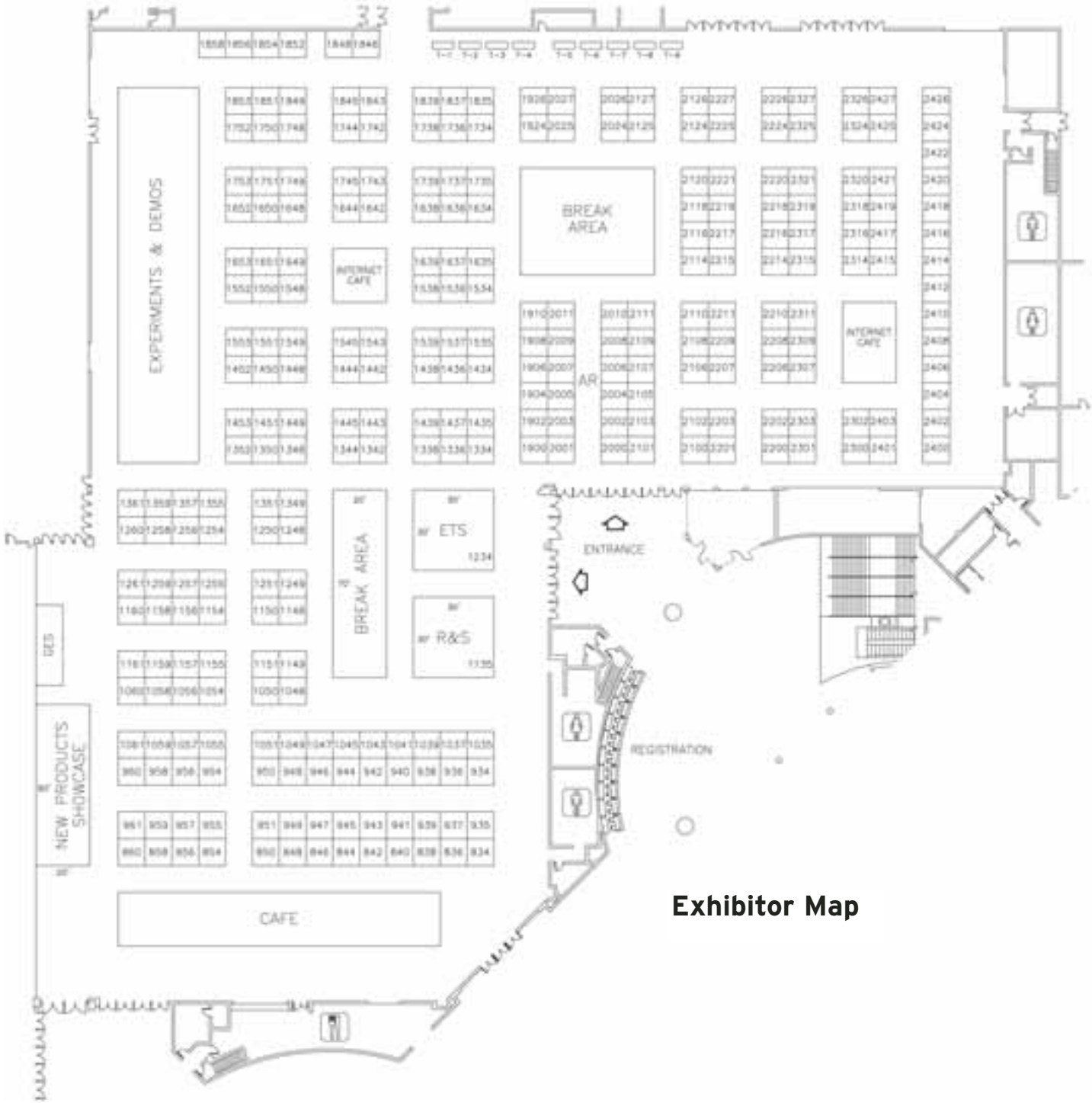
AWARDS LUNCHEON
Oregon Ballroom, Oregon Convention Center
Thursday, 17 August, 12:00 pm – 2:00 pm

A tribute to Ben Franklin. Contributors to the IEEE EMC Society will be honored, and the 2006 Best Paper Award winner will be announced. Join with other attendees in honoring the awards winners.

YOUTH PROGRAM
Tuesday 15 August 9:30am - 11:30am
Wednesday 16 August 9:30am – 12:00pm
Oregon Convention Center - Room TBD

Calling all young engineers! BOATS, BOATS, BOATS
Since we are in the Pacific Northwest why not build and race hydroplanes? Together we will be building the boats and you will install the simple circuit with motors, batteries, and wire. We can't wait to see your fantastic decorating and styling so we can race them on Lake EMC at the show. Look for Captain "Gayla Burns" to lead you on. Ahoy maties.

2006 IEEE Symposium
Oregon Convention Center
14-18 August, 2006



Exhibitor Map

Thank you to the following exhibitors for your participation in the 2006 IEEE International Symposium on Electromagnetic Compatibility!

There's still time to reserve your booth space at this year's symposium. To join this illustrious group of exhibitors, please contact Sue Kingston at s.kingston@ieee.org, phone ++1-310-937-1006 or visit the website www.emc2006.org to download the exhibit space application.

Company	Booth #
3M Company	1450;1452
A.H. Systems	1434;1436;1438
Advanced Test Equipment	1653
Agilent Technologies	1334;1336
Alco Technologies	2225
Alion Science & Technology/R&B Laboratory	1742
American Assoc. for Lab Accreditation/A2LA	1255
American TCB	934
AMIC (Advanced Materials & Integration)	950
Andro Computational Solutions	1734
ANSI-Accredited Standards Committee C63™	
Ansoft Corp.	2209
Antenna Research Assoc. (ARA)	2208
Applied Simulation Technology	2107
AR Worldwide	2000-2011
Avalon Equipment	2307
California Instruments	2024
Canon Communications	2109
Capcon International	2200
Captor Corporation	1739
Cherry Clough Consulting/Acemark	1155
Chomerics	1642;1644
CKC Laboratories, Inc.	2025
Communications & Power Industries	1043
Compliance Alliance	2302
Comsol, Inc.	1651
Conec Corp.	1536
Conformity Magazine	1636;1638
Credence Technologies	1439
CSA International	1054
CST of America	2314
Cuming Lehman Chambers	1254
Cuming Microwave	1256
Curtis Industries	1357
D.L.S. Electronic Systems, Inc.	1737
Dayton T Brown Inc	1553
Detectus	935
Dexter Magnetic Technologies, Inc.	1051
Dynamic Sciences International	1048;1050
Educated Design & Development, (ED&D)	1449
EE - Evaluation Engineering	2125
Electro-Magnetic Applications, Inc.	1649
ElectroMagnetic Investigations	2301
Elliott Laboratories	1906
EM Software & Systems	2202
EMC Solutions	1158
EMCIA (Nutwood UK Ltd)	1156
EMS-Plus	T-3
EMSCAN Corp.	2118;2120
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Fair-Rite Products	1149;1151
Ferrishield Inc	1435
Ferroxcube USA	1350
Fischer Custom Communications Inc	1342;1344;1443;1445
Flomerics, Inc.	1543;1545
G-MAG	1745
Garwood Laboratories Inc	2206
Haefely EMC	2106
HV Technologies	1648;1650
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International Express Certification Services	2027
Interpower Corporation	1551
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Narte Inc	2203
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Pearson Electronics Inc	1055
PPM Ltd.(Pulse Power & Measurement)	1154
Quantum Change / EMC Systems	1900;1902
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RF Immunity Ltd.	1749
Rohde & Schwarz	1135 island
Sabritec	1752
Sauquoit Industries LLC	1743
Schaffner EMC	1148;1150;1249;1251
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Schurter, Inc.	2210
Seiren Co., Ltd.	2211
Seven Mountains Scientific Inc	1549
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Southwest Research Institute	1924
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Sunol Science Corp.	1248;1250;1349;1351
SVAD	1736
Taiyo Yuden USA, Inc.	1639
TDK RF Solutions, Inc.	1060;1061
Tech-Etch, Inc.	1352
Tecknit, Inc.	1534
TennMax Inc.	2207
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Thermo Electron Corp.	1634;1735
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TUV Rheinland of N.A.	2221
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Vishay Intertechnology, Inc.	1635
W.L. Gore & Associates	1537
WaveZero, Inc.	2214
Webcom Communications	2220
WEMS Electronics	1748
Wurth Elektronik USA	1652
Wyle Laboratories	1355
X2Y Attenuators, LLC	1753
York EMC Services Ltd.	1161

Exhibtor listing is current as of press time. Please see www.emc2006.org for updates to the exhibitor list.

2006 IEEE International Symposium on Electromagnetic Compatibility

14-18 August 2006 • Portland, Oregon

www.emc2006.org

Symposium Registration Form

NAME & ADDRESS: *(please print)*

EMCS Member? ❑ Yes ❑ No IEEE Member? ❑ Yes ❑ No IEEE Member #_____ ❑ Amateur Radio Call Sign _____

Please check appropriate box (check one only): ❑ Manufacturer ❑ Government ❑ Education ❑ Consultant/Other

Family/Surname Personal Name MI

Company/Institution

Address

City State/Province Postal Code

Country Phone Fax

Email

Indicate if vegetarian meal(s) are required for: Attendee ❑ Yes ❑ No Companion ❑ Yes ❑ No

Other special requirements (special diet, wheelchair, etc)? ❑ Yes ❑ No _____

GUEST(S): *(please print name(s) as you would like them to appear on the badge)*

Name Name

Name Name

REGISTRATION FEES: *(please indicate quantity and amount)*

	on or before 7 July 2006	after 8 July 2006	Quantity	
Full Registration 1				
Member	$450.00	$540.00		$_____
Non-Member	$600.00	$700.00		$_____
EMCS Life Member	No Fee	No Fee		$_____
IEEE Life Member	$105.00	$120.00		$_____
Retired/Unemployed **2**	$225.00	$270.00		$_____
Full Time Student **3**	$105.00	$120.00		$_____
Guest Registration 4				
Guest (ages 18 and up)	$75.00	$80.00	_____	$_____
Jr. Guest (ages 8 - 17)	$30.00	$35.00	_____	$_____
Children under 8 free				
One Day Registration 5				
Please mark the day(s) you wish to attend				
Member M T W TH F	$150.00	$160.00	_____	$_____
Non-Member M T W TH F	$200.00	$225.00	_____	$_____
Full Time Student **3** M T W TH F	$40.00	$40.00	_____	$_____
Exhibit Hall Only	No Fee	No Fee	_____	$_____
Additional Options				
Symposium Record - Hard Copy*	$50.00	N/A	_____	$_____
Symposium - CD-ROM	$20.00	$20.00	_____	$_____
Tuesday Welcome Reception (Adult)	$60.00	$65.00	_____	$_____
Tuesday Welcome Reception (Jr. Guest)	$20.00	$25.00	_____	$_____
Wednesday Gala (Adult)	$100.00	$105.00	_____	$_____
Wednesday Gala (Jr. Guest)	$45.00	$50.00	_____	$_____
Thursday Awards Lunch (Adult)	$40.00	$45.00	_____	$_____
Thursday Awards Lunch (Jr. Guest)	$25.00	$30.00	_____	$_____

*** Only available with pre-registration by 7 July 2006**

TOURS: *(please indicate quantity, amount, and total)*

		Quantity	
Sunday 13 August			
Mt. St. Helens Tour	$77.00	_____	$_____
A Visit with Lewis & Clark/Astoria	$88.00	_____	$_____
Monday 14 August			
Mt. Hood Loop/Hood River	$39.00	_____	$_____
Tuesday 15 August			
Portland City Tour	$32.00	_____	$_____
Wednesday 16 August			
Oregon Garden/Shopping at Woodburn Company Stores	$46.00	_____	$_____
Thursday 17 August			
Seashells at the Seashore/ Seaside, Cannon Beach & Tillamook	$39.00	_____	$_____
Friday 18 August			
Mount St. Helen's	$77.00	_____	$_____
Saturday 19 August			
Evergreen Aviation Museum (Spruce Goose) & Winery	$76.00	_____	$_____

TOTAL REMITTANCE: $_____

2006 IEEE International Symposium on Electromagnetic Compatibility

14-18 August 2006 • Portland, Oregon

www.emc2006.org

Symposium Registration Form

1 Full, 5 day registrants are entitled to: CD Rom of Symposium Records and Workshop Notes, admission to the Symposium which includes Technical Sessions, Exhibit Hall, Workshops, Tuesday Welcome Reception, Wednesday Banquet, and Thursday Awards Luncheon.

2 A 50% reduction of the Registration Fee was approved for retired or unemployed IEEE EMC Society Members only. The registrant must provide the name of the company that they left and the date for retirement/unemployment.

3 Student registrations are open to full time students, and include the CD Rom of Symposium Records and Workshop Notes, admission to the Symposium which includes Technical Sessions, Exhibit Hall, Workshops, Tuesday Welcome Reception, Wednesday Banquet and Thursday Awards Luncheon.

4 Guests may include an adult companion and any accompanying children. Each guest must be registered to receive admission to the Guest Lounge, Children's Workshops, and Tuesday Welcome Reception. All guests are welcome into the Exhibit Hall.

5 One-Day Registrants are entitled to admission for one day and the CD Rom of Symposium Records and Workshop Notes.

EMC MEMBERSHIP:

Free First year membership to IEEE/EMC if you join at the Symposium. See IEEE EMC or IEEE Marketing Booth in the Exhibit Hall for details.

METHOD OF PAYMENT:

❑ Check (in USD) made out to IEEE/EMC ❑ Visa ❑ MasterCard ❑ American Express ❑ Diners Club

Credit Card Number Expiration Date

Cardholder Name Authorized Signature

❑ Wire Transfer If you are paying by wire transfer please contact Andrea Sadlowski (emc06reg@ieee.org) for bank information.

CANCELLATION POLICY:

All requests for refunds prior to 30 July 2006 must be in writing. A $50 service charge will apply. No refunds will be made after **30 July 2006**. Substitutions are permitted.

The 2006 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.

EMERGENCY CONTACT:

Name Relationship

Day-time Phone Evening Phone

Mail or Fax completed form and payments to:

IEEE/CMS, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA

Phone: +1 732 562 5337 Fax: +1 732 465 6447 Email: emc06reg@ieee.org

NEW Revised Antenna Calibration Standard (ANSI C63.5-2006) Workshop

In December 2004, ANSI ASC C63™ published its long awaited antenna calibration standard that replaces the 1988 and 1998 versions. Late last year, ASC C63™ added to this standard an interpretation that clarified some text and a flow chart. The standard takes into account the errors that are introduced when using certain broadband antennas especially at frequencies below 200 MHz and provides correction factors when these antennas are used for site validation. There are also introduced alternate measurement techniques for determining antenna factors for other types of antennas. The workshop will lead the user through the new document, highlighting which technique should be used based on the type of antenna being calibrated. This is essential to ensure that the right antenna factor is used, especially when validating semi-anechoic chambers. As time permits, attendees will get a chance to apply what they learned via problem solving and/or performing an antenna calibration in the lab at the meeting venue.

Workshop Overview

In this seminar, you will learn about:

- General test conditions
- Appropriate measurement geometry
- Methods to determine antenna factors
- Application of standard site method
- Reference antenna method
- Equivalent capacitance substitution method
- Discrete and continuous frequency calibration considerations
- Rationale for geometry specific correction factors for biconicals
- Guidelines for measurement uncertainty
- You will also participate in hands-on activity in a state-of-the-art ten meter chamber. This will drive home, in real time, the material presented

Support Material Provided

- ANSI C63.5-2006
- A complete lecture notebook
- Handouts and references

Who Should Attend

- Those responsible for using and calibrating antennas in making radiated emission compliance measurements
- Calibration technicians
- Calibration accreditation bodies
- Lab quality assessors
- Regulatory Compliance Managers
- Test instrumentation and chamber manufacturers

Date and Location

Saturday, August 12, 2006 at Northwest EMC in Hillsboro, Oregon. Transportation from the Hilton Hotel (headquarter hotel for the IEEE EMC symposium) in downtown Portland to Northwest EMC will be provided. Local transportation arrangements will be confirmed upon receipt of registration.

Agenda (approx.)

Registration and Continental Breakfast: 8:00 am
Class: 8:30 am to 5:00 pm

Registration Fee Includes

Complete lecture notebook, continental breakfast, lunch, and breaks, roundtrip local transportation between Hilton Hotel (headquarter hotel) in downtown Portland and Northwest EMC, as well as a copy of ANSI C63.5-2006.

Hotels

Several hotels in Portland have rooms reserved for those attending the IEEE EMC Symposium, including the Hilton Portland & Executive Tower Hotel (headquarter hotel for symposium). Please visit the website www.emc2006.org for complete hotel information.

Expert Instructors

- Donald N. Heirman, Workshop Director, (Don HEIRMAN Consultants)
- Dennis Camell (National Institute of Standards and Technology)
- Michael J. Windler (Underwriters Laboratories)

Registration Form

Contact: Janet O'Neil
Telephone and fax: 425-868-2558

Ms./Mr. _____

Company _____

Address _____

City _____ State ____ Zip _____

Daytime Phone _____ Fax _____

Email _____

Credit Card (check one): MC _____ Visa _____ Amex _____

Credit Card No: _____

Expiration Date: _____

Signature: _____

C63.5 workshop - 12 August 2006

By 28 July 2006 *:	Attendees	$400 USD _____
	C63 & S/C Members	$350 USD _____
Add $100 if after 28 July or at the door**		$150 USD _____
Add'l copy of notebook**		$100 USD _____
		Total $ _____ USD

Check or Credit Card Number must accompany registration.
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
22117 Northeast 10th Place
Sammamish, WA 98074
Email: j.n.oneil@ieee.org

NOTE: You are not registered until you receive confirmation
*Please do not mail after 28 July 2006.
**With prior telephone or fax registration only.

NOTE: The organizing committee may substitute speakers, modify the program (or lecture notes), restrict class size or cancel the workshop. No refunds will be made to individuals who cancel after 28 July 2006. Substitutions are allowed. Registration will be confirmed on a first come, first served basis. Workshop requires a minimum of 15 attendees; it will be cancelled if less than 15 sign up by 28 July 2006. Please do not wait to register and do not miss the 28 July 2006 absolute deadline. Registration fees will be returned if workshop is cancelled. Book refundable travel arrangements as appropriate if workshop is cancelled.

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June 13-15, 2006, Booth: 1104

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(www.murata.com/emc/index.html)

Visit Murata
at the EMC Symposium
Portland Oregon,
August 15-17, 2006
Booth #: 1442/1444

Murata Electronics offers an extensive line of products and solutions to the design community that includes, but is not limited to, Ferrite Beads, Feed-Through Capacitors and Common Mode Choke Coils.

Murata Electronics is currently supplying leading EMI filtering technology to the top electronics manufacturers throughout the world. Through continuous engineering improvements, Murata has been able to downsize surface mount EMI filters while providing improved features such as increased current capacity and high frequency characteristics, both of which are critical to maintaining Federal Communications Commission (FCC) compliance.

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Smyrna, GA 30080-7604
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